20-1025 (Lead); 20-1138 (Consolidated)

UNITED STATES COURT OF APPEALS
FOR THE DISTRICT OF COLUMBIA CIRCUIT

ENVIRONMENTAL HEALTH TRUST; CONSUMERS FOR SAFE CELL PHONES; ELIZABETH BARRIS; THEODORA SCARATO

CHILDREN'S HEALTH DEFENSE; MICHELE HERTZ; PETRA BROKKEN; DR. DAVID O. CARPENTER; DR. PAUL DART; DR. TORIL H. JELTER; DR. ANN LEE; VIRGINIA FARVER, JENNIFER BARAN; PAUL STANLEY, M.Ed.
Petitioners

v.

FEDERAL COMMUNICATIONS COMMISSION;
UNITED STATES OF AMERICA
Respondents

Petition for Review of Order Issued by the
Federal Communications Commission

DEFERRED JOINT APPENDIX

VOLUME 6

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Research Compilation; Abstracts of over 600 Studies Published Between
August 2016 - August 2019, Dr. Joel Moskowitz; 2019
(Tab 8 Part 2)

the handheld wireless phone. An evaluation of the scientific evidence on the brain tumor risk was made in May 2011 by the International Agency for Research on Cancer at World Health Organization. The scientific panel reached the conclusion that RF radiation from devices that emit nonionizing RF radiation in the frequency range 30 kHz–300 GHz is a Group 2B, that is, a "possible" human carcinogen. With respect to health implications of digital (wireless) technologies, it is of importance that neurological diseases, physiological addiction, cognition, sleep, and behavioral problems are considered in addition to cancer. Well-being needs to be carefully evaluated as an effect of changed behavior in children and adolescents through their interactions with modern digital technologies.

http://onlinelibrary.wiley.com/doi/10.1111/cdev.12831/abstract

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Can Non-Ionizing Radiation Cause Cancer?

Magda Havas. Can Non-Ionizing Radiation Cause Cancer? Archives of Physics Research, 2017, 8 (1):1-2.

Abstract

Our exposure to non-ionizing radiation (NIR) has been increasing steadily with our use of electricity, electronic equipment and-more recently-with our use of wireless technology. Concurrently, epidemiological studies have been documenting an increased cancer risk for people who use cell phones for 10 years or more [1,2] and for those who live near cell phone base stations [3,4,5], broadcast antennas [6,7], radar installations [8], or powerlines [9]. Health care authorities and physicists dismiss these studies because non-ionizing radiation doesn't have enough energy to break chemical bonds and, hence cannot cause cancer. Right? Wrong!

Open Access Paper: http://www.scholarsresearchlibrary.com/articles/can-nonionizing-radiation-cause-cancer.pdf

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Increasing levels of saliva alpha amylase in electrohypersensitive (EHS) patients

Andrianome S, Hugueville L, de Seze R, Selmaoui B. Increasing levels of saliva alpha amylase in electrohypersensitive (EHS) patients.Int J Radiat Biol. 2017 May 3:1-24. doi: 10.1080/09553002.2017.1325971. [Epub ahead of print].

Abstract

THE PURPOSE: The objective of this study was to assess the level of various salivary and urinary markers of patients with EHS and to compare them with those of the healthy control group.

MATERIALS AND METHODS: We analyzed samples from 30 EHS individuals and a matched control group of 25 individuals (non EHS) aged between 22 and 66. We quantified cortisol both in saliva and urine, alpha amylase (sAA), immunoglobulin A and C Reactive Protein levels in saliva and neopterin in urine (uNeopterin).

RESULTS: sAA was found to be significantly higher (p < 0.005) in the EHS group. uNeopterin and sAA analysis showed a significant difference based on the duration of EHS.

CONCLUSION: Higher level of sAA in EHS participants may suggest that the sympathetic adrenal medullar system is activated. However, most of the analyzed markers of the immune system, sympathetic activity and circadian rhythm did not vary significantly in EHS group. There is a trend to the higher levels of some variables in subgroups according to the EHS duration.

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Long-term exposure to continuous 900 MHz EMF disrupts cerebellar morphology in young adult male rats

Aslan A, İkinci A, Baş O, Sönmez OF, Kaya H, Odacı E. Long-term exposure to a continuous 900 MHz electromagnetic field disrupts cerebellar morphology in young adult male rats. Biotech Histochem. 2017 May 16:1-7. doi: 10.1080/10520295.2017.1310295. [Epub ahead of print]

Abstract

The pathological effects of exposure to an electromagnetic field (EMF) during childhood and adolescence may be greater than those from exposure during adulthood. We investigated possible pathological changes in the cerebellum of adolescent rats exposed to 900 MHz EMF daily for 25 days. We used three groups of six 21-day-old male rats as follows: unexposed control group (Non-EG), sham-exposed group (Sham-EG) and an EMF-exposed group (EMF-EG). EMF-EG rats were exposed to EMF in an EMF cage for 1 h daily from postnatal days 21 through 46. Sham-EG rats were placed in the EMF cage for 1 h daily, but were not subjected to EMF. No procedures were performed on the Non-EG rats. The cerebellums of all animals were removed on postnatal day 47, sectioned and stained with cresyl violet for histopathological and stereological analyses. We found significantly fewer Purkinje cells in the EMF-EG group than in the Non-EG and Sham-EG groups. Histopathological evaluation revealed alteration of normal Purkinje cell arrangement and pathological changes including intense staining of neuron cytoplasm in the EMF-EG group. We found that exposure to continuous 900 MHz EMF for 1 h/day during adolescence can disrupt cerebellar morphology and reduce the number of Purkinje cells in adolescent rats.

https://www.ncbi.nlm.nih.gov/pubmed/28506085

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Ten gigahertz microwave radiation impairs spatial memory, enzymes activity, and histopathology of developing mice brain

Sharma A, Kesari KK, Saxena VK, Sisodia R. Ten gigahertz microwave radiation impairs spatial memory, enzymes activity, and histopathology of developing mice brain. Mol Cell Biochem. 2017 May 3. doi: 10.1007/s11010-017-3051-8.

Abstract

For decades, there has been an increasing concern about the potential hazards of non-ionizing electromagnetic fields that are present in the environment and alarming as a major pollutant or electro-pollutant for health risk and neuronal diseases. Therefore, the objective of the present study was to explore the effects of 10 GHz microwave radiation on developing mice brain. Two weeks old mice were selected and divided into two groups (i) sham-exposed and (ii) microwave-exposed groups. Animals were exposed for 2 h/day for 15 consecutive days. After the completion of exposure, within an hour, half of the animals were autopsied immediately and others were allowed to attain 6 weeks of age for the follow-up study. Thereafter results were recorded in terms of various biochemical, behavioral, and histopathological parameters. Body weight result showed significant changes immediately after treatment, whereas non-significant changes were observed in mice attaining 6 weeks of age. Several other endpoints like brain weight, lipid peroxidation, glutathione, protein, catalase, and superoxide dismutase were also found significantly ($p < 0.05$) altered in mice whole brain. These significant differences were found immediately after exposure and also in follow-up on attaining 6 weeks of age in microwave exposure group. Moreover, statistically significant ($p < 0.001$) effect was investigated in spatial memory of the animals, in learning to locate the position of platform in Morris water maze test. Although in probe trial test, sham-exposed animals spent more time in searching for platform into the target quadrant than in opposite or other quadrants. Significant alteration in histopathological parameters (qualitative and quantitative) was also observed in CA1 region of the hippocampus, cerebral cortex, and ansiform lobule of cerebellum. Results from the present study concludes that the brain of 2 weeks aged mice was very sensitive to microwave exposure as observed immediately after exposure and during follow-up study at 6 weeks of age.

https://www.ncbi.nlm.nih.gov/pubmed/28470342

Excerpt

All animals were kept in such position, where the head of animals faced the horn antenna. The horn antenna was kept in H (Magnetic field) plane configuration, where electric field was perpendicular to the ground surface. Field was almost uniform because the dimension of the cage was of the order of wavelength. The maximum power density 0.25 mW/cm2 was recorded at the near field distance from the horn antenna. A power meter measured the emitted power of microwaves, which was a peak sensitive device ... The whole body specific absorption rate (SAR) was estimated to be 0.1790 W/kg ... Similar experiment with same number of sham-exposed animals was performed without energizing the microwave exposure system.

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Ameliorative effect of gallic acid on pancreas lesions induced by 2.45 GHz Wi-Fi in young rats

Senay Topsakal, Ozlem Ozmen, Ekrem Cicek, Selcuk Comlekci. The ameliorative effect of gallic acid on pancreas lesions induced by 2.45 GHz electromagnetic radiation (Wi-Fi) in young rats. Journal of Radiation Research and Applied Sciences, Available online 4 May 2017.

Highlights

• Effects of electromagnetic radiation (EMR) on pancreata examined by immunohistochemical level.
• EMR exposure has been caused both endocrine and endocrine pancreas problems.
• Our results indicate that possible relation with EMR and pancreatic lesions in developmental ages.

Abstract

The aim of this study was to investigate the effects of electromagnetic radiation (EMR) on the pancreas tissue of young rats and the ameliorative effect of Gallic acid (GA). Six-week-old, 48 male rats were equally divided into four groups: Sham group, EMR group (2.45 GHz), EMR (2.45 GHz)+GA group (30 mg/kg/daily) orally and GA group (30 mg/kg/daily). After 30 days, serum and pancreatic tissue samples were harvested for biochemical, histopathological and immunohistochemical analysis. Serum amylase, lipase, glucose, and tissue malondialdehyde, total oxidant status and oxidative stress index were increased, whereas total antioxidant status decreased in the EMR group. The histopathological examination of the pancreases indicated slight degenerative changes in some pancreatic endocrine and exocrine cells and slight inflammatory cell infiltrations in the EMR group. At the immunohistochemical examination, marked increase was observed in calcitonin gene related protein and Prostaglandin E2 expressions in pancreatic cells in this group. There were no changes in interleukin-6 expirations. GA ameliorated biochemical and pathological findings in the EMR+GA group. These findings clearly demonstrate that EMR can cause degenerative changes in both endocrine and exocrine pancreas cells in rats during the developmental period and GA has an ameliorative effect.

http://www.sciencedirect.com/science/article/pii/S1687850717300468

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Effects of Intermittent and Continuous Magnetic Fields on Trace Element Levels in Guinea Pigs

Erdem O, Akay C, Cevher SC, Canseven AG, Aydın A, Seyhan N. Effects of Intermittent and Continuous Magnetic Fields on Trace Element Levels in Guinea Pigs.Biol Trace Elem Res. 2017 May 22. doi: 10.1007/s12011-017-1053-8. [Epub ahead of print]

Abstract

Electromagnetic fields (EMFs) can affect living cells due to biochemical changes, followed by changes in levels of trace elements in serum and different organs. This study focuses on the effect of whole body exposure to EMF, presented everywhere in our environment, and on the levels of trace elements in serum, femur, brain, kidney, and liver tissues. The analyses performed on 29 guinea pigs were divided into five groups. Guinea pigs were exposed to a magnetic field of 50 Hz of 1.5 mT. Groups A and B were exposed to the magnetic field for a period of 4 h/day continuously (4 h/day) for 4 and 7 days, respectively. Groups C and D were exposed to the magnetic field for a period of 4 h/day intermittently for 4 and 7 days, respectively. Group E animals were enrolled as control. Copper (Cu), zinc (Zn), calcium (Ca), and magnesium (Mg) levels were determined by atomic absorption spectroscopy in serum, femur, brain, kidney, and liver tissues in all guinea pigs. When compared to the control groups, the changes in the levels of Cu in serum samples, femur, and kidney tissues of the treated groups were statistically significant. The same was also true for the levels of Mg in the brain, kidney, and lung tissues. Our results suggest that in vivo continuous and intermittent exposure to EMF may cause disturbances in homeostasis of bioelements. These effects could be important risk factors for toxic effects of EMF, especially in relation to deterioration of bioelements.

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Preterm birth among women living within 600 meters of high voltage overhead Power Lines: a case-control study

Sadeghi T, Ahmadi A, Javadian M, Gholamian SA, Delavar MA, Esmailzadeh S, Ahmadi B, Hadighi MSH. Preterm birth among women living within 600 meters of high voltage overhead Power Lines: a case-control study. Rom J Intern Med. 2017 Apr 18. [Epub ahead of print]

Abstract

AIM: The issue of preterm birth due to exposure to magnetic fields from power lines is unclear. Exposure to electromagnetic field in uterus has been hypothesized as possible preterm birth. The aim of the present study was to determine whether living closer to high voltage power lines increased the risk of preterm labor.

METHODS: In a nested case-control study, 135 cases of singleton live spontaneous preterm birth in Rohani hospital, Babol, Iran, during the period between 2013 and 2014 were studied. The 150 control subjects were singleton term live birth in the same year of birth and city of residence using randomized-digit dialing. The shortest distance to any of the high voltage power lines to the maternal residence during pregnancy was measured using ArcGIS software for every case and control. To test the association between the preterm births and the residential proximity to power lines, stepwise multiple logistic regression was used.

RESULTS: There were 28 households, 20 cases (14.8%) and 8 controls (5.3%) were situated within 600 meters of a high voltage power lines. The adjusted OR for spontaneous preterm birth and birth defect in women who were living in less than 600 meters from high voltage power lines was higher compared to those living in farther distance (OR=3.28, CI: 1.37 to 7.85) and (OR=5.05, CI: 1.52 to 16.78), respectively.

CONCLUSIONS: Therefore, installing overhead power lines and stations within 600 meters or making overhead underground would be useful in the prevention of the both preterm birth and birth defect.

https://www.ncbi.nlm.nih.gov/pubmed/28422709

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Evaluation of Mobile Phone and Cordless Phone Use and Glioma Risk Using the Bradford Hill Viewpoints from 1965 on Association or Causation

Carlberg M, Hardell L. Evaluation of Mobile Phone and Cordless Phone Use and Glioma Risk Using the Bradford Hill Viewpoints from 1965 on Association or Causation. Biomed Res Int. 2017;2017:9218486. doi: 10.1155/2017/9218486. Epub 2017 Mar 16.

Abstract

Objective. Bradford Hill's viewpoints from 1965 on association or causation were used on glioma risk and use of mobile or cordless phones. Methods. All nine viewpoints were evaluated based on epidemiology and laboratory studies. Results. Strength: meta-analysis of case-control studies gave odds ratio (OR) = 1.90, 95% confidence interval (CI) = 1.31-2.76 with highest cumulative exposure. Consistency: the risk increased with latency, meta-analysis gave in the 10+ years' latency group OR = 1.62, 95% CI = 1.20-2.19. Specificity: increased risk for glioma was in the temporal lobe. Using meningioma cases as comparison group still increased the risk. Temporality: highest risk was in the 20+ years' latency group, OR = 2.01, 95% CI =1.41-2.88, for wireless phones. Biological gradient: cumulative use of wireless phones increased the risk. Plausibility: animal studies showed an increased incidence of glioma and malignant schwannoma in rats exposed to radiofrequency (RF) radiation. There is increased production of reactive oxygen species (ROS) from RF radiation. Coherence: there is a change in the natural history of glioma and increasing incidence. Experiment: antioxidants reduced ROS production from RF radiation. Analogy: there is an increased risk in subjects exposed to extremely low-frequency electromagnetic fields. Conclusion. RF radiation should be regarded as a human carcinogen causing glioma.

https://www.ncbi.nlm.nih.gov/pubmed/28401165

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Asociación entre las radiaciones de teléfonos móviles y el riesgo tumoral en personas adultas

Bielsa-Fernández P, Rodríguez-Martín B. Asociación entre las radiaciones de teléfonos móviles y el riesgo tumoral en personas adultas. Gaceta Sanitaria, Available online 13 April 2017. (Review paper written in Spanish.)

Abstract

Objective To synthesize and analyse systematic reviews, case-control studies, cohort studies and meta-analysis that investigate the association between exposure to radiofrequency from mobile phones and the appearance of tumours in adults.

Methods A systematic search was conducted in Scopus, Web of Science, The Cochrane Library, Medline and Cinahl of articles published in English and Spanish between January 2005 and February 2016 that analyse the risk of tumour associated with exposure to radiofrequency from mobile phones in adults. The recommendations of the PRISMA Declaration were followed, and the quality of the articles was analysed with the AMSTAR tool and the Newcastle-Ottawa Scale.

Results 1034 studies were found, fourteen of which were included. Most studies agree that it is not possible to determine a relationship in the short term, although long-term (over 10 years) radiofrequency emitted by mobile phones can cause tumour effects, with an increased risk by ipsilateral exposure and latency.

Conclusions Although radiofrequency from mobile phones has tumour effects on humans, the available scientific evidence is not robust. More rigorous follow-up studies with larger sample sizes and broader periods are necessary to learn more about the long-term effects.

http://bit.ly/2qzqnPV

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Acute effects of mobile phone radiation on brain function

Zhang J, Sumich A, Wang GY. Acute effects of radiofrequency electromagnetic field emitted by mobile phone on brain function. Bioelectromagnetics. 2017 Apr 20. doi: 10.1002/bem.22052. [Epub ahead of print]

Abstract

Due to its attributes, characteristics, and technological resources, the mobile phone (MP) has become one of the most commonly used communication devices. Historically, ample evidence has ruled out the substantial short-term impact of radiofrequency electromagnetic field (RF-EMF) emitted by MP on human cognitive performance. However, more recent evidence suggests potential harmful effects associated with MP EMF exposure. The aim of this review is to readdress the question of whether the effect of MP EMF exposure on brain function should be reopened. We strengthen our argument focusing on recent neuroimaging and electroencephalography studies, in order to present a more specific analysis of effects of MP EMF exposure on neurocognitive function. Several studies indicate an increase in cortical excitability and/or efficiency with EMF exposure, which appears to be more prominent in fronto-temporal regions and has been associated with faster reaction time. Cortical excitability might also underpin disruption to sleep. However, several inconsistent findings exist, and conclusions regarding adverse effects of EMF exposure are currently limited. It also should be noted that the crucial scientific question of the effect of longer-term MP EMF exposure on brain function remains unanswered and essentially unaddressed.

https://www.ncbi.nlm.nih.gov/pubmed/28426166

Conclusion

While several studies suggest an effect of EMF exposure on brain function, there is little evidence of the harmful nature of these effects, and greater understanding is needed of their functional significance. To date, the crucial scientific question of the effect of longer-term MP EMF exposure on brain function remains unanswered and essentially unaddressed. The potential health effects of MP EMF exposure in children and adolescents have been identified by the World Health Organization (WHO) as a high priority research area, since they have longer lifetime exposure to MP [van Deventure et al., 2011]. Prior to establishing a clear picture of a cause-effect relationship on MPs, it is safer to minimize the MP use. It has been suggested to reduce the potential harm induced by MPs by restricting call length, or by using hands-free devices [Valentini et al., 2010]. Furthermore, more people have problems with MP use [Billieux et al., 2015], and addictive consumption styles and problematic behavior have been observed. In order to minimize possible negative consequences caused by excessive usage, further research is required to clarify neurophysiological changes associated with long-term MP EMF exposure and the impact of different behavioral characteristics of MP use on cognitive function.

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Cell phone use may increase the risk of developing parotid gland tumors

Brignardello-Petersen R. Cell phone use may increase the risk of developing parotid gland tumors. J Am Dent Assoc. 2017 May;148(5):e61. doi: 10.1016/j.adaj.2017.02.045.

No Abstract

Also see: de Siqueira EC, de Souza FT, Gomez RS, Gomes CC, de Souza RP. Does cell phone use increase the chances of parotid gland tumor development? A systematic review and meta-analysis [published online ahead of print December 9, 2016]. J Oral Pathol Med. http://dx.doi.org/10.1111/jop.12531.

https://www.ncbi.nlm.nih.gov/pubmed/28449765

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Modeled & Perceived Exposure to RF EMF From Mobile-Phone Base Stations & Development of Symptoms Over Time in General Population Cohort

Martens AL, Slottje P, Timmermans DR, Kromhout H, Reedijk M, Vermeulen RC, Smid T. Modeled and Perceived Exposure to Radio-Frequency Electromagnetic Fields From Mobile-Phone Base Stations and the Development of Symptoms Over Time in a General Population Cohort. Am J Epidemiol. 2017 Apr 7:1-10. doi: 10.1093/aje/kwx041.

Abstract

We assessed associations between modeled and perceived exposure to radio-frequency electromagnetic fields (RF-EMF) from mobile-phone base stations and the development of nonspecific symptoms and sleep disturbances over time. A population-based Dutch cohort study, the Occupational and Environmental Health Cohort Study (AMIGO) (n = 14,829; ages 31-65 years), was established in 2011/2012 (T0), with follow-up of a subgroup (n = 3,992 invited) in 2013 (T1; n = 2,228) and 2014 (T2; n = 1,740). We modeled far-field RF-EMF exposure from mobile-phone base stations at the home addresses of the participants using a 3-dimensional geospatial model (NISMap). Perceived exposure (0 = not at all; 6 = very much), nonspecific symptoms, and sleep disturbances were assessed by questionnaire. We performed cross-sectional and longitudinal analyses,

including fixed-effects regression. We found small correlations between modeled and perceived exposure in AMIGO participants at baseline (n = 14,309; rSpearman = 0.10). For 222 follow-up participants, modeled exposure increased substantially (>0.030 mW/m2) between T0 and T1. This increase in modeled exposure was associated with an increase in perceived exposure during the same time period. In contrast to modeled RF-EMF exposure from mobile-phone base stations, perceived exposure was associated with higher symptom reporting scores in both cross-sectional and longitudinal analyses, as well as with sleep disturbances in cross-sectional analyses.

https://www.ncbi.nlm.nih.gov/pubmed/28398549

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Radiofrequency exposure levels in Amsterdam schools

van Wel L, Vermeulen R, van Eijsden M, Vrijkotte T, Kromhout H, Huss A. Radiofrequency exposure levels in Amsterdam schools. Bioelectromagnetics. 2017 Apr 25. doi: 10.1002/bem.22053.

No Abstract

https://www.ncbi.nlm.nih.gov/pubmed/28444698

This letter to the editor reports the results of RF exposure levels in 102 primary schools in Amsterdam. GSM base stations (900 + 1800 MHz downlink) provided the largest contribution to the total average RF power density (38.0%), followed by DECT cordless phones (27.3%) and GSM mobile devices (11.1%), Although WiFi contributed only 4.5% of the total average power density, the assessments were conducted after school so it was unlikely that any wireless laptops or tablets were being used at the time.

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High RF radiation at Stockholm Old Town: An exposimeter study

Hardell L, Carlberg M, Koppel T, Hedendahl L. High radiofrequency radiation at Stockholm Old Town: An exposimeter study including the Royal Castle, Supreme Court, three major squares and the Swedish Parliament. Mol Clin Oncol. 2017 Apr;6(4):462-476. doi: 10.3892/mco.2017.1180. Epub 2017 Mar 3.

Abstract

Exposure to radiofrequency (RF) radiation was classified as a possible human carcinogen, Group 2B, by the International Agency for Research on Cancer at WHO in 2011. The exposure pattern is changing due to the rapid development of technology. Outdoor RF radiation level was measured during five tours in Stockholm Old Town in April, 2016 using the EME Spy 200 exposimeter with 20 predefined frequencies. The results were based on 10,437 samples in total. The mean level of the total RF radiation was 4,293 µW/m2 (0.4293 µW/cm2). The highest mean levels were obtained for global system for mobile communications (GSM) + universal mobile telecommunications system (UMTS) 900 downlink and long-term evolution (LTE) 2600 downlink (1,558 and 1,265 µW/m2, respectively). The town squares displayed highest total mean levels, with the example of Järntorget square with 24,277 µW/m2 (min 257, max 173,302 µW/m2). These results were in large contrast to areas with lowest total exposure, such as the Supreme Court, with a mean level of 404 µW/m2 (min 20.4, max 4,088 µW/m2). In addition, measurements in the streets surrounding the Royal Castle were lower than the total for the Old Town, with a mean of 756 µW/m2 (min 0.3, max 50,967 µW/m2). The BioInitiative 2012 Report defined the scientific benchmark for possible health risks as 30-60 µW/m2. Our results of outdoor RF radiation exposure at Stockholm Old Town are significantly above that level. The mean exposure level at Järntorget square was 405-fold higher than 60 µW/m2. Our results were below the reference

level on 10,000,000 µW/m2 established by the International Commission on Non-Ionizing Radiation Protection (ICNIRP), which, however, are less credible, as they do not take non-thermal effects into consideration and are not based on sound scientific evaluation. Our highest measured mean level at Järntorget was 0.24% of the ICNIRP level. A number of studies have found adverse, non-thermal (no measurable temperature increase) health effects far below the ICNIRP guidelines.

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Effect of 900 MHz GSM Mobile Phone RF Radiation on Estrogen Receptor Methylation Status in Colon Cells

Mokarram P, Sheikhi M, Mortazavi SMJ, Saeb S, Shokrpour N. Effect of Exposure to 900 MHz GSM Mobile Phone Radiofrequency Radiation on Estrogen Receptor Methylation Status in Colon Cells of Male Sprague Dawley Rats. J Biomed Phys Eng. 2017 Mar 1;7(1):79-86. eCollection 2017.

Abstract

BACKGROUND: Over the past several years, the rapidly increasing use of mobile phones has raised global concerns about the biological effects of exposure to radiofrequency (RF) radiation. Numerous studies have shown that exposure to electromagnetic fields (EMFs) can be associated with effects on the nervous, endocrine, immune, cardiovascular, hematopoietic and ocular systems. In spite of genetic diversity, the onset and progression of cancer can be controlled by epigenetic mechanisms such as gene promoter methylation. There are extensive studies on the epigenetic changes of the tumor suppressor genes as well as the identification of methylation biomarkers in colorectal cancer. Some studies have revealed that genetic changes can be induced by exposure to RF radiation. However, whether or not RF radiation is capable of inducing epigenetic alteration has not been clarified yet. To date, no study has been conducted on the effect of radiation on epigenetic alterations in colorectal cancer (CRC). Several studies have also shown that methylation of estrogen receptor α (ERα), MYOD, MGMT, SFRP2 and P16 play an important role in CRC. It can be hypothesized that RF exposure can be a reason for the high incidence of CRC in Iran. This study aimed to investigate whether epigenetic pattern of ERα is susceptible to RF radiation and if RF radiation can induce radioadaptive response as epigenetic changes after receiving the challenge dose (γ-ray).

MATERIAL AND METHOD: 40 male Sprague-Dawley rats were divided into 4 equal groups (Group I: exposure to RF radiation of a GSM cell phone for 4 hours and sacrificed after 24 hours; Group II: RF exposure for 4 hours, exposure to Co-60 gamma radiation (3 Gy) after 24 hours and sacrificed after 72 hrs; Group III: only 3Gy gamma radiation; Group 4: control group). DNA from colon tissues was extracted to evaluate the methylation status by methylation specific PCR.

RESULTS: Our finding showed that exposure to GSM cell phone RF radiation was capable of altering the pattern of ERα gene methylation compared to that of non-exposed controls. Furthermore, no adaptive response phenomenon was induced in the pattern of ERα gene methylation after exposure to the challenging dose of Co-60 γ-rays.

CONCLUSION: It can be concluded that exposure to RF radiation emitted by GSM mobile phones can lead to epigenetic detrimental changes in ERα promoter methylation pattern.

Open Access Paper: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5401136/

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Proteomic analysis of continuous 900-MHz RF EMF exposure in testicular tissue: a rat model of human cell phone exposure

Sepehrimanesh M, Kazemipour N, Saeb M, Nazifi S, Davis DL.Proteomic analysis of continuous 900-MHz radiofrequency electromagnetic field exposure in testicular tissue: a rat model of human cell phone exposure. Environ Sci Pollut Res Int. 2017 Apr 10. doi: 10.1007/s11356-017-8882-z.

Abstract

Although cell phones have been used worldwide, some adverse and toxic effects were reported for this communication technology apparatus. To analyze in vivo effects of exposure to radiofrequency-electromagnetic field (RF-EMF) on protein expression in rat testicular proteome, 20 Sprague-Dawley rats were exposed to 900 MHz RF-EMF for 0, 1, 2, or 4 h/day for 30 consecutive days. Protein content of rat testes was separated by high-resolution two-dimensional electrophoresis using immobilized pH gradient (pI 4-7, 7 cm) and 12% acrylamide and identified by MALDI-TOF/TOF-MS. Two protein spots were found differentially overexpressed ($P < 0.05$) in intensity and volume with induction factors 1.7 times greater after RF-EMF exposure. After 4 h of daily exposure for 30 consecutive days, ATP synthase beta subunit (ASBS) and hypoxia up-regulated protein 1 precursor (HYOU1) were found to be significantly up-regulated. These proteins affect signaling pathways in rat testes and spermatogenesis and play a critical role in protein folding and secretion in the endoplasmic reticulum. Our results indicate that exposure to RF-EMF produces increases in testicular proteins in adults that are related to carcinogenic risk and reproductive damage. In light of the widespread practice of men carrying phones in their pockets near their gonads, where exposures can exceed as-tested guidelines, further study of these effects should be a high priority.

https://www.ncbi.nlm.nih.gov/pubmed/28397118

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Exposure to mobile phone (900-1800 MHz) during pregnancy: tissue oxidative stress after childbirth

Bahreyni Toossi MH, Sadeghnia HR, Mohammad Mahdizadeh Feyzabadi M, Hosseini M, Hedayati M, Mosallanejad R, Beheshti F, Alizadeh Rahvar Z.
Exposure to mobile phone (900-1800 MHz) during pregnancy: tissue oxidative stress after childbirth. J Matern Fetal Neonatal Med. 2017 Apr 23:1-6. doi: 10.1080/14767058.2017.1315657. [Epub ahead of print]

Abstract

BACKGROUND: The present study has investigated the effects of mobile phone (900-1800 MHz)-induced electromagnetic radiation on redox status in the heart, liver, kidney, cerebellum, and hippocampus of dams and the offspring mice.

MATERIALS AND METHODS: Pregnant Balb/C were divided into two groups including the control and the experimental group. The experimental group was exposed to mobile phone (900-1800 MHz), during pregnancy (2 h/d for 20 d). The dams and the offspring of both groups were sacrificed and tissues of interest were harvested immediately after delivery. Malondialdehyde (MDA) concentration, total thiol groups (TTG) content, superoxide dismutase (SOD), and catalase (CAT) activities were determined in the tissues.

RESULTS: In the experimental groups, MDA levels were significantly increased, while TTG, SOD, and CAT were significantly decreased in the total tissues of dams and their offspring.

CONCLUSION: Exposure to mobile phone (900-1800 MHz) during pregnancy induced oxidative stress in tissues of dams and their offspring.

https://www.ncbi.nlm.nih.gov/pubmed/28434276

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Postnatal development & behavior effects of in-utero exposure of rats to RF emitted from WiFi devices

Othman H, Ammari M, Rtibi K, Bensaid N, Sakly M, Abdelmelek H. Postnatal development and behavior effects of in-utero exposure of rats to radiofrequency waves emitted from conventional WiFi devices.Environ Toxicol Pharmacol. 2017 Apr 22;52:239-247. doi: 10.1016/j.etap.2017.04.016.

Highlights

• Effects of gestational exposure to 2.45 GHz WiFi signal for 2 h/day along gestation period on the offspring were studied.
• Offspring showed neurodevelopment impairments but no behavior alteration at adult age.
• Cerebral oxidative stress equilibrium as well as cholinesterase activity in brain and serum were altered.

Abstract

The present work investigated the effects of prenatal exposure to radiofrequency waves of conventional WiFi devices on postnatal development and behavior of rat offspring. Ten Wistar albino pregnant rats were randomly assigned to two groups (n=5). The experimental group was exposed to a 2.45GHz WiFi signal for 2h a day throughout gestation period. Control females were subjected to the same conditions as treated group without applying WiFi radiations. After delivery, the offspring was tested for physical and neurodevelopment during its 17 postnatal days (PND), then for anxiety (PND 28) and motricity (PND 40-43), as well as for cerebral oxidative stress response and cholinesterase activity in brain and serum (PND 28 and 43). Our main results showed that the in-utero WiFi exposure impaired offspring neurodevelopment during the first seventeen postnatal days without altering emotional and motor behavior at adult age. Besides, prenatal WiFi exposure induced cerebral oxidative stress imbalance (increase in malondialdehyde level (MDA) and hydrogen peroxide (H_2O_2) levels and decrease in catalase (CAT) and superoxide dismutase (SOD) activities) at 28 but not 43days old, also the exposure affected acethylcolinesterase activity at both cerebral and seric levels. Thus, the current study revealed that maternal exposure to WiFi radiofrequencies led to various adverse neurological effects in the offspring by affecting neurodevelopment, cerebral stress equilibrium and cholinesterase activity.

https://www.ncbi.nlm.nih.gov/pubmed/28458069

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Effect of long-term exposure of mice to 900 MHz GSM radiation on cutaneous candidiasis

Bayat M, Hemati S, Soleimani-Estyar R, Shahin-Jafari A. Effect of long-term exposure of mice to 900 MHz GSM radiation on experimental cutaneous candidiasis. Saudi Journal of Biological Sciences. 24(4):907-914. May 2017.

Abstract

Mobile phones communicate with base stations using 900 MHz microwaves. The current study was aimed to survey the effects of long-term 900 MHz microwave exposure of mice on experimentally induced cutaneous candidiasis. Forty inbred, male, BALB/c mice were randomly divided into four groups. Cutaneous lesions with Candida albicans were experimentally induced on the lateral-back skin of the 20 mice. One group of the diseased mice were exposed (6 h per day and 7 d per week) to 900 MHz microwave radiation, while the other groups were not exposed. Two unexposed control groups were also included. The skin lesions were regularly monitored and the live candida cell density was enumerated using the colony-forming unit (CFU) assay. The process was repeated after a one week resting interval. One week later, all mice were challenged through intra tail veins using LD90 dose of C. albicans. Mortality of the mice was recorded and the candida load of the kidney homogenates from died animals was counted. 900 MHz microwave exposed mice had 1.5 day and 3.7 day delays on wound healing in stages two. Live Candida inoculated Wave exposed (LCW) mice also showed higher yeast loads in skin lesions at days 5, 7 and 9 post inoculation. Survival analysis of live candida challenged mice showed the radiation exposed group is prone to death induced by systemic infection and

candida enumeration from the kidney homogenates showed radiation exposed animals have had significantly higher yeast load in the tissue. In collection, long-term 900 MHz radiation exposure of mice led to longevity of skin wounds and susceptibility of the animals to systemic challenge and higher incidences of microorganisms in internal tissues.

http://bit.ly/2p8URXX

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RF radiation induced genotoxic & carcinogenic effects on chickpea root tip cells

Qureshi ST , Memon SA, Abassi AR, Sial MA, Bughio FA. Radiofrequency radiations induced genotoxic and carcinogenic effects on chickpea (Cicer arietinum L.) root tip cells. Saudi Journal of Biological Sciences, 24(4):883-391. May 2017.

Abstract

Present study was under taken to predict the possible DNA damages (genotoxicity) and carcinogenicity caused by radiofrequency radiations (RF) to living tissue. Dry seeds of chickpea were treated with GSM cell phone (900 MHz) and laptop (3.31 GHz) as RF source for 24 and 48 h. Untreated seeds were used as (0 h) negative control and Gamma rays (250 Gray) as positive control. Plant chromosomal aberration assay was used as genotoxicity marker. All the treatment of RF inhibits seed germination percentage. 48 h laptop treatment has the most negative effect as compared to untreated control. A decrease was observed in mitotic index (M.I) and increase in abnormality index (A.I) with the increase in exposure duration and frequency in (Hz). Cell membrane damages were also observed only in 48 h exposure of cell phone and laptop (RF). Maximum nuclear membrane damages and ghost cells were again recorded in 48 h exposure of cell phone and laptop. The radiofrequency radiations (900 MHz and 3.31 GHz) are only genotoxic as they induce micronuclei, bi-nuclei, multi-nuclei and scattered nuclei but could be carcinogenic as 48 h incubation of RF induced fragmentation and ghost cells. Therefore cell phones and laptop should not be used unnecessarily to avoid possible genotoxic and carcinogenic effects.

http://bit.ly/2pYJXrU

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Biological effects of exposure to static electric fields in humans and vertebrates: a systematic review

Petri AK, Schmiedchen K, Stunder D, Dechent D, Kraus T, Bailey WH, Driessen S. Biological effects of exposure to static electric fields in humans and vertebrates: a systematic review. Environ Health. 2017 Apr 17;16(1):41. doi: 10.1186/s12940-017-0248-y.

Abstract

BACKGROUND: High-voltage direct current (HVDC) lines are the technology of choice for the transport of large amounts of energy over long distances. The operation of these lines produces static electric fields (EF), but the data reviewed in previous assessments were not sufficient to assess the need for any environmental limit. The aim of this systematic review was to update the current state of research and to evaluate biological effects of static EF.

METHODS: Using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) recommendations, we collected and evaluated experimental and epidemiological studies examining biological effects of exposure to static EF in humans (n = 8) and vertebrates (n = 40).

RESULTS: There is good evidence that humans and animals are able to perceive the presence of static EF at sufficiently high levels. Hair movements caused by electrostatic forces may play a major role in this perception. A large number of studies reported responses of animals (e.g., altered metabolic, immunologic or developmental parameters) to a broad range of static EF strengths as well, but these responses are likely secondary physiological responses to sensory stimulation. Furthermore, the quality of many of the studies reporting physiological responses is poor, which raises concerns about confounding.

CONCLUSION: The weight of the evidence from the literature reviewed did not indicate that static EF have adverse biological effects in humans or animals. The evidence strongly supported the role of superficial sensory stimulation of hair and skin as the basis for perception of the field, as well as reported indirect behavioral and physiological responses. Physical considerations also preclude any direct effect of static EF on internal physiology, and reports that some physiological processes are affected in minor ways may be explained by other factors. While this literature does not support a level of concern about biological effects of exposure to static EF, the conditions that affect thresholds for human detection and possible annoyance at suprathreshold levels should be investigated.

https://www.ncbi.nlm.nih.gov/pubmed/28416002

Excerpt

The vast majority of the evaluated studies dealt with static EF influences on health and physiological functions in humans and animals. An experimental study in visual display unit users found indications that a combination of static EF exposure and high dust concentrations might induce external facial skin irritation [33]. Two other human studies reported that static EF did not induce facial skin symptoms [32] or impair cardiovascular, hematologic, or psychomotor functions [28]. Neither were adverse health effects reported upon long-term exposure to a HVDC power line [35]. A great many of the animal studies reported effects on metabolic activity [49, 56, 60, 62, 68], collagen synthesis [59, 63, 64, 65], bone density [61], expression of oxidative stress markers [66, 67, 70, 71, 76], hematologic and immunologic blood parameters [41, 42, 43, 50, 69, 70, 71, 72, 74, 75, 76, 77, 78], neurotransmitter concentrations [56], brain activity [58], litter number [52], genotoxicity [69, 79], and tumor regression [37]. However, the results regarding these parameters were not always consistent and partially contradictory. Some studies could not confirm static EF influences on metabolic functions [52], histological appearance of diverse organ systems [43, 50, 69], neurotransmitter concentrations in the brain [38, 40, 57], functions of the immune system [73] or reproductive and developmental parameters [44].

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Absorption of millimeter waves by human beings and its biological implications
A classic paper that has implications for 5G wireless technology

Gandhi OP, Riazi A. Absorption of millimeter waves by human beings and its biological implications. IEEE Transactions on Microwave Theory and Techniques. MTT-34(2):228-235. 1986. http://bit.ly/2oS3rKD

Also see: http://www.saferemr.com/2016/08/is-5g-cellular-technology-harmful-to.html

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Prospects for Millimeter-Wave Compliance Measurement Technologies

Alon L, Gabriel S, Cho GY, Brown R, Deniz CM. Prospects for Millimeter-Wave Compliance Measurement Technologies [Measurements Corner]. IEEE Antennas Propag Mag 2017; 59 (2).

http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7892071

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Maternal cell phone use during pregnancy and child behavioral problems in five birth cohorts

Laura Birks, Mònica Guxens, Eleni Papadopoulou, Jan Alexander, Ferran Ballester, Marisa Estarlich, Mara Gallastegi, Mina Ha, Margaretha Haugen, Anke Huss, Leeka Kheifets et al. Maternal cell phone use during pregnancy and child behavioral problems in five birth cohorts. Environment International. Published online April 7, 2017. http://doi.org/10.1016/j.envint.2017.03.024

"This is the largest study to date to evaluate these associations and to show mostly consistent results across cohorts with retrospectively and prospectively assessed maternal cell phone use."

Highlights

• Largest study to date to use prenatal cell phone use data collected prospectively.
• High prenatal cell phone use linked to hyperactivity/inattention problems in child.
• No prenatal cell phone use linked to low risk for any behavioral problems in child.
• Analysis adjusted for many confounders, but associations cannot be judged causal.
• Future research should adjust for parenting style, maternal hyperactivity, and more.

Introduction Previous studies have reported associations between prenatal cell phone use and child behavioral problems, but findings have been inconsistent and based on retrospective assessment of cell phone use. This study aimed to assess this association in a multi-national analysis, using data from three cohorts with prospective data on prenatal cell phone use, together with previously published data from two cohorts with retrospectively collected cell phone use data.

Methods We used individual participant data from 83,884 mother-child pairs in the five cohorts from Denmark (1996–2002), Korea (2006–2011), the Netherlands (2003–2004), Norway (2004–2008), and Spain (2003–2008). We categorized cell phone use into none, low, medium, and high, based on frequency of calls during pregnancy reported by the mothers. Child behavioral problems (reported by mothers using the Strengths and Difficulties Questionnaire or Child Behavior Checklist) were classified in the borderline/clinical and clinical ranges using validated cut-offs in children aged 5–7 years. Cohort specific risk estimates were meta-analyzed.

Results Overall, 38.8% of mothers, mostly from the Danish cohort, reported no cell phone use during pregnancy and these mothers were less likely to have a child with overall behavioral, hyperactivity/inattention or emotional problems. Evidence for a trend of increasing risk of child behavioral problems through the maternal cell phone use categories was observed for hyperactivity/inattention problems (OR for problems in the clinical range: 1.11, 95% CI 1.01, 1.22; 1.28, 95% CI 1.12, 1.48, among children of medium and high users, respectively). This association was fairly consistent across cohorts and between cohorts with retrospectively and prospectively collected cell phone use data.

Conclusions Maternal cell phone use during pregnancy may be associated with an increased risk for behavioral problems, particularly hyperactivity/inattention problems, in the offspring. The interpretation of these results is unclear as uncontrolled confounding may influence both maternal cell phone use and child behavioral problems.

https://www.ncbi.nlm.nih.gov/pubmed/28392066

Also see:
Pregnancy & Wireless Radiation Risks

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Effects of prenatal exposure to WiFi signal on postnatal development and behavior in rat: Influence of

maternal restraint

Haifa Othman, Mohamed Ammari, Mohsen Sakly, Hafedh Abdelmelek. Effects of prenatal exposure to WiFi signal (2.45 GHz) on postnatal development and behavior in rat: Influence of maternal restraint. Behavioural Brain Research. 36:291-302. May 2017. http://dx.doi.org/10.1016/j.bbr.2017.03.011

Highlights

• Effects of gestational exposure to WiFi signal and restraint along gestation period on the offspring were studied.
• The pups were evaluated for physical development and neuromotor maturation.
• Gestational WiFi exposure and restraint, adversely affected offspring neurodevelopment and behavior at adulthood.
• Progeny brain oxidative balance and serum biochemistry were disrupted.

Abstract

The present study was carried out to investigate the potential combined influence of maternal restraint stress and 2.45 GHz WiFi signal exposure on postnatal development and behavior in the offspring of exposed rats. 24 pregnant albino Wistar rats were randomly assigned to four groups: Control, WiFi-exposed, restrained and both WiFi-exposed and restrained groups. Each of WiFi exposure and restraint occurred 2 h/day along gestation till parturition. The pups were evaluated for physical development and neuromotor maturation. Moreover, elevated plus maze test, open field activity and stationary beam test were also determined on postnatal days 28, 30 and 31, respectively. After behavioral tests, the rats were anesthetized and their brains were removed for biochemical analysis. Our main findings showed no detrimental effects on gestation progress and outcomes at delivery in all groups. Subsequently, WiFi and restraint, *per se* and mainly *in concert* altered physical development of pups with slight differences between genders. Behaviorally, the gestational WiFi irradiation, restraint and especially the associated treatment affected the neuromotor maturation mainly in male progeny. At adult age, we noticed anxiety, motor deficit and exploratory behavior impairment in male offspring co-exposed to WiFi radiation and restraint, and in female progeny subjected to three treatments. The biochemical investigation showed that, all three treatments produced global oxidative stress in brain of both sexes. As for serum biochemistry, phosphorus, magnesium, glucose, triglycerides and calcium levels were disrupted. Taken together, prenatal WiFi radiation and restraint, alone and combined, provoked several behavioral and biochemical impairments at both juvenile and adult age of the offspring.

http://www.sciencedirect.com/science/article/pii/S0166432816313018

Also see:
Pregnancy & Wireless Radiation Risks

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The effect of cell phone usage on semen quality and fertility among Jordanian males

Nahla Al-Bayyari. Middle East Fertility Society Journal. The effect of cell phone usage on semen quality and fertility among Jordanian males. Published online Apr 7, 2017. http://doi.org/10.1016/j.mefs.2017.03.006

Abstract

Background and objective Cell phones emit radiofrequency electromagnetic radiation are prejudicial to human fertility. The objective was to study the effect of cell phone usage on semen quality and men's fertility.

Materials and methods A cross-sectional observational study conducted on 159 men attending infertility clinics at North, Middle and South Governorates in Jordan and undergoing infertility evaluation were divided into two groups according to their active cell phone use: group A: ≤1 h/day and group B: >1 h/day. No interventions were given to patients and semen samples were collected by masturbation in a sterile container after an abstinence period of 5 days. The main outcome measures were sperm volume, liquefaction time, pH, viscosity, count, motility and morphology.

Results There were no statistical significance differences (p > 0.05) between both groups regarding sperm quality parameters according to cell phone use, but there were statistical differences in the frequencies of sperm concentration, volume, viscosity, liquefaction time and means of immotile sperms and abnormal morphology. In addition, time spend on watching television and using wireless phones were significantly (p ≤ 0.05) associated with decreasing mean percentages of normal morphology. The distance from telecommunication tower was significantly (p ≤ 0.05) associated with decreasing sperms volume. Meanwhile, the time spend on sending or receiving messages was significantly (p ≤ 0.05) associated with decreasing sperms count and carrying mobile phone in trouser pocket was significantly associated with increasing means of immotile sperms.

Conclusion Cell phone use might have a negative effect on semen quality parameters and further research is needed.

http://www.sciencedirect.com/science/article/pii/S1110569017300602

Also see:
Effect of Mobile Phones on Sperm Quality

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Behavioral risk factors of breast cancer in Bangui of Central African Republic: A retrospective case-control study

Balekouzou A, Yin P, Afewerky HK, Bekolo C, Pamatika CM, Nambei SW, et al. Behavioral risk factors of breast cancer in Bangui of Central African Republic: A retrospective case-control study. PLoS One. 2017 Feb 8;12(2):e0171154. doi: 10.1371/journal.pone.0171154.

Abstract

Breast cancer is recognized as a major public health problem in developing countries; however, there is very little evidence of behavioral factors associated with breast cancer risk. This study was conducted to identify lifestyles as risk factors for breast cancer among Central African women. A case-control study was conducted with 174 cases confirmed histologically by the pathology unit of the National Laboratory and 348 age-matched controls. Data collection tools included a questionnaire with interviews and medical records of patients. Data were analyzed using SPSS software version 20. Odd ratio (OR) and 95% confidence intervals (95% CI) were obtained by unconditional logistic regression. In total, 522 women were studied with a mean age of 45.8 (SD = 13.4) years. By unconditional logistic regression model, women with breast cancer were more likely to have attained illiterate and elementary education level [11.23 (95% CI, 4.65-27.14) and 2.40 (95% CI, 1.15-4.99)], married [2.09 (95% CI, 1.18-3.71)], positive family history [2.31 (95% CI, 1.36-3.91)], radiation exposure [8.21 (95% CI, 5.04-13.38)], consumption charcuterie [10.82 (95% CI, 2.39-48.90)], fresh fish consumption [4.26 (95% CI, 1.56-11.65)], groundnut consumption [6.46 (95% CI, 2.57-16.27)], soybean consumption [16.74 (95% CI, 8.03-39.84)], alcohol [2.53 (95% CI, 1.39-4.60)], habit of keeping money in bras[3.57 (95% CI, 2.24-5.69)], overweight [5.36 (95% CI, 4.46-24.57)] and obesity [3.11(95% CI, 2.39-20.42)]. However, decreased risk of breast cancer was associated with being employed [0.32 (95% CI, 0.19-0.56)], urban residence [0.16 (95% CI, 0.07-0.37)], groundnut oil consumption [0.05 (95% CI, 0.02-0.14)], wine consumption [0.16 (95% CI, 0.09-0.26)], **non habit of keeping cell phone in bras [0.56 (95% CI, 0.35-0.89)]** and physical activity [0.71(95% CI, 0.14-0.84)]. The study showed that little or no education, marriage, positive family history of cancer, radiation exposure, charcuterie, fresh fish, groundnut, soybean, alcohol, habit of keeping money in bras, overweight and obesity were associated with breast cancer risk among Central African women living in Bangui.

Women living in Bangui should be more cautious on the behavioral risk associated with breast cancer.

http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0171154

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Ecological momentary assessments integrating real-time exposure measurements & health assessment using a smartphone application

van Wel L, Huss A, Bachmann P, Zahner M, Kromhout H, Fröhlich J, Vermeulen R. Context-sensitive ecological momentary assessments; integrating real-time exposure measurements, data-analytics and health assessment using a smartphone application. Environ Int. 2017 Mar 25;103:8-12. doi: 10.1016/j.envint.2017.03.016. [Epub ahead of print]

Abstract

INTRODUCTION: Modern sensor technology makes it possible to collect vast amounts of environmental, behavioural and health data. These data are often linked to contextual information on for example exposure sources which is separately collected with considerable lag time, leading to complications in assessing transient and/or highly spatially variable environmental exposures. Context-Sensitive Ecological Momentary Assessments1 (CS-EMAs) could be used to address this. We present a case study using radiofrequency-electromagnetic fields (RF-EMF) exposure as an example for implementing CS-EMA in environmental research.

METHODS: Participants were asked to install a custom application on their own smartphone and to wear an RF-EMF exposimeter for 48h. Questionnaires were triggered by the application based on a continuous data stream from the exposimeter. Triggers were divided into four categories: relative and absolute exposure levels, phone calls, and control condition. After the two days of use participants filled in an evaluation questionnaire.

RESULTS: 74% of all CS-EMAs were completed, with an average time of 31s to complete a questionnaire once it was opened. Participants reported minimal influence on daily activities. There were no significant differences found between well-being and type of RF-EMF exposure.

CONCLUSIONS: We show that a CS-EMA based method could be used in environmental research. Using several examples involving environmental stressors, we discuss both current and future applications of this methodology in studying potential health effects of environmental factors.

https://www.ncbi.nlm.nih.gov/pubmed/28351768

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Tumor-treating fields elicit a conditional vulnerability to ionizing radiation via the downregulation of BRCA1 signaling and reduced DNA double-strand break repair capacity in non-small cell lung cancer cell lines

Karanam NK, Srinivasan K, Ding L, Sishc B, Saha D, Story MD. Tumor-treating fields elicit a conditional vulnerability to ionizing radiation via the downregulation of BRCA1 signaling and reduced DNA double-strand break repair capacity in non-small cell lung cancer cell lines. Cell Death Dis. 2017 Mar 30;8(3):e2711. doi: 10.1038/cddis.2017.136.

Abstract

The use of tumor-treating fields (TTFields) has revolutionized the treatment of recurrent and newly diagnosed glioblastoma (GBM). TTFields are low-intensity, intermediate frequency, alternating electric fields that are

applied to tumor regions and cells using non-invasive arrays. The predominant mechanism by which TTFields are thought to kill tumor cells is the disruption of mitosis. Using five non-small cell lung cancer (NSCLC) cell lines we found that there is a variable response in cell proliferation and cell killing between these NSCLC cell lines that was independent of p53 status. TTFields treatment increased the G2/M population, with a concomitant reduction in S-phase cells followed by the appearance of a sub-G1 population indicative of apoptosis. Temporal changes in gene expression during TTFields exposure was evaluated to identify molecular signaling changes underlying the differential TTFields response. The most differentially expressed genes were associated with the cell cycle and cell proliferation pathways. However, the expression of genes found within the BRCA1 DNA-damage response were significantly downregulated ($P<0.05$) during TTFields treatment. DNA double-strand break (DSB) repair foci increased when cells were exposed to TTFields as did the appearance of chromatid-type aberrations, suggesting an interphase mechanism responsible for cell death involving DNA repair. Exposing cells to TTFields immediately following ionizing radiation resulted in increased chromatid aberrations and a reduced capacity to repair DNA DSBs, which were likely responsible for at least a portion of the enhanced cell killing seen with the combination. These findings suggest that TTFields induce a state of 'BRCAness' leading to a conditional susceptibility resulting in enhanced sensitivity to ionizing radiation and provides a strong rationale for the use of TTFields as a combined modality therapy with radiation or other DNA-damaging agents.

https://www.ncbi.nlm.nih.gov/pubmed/28358361

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Are media reports able to cause somatic symptoms attributed to WiFi radiation? An experimental test of the negative expectation hypothesis

Bräscher AK, Raymaekers K, Van den Bergh O, Witthöft M. Are media reports able to cause somatic symptoms attributed to WiFi radiation? An experimental test of the negative expectation hypothesis. Environ Res. 2017 Mar 31;156:265-271. doi: 10.1016/j.envres.2017.03.040.

Abstract

People suffering from idiopathic environmental intolerance attributed to electromagnetic fields (IEI-EMF) experience numerous non-specific symptoms that they attribute to EMF. The cause of this condition remains vague and evidence shows that psychological rather than bioelectromagnetic mechanisms are at work. We hypothesized a role of media reports in the etiology of IEI-EMF and investigated how somatosensory perception is affected. 65 healthy participants were instructed that EMF exposure can lead to enhanced somatosensory perception. Participants were randomly assigned to watch either a television report on adverse health effects of EMF or a neutral report. During the following experiment, participants rated stimulus intensities of tactile (electric) stimuli while being exposed to a sham WiFi signal in 50% of the trials. Sham WiFi exposure led to increased intensity ratings of tactile stimuli in the WiFi film group, especially in participants with higher levels of somatosensory amplification. Participants of the WiFi group reported more anxiety concerning WiFi exposure than the Control group and tended to perceive themselves as being more sensitive to EMF after the experiment compared to before. Sensational media reports can facilitate enhanced perception of tactile stimuli in healthy participants. People tending to perceive bodily symptoms as intense, disturbing, and noxious seem most vulnerable. Receiving sensational media reports might sensitize people to develop a nocebo effect and thereby contribute to the development of IEI-EMF. By promoting catastrophizing thoughts and increasing symptom-focused attention, perception might more readily be enhanced and misattributed to EMF.

https://www.ncbi.nlm.nih.gov/pubmed/28371755

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Mitochondrial hyperpolarization and cytochrome-c release in microwave-exposed MCF-7 cells

Esmekaya MA, Canseven AG, Kayhan H, Tuysuz MZ, Sirav B, Seyhan N. Mitochondrial hyperpolarization and cytochrome-c release in microwave-exposed MCF-7 cells. Gen Physiol Biophys. 2016 Sep 12. [Epub ahead of print]

Abstract

This study examines the effects of a 2.1-GHz WCDMA-modulated microwave (MW) radiation on apoptotic activity and mitochondrial membrane potential (ΔΨm) in MCF-7 cells. The cells were exposed to the MW at a specific absorption rate (SAR) of 0.528 W/kg for 4 or 24 h. The antiproliferative effect of MW exposure was determined by the MTT test. Cytochrome-c and p53 levels were determined by an ELISA method. The relative ΔΨm was analysed by JC-1 staining using flow cytometer. Apoptotic rate of the cells was measured by Annexin-V-FITC staining. All assays were performed after certain time of incubations (15 min-4 h) following MW exposure. MW-exposed cells showed a significant decrease in viability when compared to unexposed cells. A significantly larger decrease was observed after longer exposure. The percentage of apoptotic cells, amount of cytochrome-c, and relative ΔΨm were significantly higher in MW-exposed cells. The percent of apoptotic cells and relative ΔΨm in 24 h MW-exposed group was significantly higher than those in 4 h MW-exposed group. However, no significant change was observed in p53 levels. These results demonstrated that exposure to 2.1-GHz WCDMA-modulated MW radiation caused hyperpolarization of mitochondria that in turn induced apoptosis in MCF-7 cells.

https://www.ncbi.nlm.nih.gov/pubmed/27615380

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Case-control study on occupational exposure to extremely low-frequency electromagnetic fields and glioma risk

Carlberg M, Koppel T, Ahonen M, Hardell L. Case-control study on occupational exposure to extremely low-frequency electromagnetic fields and glioma risk. Am J Ind Med. 2017 Apr 10. doi: 10.1002/ajim.22707. [Epub ahead of print]

Abstract

BACKGROUND: Exposure to extremely low-frequency electromagnetic fields (ELF-EMF) was in 2002 classified as a possible human carcinogen, Group 2B, by the International Agency for Research on Cancer at WHO.

METHODS: Life time occupations were assessed in case-control studies during 1997-2003 and 2007-2009. An ELF-EMF Job-Exposure Matrix was used for associating occupations with ELF exposure (μT). Cumulative exposure (μT-years), average exposure (μT), and maximum exposed job (μT) were calculated.

RESULTS: Cumulative exposure gave for astrocytoma grade IV (glioblastoma multiforme) in the time window 1-14 years odds ratio (OR) = 1.9, 95% confidence interval (CI) = 1.4-2.6, p linear trend <0.001, and in the time window 15+ years OR = 0.9, 95%CI = 0.6-1.3, p linear trend = 0.44 in the highest exposure categories 2.75+ and 6.59+ μT years, respectively.

CONCLUSION: An increased risk in late stage (promotion/progression) of astrocytoma grade IV for occupational ELF-EMF exposure was found.

https://www.ncbi.nlm.nih.gov/pubmed/28394434

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Occupational exposure and amyotrophic lateral sclerosis in a prospective cohort

Koeman T, Slottje P, Schouten LJ, Peters S, Huss A, Veldink JH, Kromhout H, van den Brandt PA, Vermeulen R. Occupational exposure and amyotrophic lateral sclerosis in a prospective cohort. Occup Environ Med. 2017 Mar 29. pii: oemed-2016-103780. doi: 10.1136/oemed-2016-103780.

Abstract

OBJECTIVE: To prospectively study suspected occupational risk factors for amyotrophic lateral sclerosis (ALS).

METHODS: For this case-cohort analysis within the prospective Netherlands Cohort Study, 58 279 men and 62 573 women aged 55-69 years at enrollment in 1986 were followed up for 17.3 years on ALS mortality. Information on occupational history and potential confounders were collected at baseline through a self-administered questionnaire and entered for a random subcohort (2092 men and 2074 women) and ALS deaths (76 men and 60 women). Occupational exposure to solvents, pesticides, metals, extremely low frequency magnetic fields (ELF-MFs) and electrical shocks was estimated by means of job exposure matrices (JEMs). Associations between ever/never occupationally exposed and cumulative exposure and ALS mortality were analysed by gender using Cox regression.

RESULTS: Occupational exposure to ELF-MF showed a possible association with ALS mortality among men: HR for ever holding a job with high exposure versus background 2.19 (95% (CI): 1.02 to 4.73) and HR for the highest tertile of cumulative exposure versus background 1.93 (95% CI 1.05 to 3.55).

INTERPRETATION: These results strengthen the evidence suggesting a positive association between ELF-MF exposure and ALS. We did not replicate earlier positive findings for other occupational exposures.

https://www.ncbi.nlm.nih.gov/pubmed/28356332

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Parkinson's disease and occupational exposures: a systematic literature review and meta-analyses

Gunnarsson LG, Bodin L. Parkinson's disease and occupational exposures: a systematic literature review and meta-analyses.
Scand J Work Environ Health. 2017 Apr 5. pii: 3641. doi: 10.5271/sjweh.3641.

Abstract

Objectives We conducted a systematic literature review to identify studies fulfilling good scientific epidemiological standards for use in meta-analyses of relevant risk factors for Parkinson's disease. Methods Our search identified 103 original publications on associations between work and Parkinson's disease. GRADE guidelines were used to ensure high scientific quality, and reliable guidelines were applied to classify the papers. Of the 103 articles, 47 fulfilled good scientific standards while 56 were methodologically deficient and thus excluded from our meta-analyses. Results A total of 23 publications concerned work exposure to pesticides. The weighted relative risk estimate was 1.67 (95% confidence interval 1.42-1.97). A funnel plot and bias test indicated that some publication bias concerning smaller studies might have been present. The risk estimate was not influenced by study design (case-control, cohort, or cross-sectional study) or gender. Higher estimates were found when there was a hereditary taint or onset below age 60. Studies on exposure to metals or electromagnetic fields did not show increased risk. Conclusions Using an elaborated quality protocol, there is now strong evidence that exposure to any pesticide involves a ≥50% increased risk for developing Parkinson's disease.

https://www.ncbi.nlm.nih.gov/pubmed/?term=28379585

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ELF EMF promotes astrocytic differentiation of human bone marrow stem cells by modulating SIRT1 expression

Jeong WY, Kim JB, Kim HJ, Kim CW. Extremely low-frequency electromagnetic field promotes astrocytic differentiation of human bone marrow mesenchymal stem cells by modulating SIRT1 expression. Biosci Biotechnol Biochem. 2017 Mar 29:1-7. doi: 10.1080/09168451.2017.1308243.

Abstract

It has been shown that extremely low-frequency electromagnetic fields (ELFMF) affect regulation of cell fate and differentiation. Thus, the aim of this study was to investigate the role of ELFMFs in the enhancement of astrocytic differentiation. ELFMF exposure reduced the rate of proliferation and enhanced astrocytic differentiation. The ELFMF-treated cells showed increased levels of the astrocyte marker (GFAP), while those of the early neuronal marker (Nestin) and stemness marker (OCT3/4) were downregulated. The reactive oxygen species (ROS) level was observed to be significantly elevated after ELFMF exposure, which strengthens the modulatory role of SIRT1 and SIRT1 downstream molecules (TLE1, HES1, and MASH1) during astrocytic differentiation. After nicotinamide (5 mM) mediated inhibition of SIRT1, levels of TLE1, HES1, and MASH1 were examined; TLE1 was significantly upregulated and MASH1 was downregulated. These results suggest that ELFMFs induce astrocytic differentiation through activation of SIRT1 and SIRT1 downstream molecules.

https://www.ncbi.nlm.nih.gov/pubmed/28351214

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ELF EMF exposure enhances inflammatory response and inhibits effect of antioxidant in RAW 264.7 cells

Kim SJ, Jang YW, Hyung KE, Lee DK, Hyun KH, Jeong SH, Min KH, Kang W, Jeong JH, Park SY, Hwang KW. Extremely low-frequency electromagnetic field exposure enhances inflammatory response and inhibits effect of antioxidant in RAW 264.7 cells. Bioelectromagnetics. 2017 Mar 29. doi: 10.1002/bem.22049. [Epub ahead of print]

Abstract

In recent years there has been a dramatic increase in the number and variety of electronic devices that emit electromagnetic waves. Because people live and work in close proximity to these pieces of electrical equipment, there is growing concern surrounding the destruction of homeostasis by electromagnetic field exposure. In the present study, the effects of 60 Hz 0.8 mT extremely low-frequency electromagnetic fields (ELF-EMF) on a macrophage cell line (RAW 264.7) were examined. Under defined ELF-EMF exposure conditions, the production of nitric oxide and pro-inflammatory cytokines, TNF-α, IL-1β, and IL-6, were increased in RAW 264.7 cells and the expression of those genes was also upregulated. However, cell proliferation was not altered. Translocation of NF-κB (nuclear factor kappa B), molecules that act downstream of the pro-inflammatory cytokines, were increased to the nucleus under ELF-EMF exposure conditions. In addition, we found that ELF-EMF exposure elevated activation of nuclear factor of activated T cells (NFAT) 2, as well as positively affected the influx of calcium. Furthermore, with both the presence of a potent antioxidant (Resveratrol) and downregulation of the antioxidant-related gene Prx-1 (Peroxiredoxin-1), ELF-EMF was associated with higher inflammatory responses of macrophages. These results suggest that an ELF-EMF amplifies inflammatory responses through enhanced macrophage activation and can decrease the effectiveness of antioxidants.

https://www.ncbi.nlm.nih.gov/pubmed/28370033

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ELF EMF induces neural differentiation of hBM-MSCs through regulation of (Zn)-metallothionein-3

Aikins AR, Hong SW, Kim HJ, Yoon CH, Chung JH, Kim M, Kim CW. Extremely low-frequency electromagnetic field induces neural differentiation of hBM-MSCs through regulation of (Zn)-metallothionein-3. Bioelectromagnetics. 2017 Mar 29. doi: 10.1002/bem.22046.

Abstract

Extremely low-frequency electromagnetic field (ELFEMF) can stimulate neural differentiation in human bone marrow-derived mesenchymal cells (hBM-MSCs), and this provides an opportunity for research on neurodegenerative diseases such as Alzheimer's disease (AD). Metallothionein-3 (MT3), an isoform of the metal-binding proteins, metallothioneins, involved in maintaining intracellular zinc (Zn) homeostasis and the deregulation of zinc homeostasis, has separately been implicated in AD. Here, we investigated the effect of ELFEMF-induced neural differentiation of hBM-MSCs on Zn-MT3 homeostatic interaction. Exposure to ELFEMF induced neural differentiation of hBM-MSCs, which was characterized by decreased proliferation and enhanced neural-like morphology. We observed expression of neuronal markers such as β-tubulin3, pleiotrophin, and neurofilament-M at the mRNA level and MAP2 at the protein level. ELFEMF-induced neural differentiation correlated with decreased expression of metal-response element-transcription factor 1 and MT3, as well as decreased intracellular Zn concentration. In addition, upregulation of dihydropyrimidinase-related protein 2 was observed, but there was no change in γ-enolase expression. These data indicate a possible regulatory mechanism for MT3 during neural differentiation. Our findings provide considerable insight into molecular mechanisms involved in neural differentiation, which is useful for developing new treatments for neurodegenerative diseases.

https://www.ncbi.nlm.nih.gov/pubmed/28370392

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Effects of 50 Hz MF exposure on DNA damage and cellular functions in various neurogenic cells

Su L, Yimaer A, Wei X, Xu Z, Chen G. The effects of 50 Hz magnetic field exposure on DNA damage and cellular functions in various neurogenic cells.J Radiat Res. 2017 Mar 21:1-13. doi: 10.1093/jrr/rrx012.

Abstract

Epidemiological studies have indicated a possible association between extremely low-frequency magnetic field (ELF-MF) exposure and the risk of nervous system diseases. However, laboratory studies have not provided consistent results for clarifying this association, despite many years of studies. In this study, we have systematically investigated the effects of 50 Hz MF exposure on DNA damage and cellular functions in both neurogenic tumor cell lines (U251, A172, SH-SY5Y) and primary cultured neurogenic cells from rats (astrocytes, microglia, cortical neurons). The results showed that exposure to a 50 Hz MF at 2.0 mT for up to 24 h did not influence γH2AX foci formation (an early marker of DNA double-strand breaks) in any of six different neurogenic cells. Exposure to a 50 Hz MF did not affect cell cycle progression, cell proliferation or cell viability in neurogenic tumor U251, A172 or SH-SY5Y cells. Furthermore, the MF exposure for 24 h did not significantly affect the secretion of cytokines (TNF-α, IL-6 or IL-1β) in astrocytes or microglia, or the phagocytic activity of microglia. In addition, MF exposure for 1 h per day did not significantly influence expression levels of microtubule-associated protein tau, microtubule-associated protein 2, postsynaptic density 95 or gephyrin in cortical neurons, indicating an absence of effects of MF exposure on the development of cortical neurons. In conclusion, our data suggest that exposure to a 50 Hz MF at 2.0 mT did not elicit DNA damage effects or abnormal cellular functions in the neurogenic cells studied.

https://www.ncbi.nlm.nih.gov/pubmed/28369556

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Electric Fields and Enzyme Catalysis

Fried SD, Boxer SG. Electric Fields and Enzyme Catalysis. Annu Rev Biochem. 2017 Mar 24. doi: 10.1146/annurev-biochem-061516-044432

Abstract

What happens inside an enzyme's active site to allow slow and difficult chemical reactions to occur so rapidly? This question has occupied biochemists' attention for a long time. Computer models of increasing sophistication have predicted an important role for electrostatic interactions in enzymatic reactions, yet this hypothesis has proved vexingly difficult to test experimentally. Recent experiments utilizing the vibrational Stark effect make it possible to measure the electric field a substrate molecule experiences when bound inside its enzyme's active site. These experiments have provided compelling evidence supporting a major electrostatic contribution to enzymatic catalysis. Here, we review these results and develop a simple model for electrostatic catalysis that enables us to incorporate disparate concepts introduced by many investigators to describe how enzymes work into a more unified framework stressing the importance of electric fields at the active site.

https://www.ncbi.nlm.nih.gov/pubmed/28375745

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Is electromagnetism one of the causes of Colony Collapse Disorder? A work plan for testing this hypothesis

Marie-Claire Cammaerts. Is electromagnetism one of the causes of the CCD? A work plan for testing this hypothesis. Journal of Behavior. 2(1): 1006. Published Mar 28, 2017.

Abstract

The decline of domestic bees all over the world is an important problem still not well understood by scientists and beekeepers, and far from being solved. Its reasons are numerous: among others, the use of pesticides and insecticides, the decrease of plant diversity, and bee’s parasites. Besides these threats, there is a potential adverse factor little considered: manmade electromagnetism. The production of electromagnetic waves by human settlements, cellphones relay and power lines largely increases nowadays. Bees are very sensitive to this electromagnetism. The present paper suggests two simple experimental protocols for bringing to the fore the potential adverse effect of electromagnetism on bees and to act consequently. The first one is the observation of bees’ avoidance of a wireless apparatus; the second one is the assessment of colonies’ strength and of the intensity of the electromagnetism field (EMF) surrounding them. If bees avoid a wireless apparatus, if hives in bad health are located in EMF of a rather high intensity, it can be presumed that bees are affected by manmade electromagnetism. This should enable searching for palliative measures.

https://www.jscimedcentral.com/Behavior/behavior-2-1006.php

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Zebra finches have a light-dependent magnetic compass similar to migratory birds

Pinzon-Rodriguez A, Muheim R. Zebra finches have a light-dependent magnetic compass similar to migratory birds. J Exp Biol. 2017 Apr 1;220(Pt 7):1202-1209. doi: 10.1242/jeb.148098.

Abstract

Birds have a light-dependent magnetic compass that provides information about the spatial alignment of the geomagnetic field. It is proposed to be located in the avian retina and mediated by a light-induced, radical-pair mechanism involving cryptochromes as sensory receptor molecules. To investigate how the behavioural responses of birds under different light spectra match with cryptochromes as the primary magnetoreceptor, we examined the spectral properties of the magnetic compass in zebra finches. We trained birds to relocate a food reward in a spatial orientation task using magnetic compass cues. The birds were well oriented along the trained magnetic compass axis when trained and tested under low-irradiance 521 nm green light. In the presence of a 1.4 MHz radio-frequency electromagnetic (RF)-field, the birds were disoriented, which supports the involvement of radical-pair reactions in the primary magnetoreception process. Birds trained and tested under 638 nm red light showed a weak tendency to orient ~45 deg clockwise of the trained magnetic direction. Under low-irradiance 460 nm blue light, they tended to orient along the trained magnetic compass axis, but were disoriented under higher irradiance light. Zebra finches trained and tested under high-irradiance 430 nm indigo light were well oriented along the trained magnetic compass axis, but disoriented in the presence of a RF-field. We conclude that magnetic compass responses of zebra finches are similar to those observed in nocturnally migrating birds and agree with cryptochromes as the primary magnetoreceptor, suggesting that light-dependent, radical-pair-mediated magnetoreception is a common property for all birds, including non-migratory species.

https://www.ncbi.nlm.nih.gov/pubmed/28356366

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Evaluation of children exposure to electromagnetic fields of mobile phones using age-specific head models with age-dependent dielectric properties

Mohammed B, Jin J, Abbosh A, Bialkowski K, Manoufali M, Crozier S. Evaluation of children exposure to electromagnetic fields of mobile phones using age-specific head models with age-dependent dielectric properties. IEEE Access. PP(99). 2017

Abstract

Given the rapid introduction of mobile phones and other portable wireless devices into society, and the increased possibility of young children using or being exposed to electromagnetic (EM) fields, a study of specific absorption rate (SAR) in the head of young children is becoming increasingly relevant. To accurately evaluate the exposure of children to electromagnetic fields, realistic head models, which consider the age-specific anatomical structure and age-dependent tissues dielectric properties, are developed. During postnatal development of human tissues, the number and size of cells increase while the proportion of water content decreases. Such changes result generally in significant changes in the dielectric properties of tissues. The SAR levels for different ages are investigated using the developed child's head models when young children or their parents use a standard mobile phone.

The results show that the maximum SAR levels in brain tissues of young children (3 months) are higher by up to 61% and 78% than adults at the lowest (700 MHz) and highest (2600 MHz) investigated frequencies, respectively. The percentage absorption power in the heads of young children (3 months) is higher by up to 40.6% and 24% than the values for adults at 700 MHz and 2600 MHz, respectively.

Our investigation shows that previous studies, which used scaled head models without considering the age-dependent variations in the head anatomy and/or age-dependent tissues' dielectric properties, underestimated SAR levels in the children's heads. **The obtained results using the developed realistic head models**

indicate that for young children, a lower limit on radiated power might be required to meet the acceptable dosimetry levels.

http://ieeexplore.ieee.org/document/8086149/

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An international prospective cohort study of mobile phone users and health (COSMOS): Factors affecting validity of self-reported mobile phone use

Toledano MB, Auvinen A, Tettamanti G, Cao Y, Feychting M, Ahlbom A, Fremling K, Heinävaara S, Kojo K, Knowles G, Smith RB, Schüz J, Johansen C, Poulsen AH, Deltour I, Vermeulen R, Kromhout H, Elliott P, Hillert L. An international prospective cohort study of mobile phone users and health (COSMOS): Factors affecting validity of self-reported mobile phone use. Int J Hyg Environ Health. 2017 Sep 20. pii: S1438-4639(17)30321-8. doi: 10.1016/j.ijheh.2017.09.008.

Highlights

• Agreement for self-reported phone use was higher for call duration than frequency.
• Subjects tended to underestimate rather than overestimate mobile phone use.
• Agreement for self-reported call frequency was higher in men and older subjects.
• Subjects who reported symptoms were more likely to overestimate low call duration.

Abstract

This study investigates validity of self-reported mobile phone use in a subset of 75 993 adults from the COSMOS cohort study. Agreement between self-reported and operator-derived mobile call frequency and duration for a 3-month period was assessed using Cohen's weighted Kappa (κ). Sensitivity and specificity of both self-reported high (≥10 calls/day or ≥4h/week) and low (≤6 calls/week or <30min/week) mobile phone use were calculated, as compared to operator data. For users of one mobile phone, agreement was fair for call frequency (κ=0.35, 95% CI: 0.35, 0.36) and moderate for call duration (κ=0.50, 95% CI: 0.49, 0.50). Self-reported low call frequency and duration demonstrated high sensitivity (87% and 76% respectively), but for high call frequency and duration sensitivity was lower (38% and 56% respectively), reflecting a tendency for greater underestimation than overestimation. Validity of self-reported mobile phone use was lower in women, younger age groups and those reporting symptoms during/shortly after using a mobile phone. This study highlights the ongoing value of using self-report data to measure mobile phone use. Furthermore, compared to continuous scale estimates used by previous studies, categorical response options used in COSMOS appear to improve validity considerably, most likely by preventing unrealistically high estimates from being reported.

https://www.ncbi.nlm.nih.gov/pubmed/29056311

Excerpts

The target population for COSMOS was adult mobile phone users, aged 18–69 years, in 5 European countries: Denmark, Finland, the Netherlands, Sweden and the UK, and recently a 6th cohort has been initiated in France.

This analysis focuses on participants recruited into the study in Finland, Sweden and the UK between 2007 and 2010.

Participants were asked to report frequency and duration of mobile phone voice calls for the preceding three months via the following two questions:

"Over the last three months, how often did you talk on a mobile phone?" with the response options: <1 call per week (Finland and Sweden only; the UK web-based questionnaire filtered out these respondents in a previous question), 1–6 calls per week, 1–9 calls per day, ≥10 calls per day.

"Over the last three months, on average, how much time per week did you spend talking on a mobile phone?" with the response options: <5 min, 5–29 min, 30–59 min, 1–3 h, 4–6 h, >6 h.

Participants were asked if they experienced symptoms ("no symptoms, headache, dizziness, numbness in hands, nausea, hearing loss, tinnitus/ringing sound in ear, warming sensation on face and/or ear") whilst using, or shortly after using, a mobile phone.

Approximately 20% of participants spent at least 4 h per week on calls and/or made at least 10 calls per day, and were thus defined as having high mobile phone use (Table 1).

We found that a considerable proportion of respondents misclassified their mobile phone use (approximately 60% and 40% for call duration and frequency, respectively) (Table 2, Supplementary Tables 1 & 2). Approximately a third of the participants underestimated their mobile phone call duration and frequency. The proportion of participants overestimating mobile phone use was much lower (23% for duration and 5% for call frequency among one- phone users) (Table 2).

Agreement between self-reported and operator call duration was significantly lower among those who reported experiencing symptoms whilst (or shortly after) using a mobile phone (κ = 0.44 (95% CI: 0.43, 0.46)) compared with those without symptoms (κ = 0.50 (95% CI: 0.49, 0.50)), primarily because those with symptoms were more likely to overestimate low call duration (sensitivity = 65% (95% CI: 62%, 67%) vs. 78% (95% CI: 77%, 79%) for those with and without symptoms respectively) (Table 4). A similar pattern was observed for call frequency, but the differences were smaller.

In this largest validation study to date, we found fair to moderate agreement between self-reported and operator-derived data on mobile phone use. The sensitivity of self-report was generally high for correctly identifying those with the smallest amount of mobile phone use, but lower for identifying heavy mobile phone use, in line with our observation that respondents in this study were more likely to underestimate than overestimate their mobile phone use.

Our findings demonstrate that those who experience symptoms when using a mobile phone are more likely to overestimate light mobile phone use, particularly call duration, compared to those without symptoms. This suggests that an individual's experience and/or perception of their health may influence the self-reporting of mobile phone use, likely affecting the validity of such exposure assessments. More specifically, it is possible that rumination bias (a form of information bias), whereby those with symptoms overestimate (consciously or subconsciously) their phone use in an effort to explain their symptoms, could be occurring in this subset of individuals. This finding has potential implications for the interpretation of previous cross-sectional studies investigating associations between mobile phone use and the symptoms reported here (Mortazavi et al., 2007; Soderqvist et al., 2008; Sandstrom et al., 2001). Overestimation of mobile phone use among those who report such symptoms would likely bias cross-sectional risk estimates away from the null, even if a true association does not exist (Armstrong, 1998), thus potentially distorting any observed associations.

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Total recall in the SCAMP cohort: Validation of self-reported mobile phone use in the smartphone era

Mireku MO, Mueller W, Fleming C, Chang I, Dumontheil I, Thomas MSC, Eeftens M, Elliott P, Röösli M, Toledano MB. Total recall in the SCAMP cohort: Validation of self-reported mobile phone use in the smartphone era. Environ Res. 2017 Oct 30;161:1-8. doi: 10.1016/j.envres.2017.10.034. [Epub ahead of print]

Abstract

Mobile phone use, predominantly smartphones, is almost ubiquitous amongst both adults and children. However adults and children have different usage patterns. A major challenge with research on mobile phone use is the reliability of self-reported phone activity for accurate exposure assessment.

We investigated the agreement between self-reported mobile phone use data and objective mobile operator traffic data in a subset of adolescents aged 11-12 years participating in the Study of Cognition, Adolescents and Mobile Phones (SCAMP) cohort. We examined self-reported mobile phone use, including call frequency, cumulative call time duration and text messages sent among adolescents from SCAMP and matched these data with records provided by mobile network operators (n = 350). The extent of agreement between self-reported mobile phone use and mobile operator traffic data use was evaluated using Cohen's weighted Kappa (κ) statistics. Sensitivity and specificity of self-reported low (< 1 call/day, ≤ 5min of call/day or ≤ 5 text messages sent/day) and high (≥ 11 calls/day, > 30min of call/day or ≥ 11 text messages sent /day) use were estimated.

Agreement between self-reported mobile phone use and mobile operator traffic data was highest for the duration spent talking on mobile phones per day on weekdays (38.9%) and weekends (29.4%) compared to frequency of calls and number of text messages sent. Adolescents overestimated their mobile phone use during weekends compared to weekdays. Analysis of agreement showed little difference overall between the sexes and socio-economic groups. Weighted kappa between self-reported and mobile operator traffic data for call frequency during weekdays was κ = 0.12, 95% CI 0.06-0.18. Of the three modes of mobile phone use measured in the questionnaire, call frequency was the most sensitive for low mobile phone users on weekdays and weekends (77.1, 95% CI: 69.3-83.7 and 72.0, 95% CI: 65.0-78.4, respectively). Specificity was moderate to high for high users with the highest for call frequency during weekdays (98.4, 95% CI: 96.4-99.5).

Despite differential agreement between adolescents' self-reported mobile phone use and mobile operator traffic data, our findings demonstrate that self-reported usage adequately distinguishes between high and low use.

The greater use of mobile smartphones over Wi-Fi networks by adolescents, as opposed to mobile phone networks, means operator data are not the gold standard for exposure assessment in this age group. This has important implications for epidemiologic research on the health effects of mobile phone use in adolescents.

https://www.ncbi.nlm.nih.gov/pubmed/29096315

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Long term variations measurement of electromagnetic field exposures in Alcalá de Henares (Spain)

Sánchez-Montero R, Alén-Corderoa C, López-Espí PL, Rigelsford JM, Aguilera-Benavente F, J.Alpuente-Hermosilla J. Long term variations measurement of electromagnetic field exposures in Alcalá de Henares (Spain). Science of the Total Environment. 598: 657-668. Nov 2017. https://doi.org/10.1016/j.scitotenv.2017.03.131.

Highlights

• The evolution of EMF exposure for Alcalá de Henares over a 2006–2015 is presented.
• Measurements take into account all the sources and their evolution in a 35 km2 area.
• A statistical and spatial analysis and their variations are also analysed.
• We have measured lower EMF levels where the population has remained unaltered.
• New areas have demanded new resources and it has led to an increase of the EMF.

Abstract

Electromagnetic radiowave exposure is a major concern in most countries due to possible adverse health effects. Over the last 10 years, many technological changes (digital television, mobile technologies, wireless networks…) have led to variations in the electromagnetic field (EMF) levels.

A large number of studies devoted to the analysis of EMF levels with personal dosimeters or computer models of the exposure of mobile stations have been conducted. However, the study of the exposure values, taking into account all the existing sources, and their evolution in a wide area, using measurements, has rarely been performed.

In this paper, we provide a comparison of the EMF exposure levels for the city of Alcalá de Henares (Spain) over a ten-year period using a broadband isotropic probe in the range from 100 kHz to 3 GHz. A statistical and spatial analysis of the measurements and their variations are also presented for the study of the global and local variations.

The measured values in the period from 2006 to 2015 were ranging from 0.02 to 2.05 V/m. Our global results show a moderate increase from 2006 to 2010 and they are almost invariant from 2010 to 2015. Although the whole dataset does not have relevant statistical difference, we have found marked local differences. In the city areas where the population density has remained unaltered, we have measured lower exposure levels. Conversely, new urban and industrial developments have demanded new resources, which have potentially contributed to the observed increase in the measured electric field levels within these areas.

Conclusions

This work considers the long term evolution of radio frequency electric field values from 2006 to 2015 for the city of Alcalá de Henares, Spain. This study has been based on 78 measurement locations across a 35 km2 area of the city, providing an average sample density of 2.2 points per square km. During the period considered, officially published statistical data shows a greater use of the radio electric spectrum for television and especially for mobile phones and wireless technologies. At the same time, significant technological changes have been introduced and widely adopted, such as the switch to digital television broadcasting and the proliferation of Wi-Fi. In 2006, the measured mean electric field value was 0.277 V/m, in 2010 this increased to 0.406 V/m and finally, in 2015 this was 0.395 V/m. The greatest increase in the exposure level of electric field strength occurred between 2006 and 2010. This general trend is largely consistent with the increase of radio resources at that time.

The statistical analysis of the measured data shows that it fits a lognormal distribution with a confidence greater than 95%. These results show a moderate increase of the global mean values from 2006 to 2010 and that they are almost invariant from 2010 to 2015. Using this statistical analysis, we can conclude that the probability of finding a value of 14 V/m (half of the prescribed public exposure limit) is less than 0.01% and the probability of finding a value of 28 V/m is negligible.

A narrowband measurement based study could help to a better understanding of the actual influence of the different sources (radio, TV, Mobile, WiFi etc.) in the observed exposure values.

http://www.sciencedirect.com/science/article/pii/S0048969717306502?via%3Dihub

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IEC/IEEE International Standard - Determining SAR in the human body from wireless communications devices, 30 MHz to 6 GHz

IEC/IEEE International Standard - Determining the peak spatial-average specific absorption rate (SAR) in the human body from wireless communications devices, 30 MHz to 6 GHz - Part 1: General requirements for using the finite difference time domain (FDTD) method for SAR calculations (IEEE Std. 62704-1-2017). No authors listed, IEEE, 2017, ISBN 9781504442596

http://ieeexplore.ieee.org/document/8088404/

IEC/IEEE International Standard - Determining the peak spatial-average specific absorption rate (SAR) in the human body from wireless communications devices, 30 MHz to 6 GHz - Part 2: Specific requirements for finite difference time domain (FDTD) modelling of exposure from vehicle mounted antennas (IEEE Std. 62704-2-2017). No authors listed, IEEE, 2017, ISBN 9781504441162

http://ieeexplore.ieee.org/document/7964816/

IEC/IEEE International Standard - Determining the peak spatial-average specific absorption rate (SAR) in the human body from wireless communications devices, 30 MHz to 6 GHz - Part 3: Specific requirements for using the finite difference time domain (FDTD) method for SAR calculations of mobile phones (IEEE Std. 62704-3-2017) No authors listed, IEEE, 2017, ISBN 9781504442619

http://ieeexplore.ieee.org/document/8089724/

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Combined effects of varicocele and cell phones on semen and hormonal parameters

Schauer I, Mohamad Al-Ali B. Combined effects of varicocele and cell phones on semen and hormonal parameters. Wien Klin Wochenschr. 2017 Oct 13. doi: 10.1007/s00508-017-1277-9.

Abstract

BACKGROUND: The objective of this study was to evaluate if there is a combined effect of varicocele and cell phone storage in trousers pockets on semen and hormonal parameters.

METHODS: A retrospective analysis of 468 men attending an infertility clinic from 1993-2007 was performed. Varicoceles were determined by clinical examination and patients were questioned on cell phone usage and storage fashion. Semen samples were analyzed according to the World Health Organization (WHO) guidelines of 1999. Serum testosterone, luteinizing hormone (LH) and follicle stimulating hormone (FSH) were assessed.

RESULTS: There was a significant effect of cell phone storage in trousers pockets and varicocele in multivariate analysis (both $p < 0.001$). Varicocele showed an effect on sperm concentration ($p = 0.003$), LH ($p = 0.014$) and testosterone ($p = 0.003$). Compared to grade 1, grade 2 varicoceles showed a difference in sperm concentration ($p = 0.004$). Regarding testosterone differences were shown for grade 3 versus grade 1 ($p = 0.002$) and grade 3 compared to grade 2 ($p = 0.003$). Cell phone storage in trousers pockets showed an influence on the percentage of normal sperm morphology and LH (both $p < 0.001$). Varicocele and cell phone storage in trousers pockets did not show a combined effect ($p = 0.76$).

CONCLUSIONS: This analysis showed an inverse relation between sperm concentration and degree of varicocele, with lower concentrations in higher grade varicoceles. Testosterone was significantly higher in higher grade varicoceles, which could reflect a compensatory mechanism to the impaired testicular function. Cell phone storage in trousers pockets showed an effect on LH and sperm morphology. A combined effect of varicocele and cell phone storage in trousers pockets was not detected.

https://www.ncbi.nlm.nih.gov/pubmed/29030685

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Biological effects of cell-phone radiofrequency waves exposure on fertilization in mice; an in vivo and in vitro study

Fatehi D, Anjomshoa M, Mohammadi M, Seify M, Rostamzadeh A. Biological effects of cell-phone radiofrequency waves exposure on fertilization in mice; an in vivo and in vitro study. Middle East Fertility Society Journal, Available online 23 October 2017.

Abstract

Increasing use of cell-phone is one of the most important risk factors for population health. We designed an experimental study aimed at evaluating the effects of cell-phone radiofrequency (RF) waves exposure on fertilization in mice. Two hundred male and female NMRI-mice were used. One hundred males divided in five groups (n = 20) as control and exposed groups. Those irradiated with cell-phone RF in "Standby-mode" 1, 5 and 10 h daily named groups II, III and IV; respectively. Group V irradiated with cell-phone on "Active-mode" one hour daily. After 30 days irradiation, 50 males and 50 females were kept 24 h to assess their embryos. Fifty males were scarified to evaluate both in vitro and in vivo parameters, and 50 females received PMSG & HCG for both quantitative and qualitative evaluation. Comparing groups III, IV and V with control-group showed significantly decreased in the number of two-cell embryos (p = .000); however, a significant increase was found in the number of dead embryos (p = .000). Furthermore, 5 h daily irradiation significantly decreased grade-A embryos (p = .015); while, it significantly increased grade-B, C and D embryos (p-values = 0.026, 0.007, 0.006; respectively). Moreover, comparing groups IV and V to control-group, significant increase was found in pregnancy duration (p = .005, p = .009; respectively). However, in the mentioned groups a significant decrease was seen in number of newborn mice (p = .001, p = .004; respectively). In conclusion our findings showed that the cell-phone radiation can affect development of embryos as well as the number of newborn and pregnancy duration in NMRI-mouse, which might be a significant cause of reproductive failure.

Conclusions

The results of this study indicate that cell-phone RF waves decreases the quantity of two cells embryos as well as embryos with grade-A quality at the developmental process; while it increases the fragmentation of IVF-derived cells as well as grade-C and D cells in the NMRI-mouse. Cell-phone RF waves also reduces the number of newborn mice, where it increases the pregnancy duration which result in fertility failure in NMRI-mouse.

http://www.sciencedirect.com/science/article/pii/S1110569017301875

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Interaction between pancreatic β cell and EMF: A systematic study toward finding the natural frequency spectrum of β cell system

Farashi S. Interaction between pancreatic β cell and electromagnetic fields: A systematic study toward finding the natural frequency spectrum of β cell system. Electromagn Biol Med. 2017 Oct 31:1-16. doi: 10.1080/15368378.2017.1389751. [Epub ahead of print]

Abstract

Interaction between biological systems and environmental electric or magnetic fields has gained attention during the past few decades. Although there are a lot of studies that have been conducted for investigating such interaction, the reported results are considerably inconsistent. Besides the complexity of biological systems, the important reason for such inconsistent results may arise due to different excitation protocols that have been applied in different experiments. In order to investigate carefully the way that external electric or magnetic fields interact with a biological system, the parameters of excitation, such as intensity or frequency, should be selected purposefully due to the influence of these parameters on the system response. In this

study, pancreatic β cell, the main player of blood glucose regulating system, is considered and the study is focused on finding the natural frequency spectrum of the system using modeling approach. Natural frequencies of a system are important characteristics of the system when external excitation is applied. The result of this study can help researchers to select proper frequency parameter for electrical excitation of β cell system. The results show that there are two distinct frequency ranges for natural frequency of β cell system, which consist of extremely low (or near zero) and 100-750 kHz frequency ranges. There are experimental works on β cell exposure to electromagnetic fields that support such finding.

https://www.emf-portal.org/en/article/33742

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In vitro non-thermal oxidative stress response after 1800 MHz radiofrequency radiation

Marjanovic Cermak AM, Pavicic I, Tariba Lovakovic B, Pizent A, Trosic I. In vitro non-thermal oxidative stress response after 1800 MHz radiofrequency radiation. General Physiology and Biophysics. 36(4):407-414. Oct 2017.

Abstract
In this study possible connection between radiofrequency exposure (RF) and development of oxidative stress was investigated by measuring impairment in cellular oxidation-reduction balance immediately after RF exposure. Fibroblast cells V79 were exposed for 10, 30 and 60 minutes to 1800 MHz RF radiation. Electric field strength was 30 V/m and specific absorption rate (SAR) was calculated to be 1.6 W/kg. Electromagnetic field was generated within Gigahertz Transversal Electromagnetic Mode cell (GTEM) equipped by signal generator, amplifier and modulator. Cell viability was determined by CCK-8 colorimetric assay and level of reactive oxygen species (ROS) was detected by dihydroethidium staining. Reduced glutathione (GSH) and glutathione peroxidase (GSH-Px) were used to assess cell antioxidant activity while lipid oxidative damage was evaluated measuring concentration of malondialdehyde. Viability of V79 cells remained within normal physiological values regardless of exposure time. Increased level of superoxide radicals was detected after 60-min exposure. Significantly higher GSH level was observed immediately after 10-min exposure with higher but insignificant activity of GSH-Px. Lipid oxidative damage in exposed cell samples was not observed. Short-term RF exposure revealed transient oxidation-reduction imbalance in fibroblast cells following adaptation to applied experimental conditions.

https://www.ncbi.nlm.nih.gov/pubmed/28836500

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Involvement of the p38 MAPK signaling cascade in stress response of RAW 264.7 macrophages

Novoselova EG, Glushkova OV, Khrenov MO, Parfenyuk SB, Lunin SM, Vinogradova EV, Novoselova TV, Fesenko EE. Involvement of the p38 MAPK signaling cascade in stress response of RAW 264.7 macrophages. Dokl Biol Sci. 2017 Sep;476(1):203-205. doi: 0.1134/S0012496617050015. Epub 2017 Nov 4.

Abstract

The role of the p38 MAPK signaling cascade was studied in stress response of RAW 264.7 macrophages to extremely low-intensity centimeter microwaves. Irradiation stimulated production of a number of cytokines (IL-1, IL-6, TNF-α, INF-γ and IL-10), as well as induced activation of the signaling cascades NF- κB and p38 MAPK, and enhanced expression of Hsp72 heat shock protein. In the presence of the cascade p38 MAPK inhibitor (p38 MAP kinase inhibitor XI), the stimulating effects of electromagnetic waves were abrogated either completely (for NF-κB and Hsp72) or partially (for p38 MAPK and cytokines). The results obtained are indicative of a high sensitivity of the signaling cascade p38 MAPK to the effect of low-intensity physical fields.

https://www.ncbi.nlm.nih.gov/pubmed/29101623

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Cellular Response to ELF-MF and Heat: Evidence for a Common Involvement of Heat Shock Proteins?

Zeni O, Simkó M, Scarfi MR, Mattsson MO. Cellular Response to ELF-MF and Heat: Evidence for a Common Involvement of Heat Shock Proteins? Front Public Health. 2017 Oct 18;5:280. doi: 10.3389/fpubh.2017.00280.

Abstract

It has been shown that magnetic fields in the extremely low frequency range (ELF-MF) can act as a stressor in various in vivo or in vitro systems, at flux density levels below those inducing excitation of nerve and muscle cells, which are setting the limits used by most generally accepted exposure guidelines, such as the ones published by the International Commission on Non-Ionizing Radiation Protection. In response to a variety of physiological and environmental factors, including heat, cells activate an ancient signaling pathway leading to the transient expression of heat shock proteins (HSPs), which exhibit sophisticated protection mechanisms. A number of studies suggest that also ELF-MF exposure can activate the cellular stress response and cause increased HSPs expression, both on the mRNA and the protein levels. In this review, we provide some of the presently available data on cellular responses, especially regarding HSP expression, due to single and combined exposure to ELF-MF and heat, with the aim to compare the induced effects and to detect possible common modes of action. Some evidence suggest that MF and heat can act as costressors inducing a kind of thermotolerance in cell cultures and in organisms. The MF exposure might produce a potentiated or synergistic biological response such as an increase in HSPs expression, in combination with a well-defined stress, and in turn exert beneficial effects during certain circumstances.

Summary

In summary, on the basis of the available data dealing with single exposure to ELF-MF showing HSP expression modulations, no (co)relation to MF-dose, specific exposure conditions, or cell type could be identified. The data regarding coexposures to MF and heat are very similar, and we cannot derive any consistent clue regarding a possible common mode of action. There is some evidence that MF and heat might act as costressors inducing thermotolerance in cell cultures and in organisms. The MF exposure might produce a potentiated biological response, such as the increase in HSPs expression in combination with a well-defined stress, and in turn exerts beneficial effects. It is also possible that ELF-MF exposure protects the cells *via* desensitization against heat stress, and so from secondary effects. Since the mode of action is not clear, we can only speculate if the applied temperature or the MF parameters or the cell type used (cell receptors and metabolic state, culture media, serum, etc.) is a relevant factor influencing the outcome, or if all together are important players in the biological response. Since systematic investigations are not available, we have to consider that beside the physical parameters used, more knowledge is needed about metabolic status and the absolute basal HSP levels of the cell models. Experiments, carried out under strictly controlled conditions from both electromagnetic and biological point of view, are needed to address specifically the underlying mechanisms involving HSPs and cellular responses to ELF-MF and heat.

Open Access Paper: https://www.frontiersin.org/articles/10.3389/fpubh.2017.00280/full

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Magnetic Fields and Reactive Oxygen Species

Wang H, Zhang X. Magnetic Fields and Reactive Oxygen Species. Int J Mol Sci. 2017 Oct 18;18(10). pii: E2175. doi: 10.3390/ijms18102175

Abstract

Reactive oxygen species (ROS) ubiquitously exist in mammalian cells to participate in various cellular signaling pathways. The intracellular ROS levels are dependent on the dynamic balance between ROS generation and elimination. In this review, we summarize reported studies about the influences of magnetic fields (MFs) on ROS levels. Although in most cases, MFs increased ROS levels in human, mouse, rat cells, and tissues, there are also studies showing that ROS levels were decreased or not affected by MFs. Multiple factors could cause these discrepancies, including but not limited to MF type/intensity/frequency, exposure time and assay time-point, as well as different biological samples examined. It will be necessary to investigate the influences of different MFs on ROS in various biological samples systematically and mechanistically, which will be helpful for people to get a more complete understanding about MF-induced biological effects. In addition, reviewing the roles of MFs in ROS modulation may open up new scenarios of MF application, which could be further and more widely adopted into clinical applications, particularly in diseases that ROS have documented pathophysiological roles.

Open Access Paper: http://www.mdpi.com/1422-0067/18/10/2175

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Mobile phones, cordless phones and rates of brain tumors in different age groups in the Swedish National Inpatient Register and the Swedish Cancer Register during 1998-2015

Hardell L, Carlberg M. Mobile phones, cordless phones and rates of brain tumors in different age groups in the Swedish National Inpatient Register and the Swedish Cancer Register during 1998-2015. PLoS One. 12(10): e0185461. Published online Oct 4, 2017.

Abstract

We used the Swedish Inpatient Register (IPR) to analyze rates of brain tumors of unknown type (D43) during 1998–2015. Average Annual Percentage Change (AAPC) per 100,000 increased with +2.06%, 95% confidence interval (CI) +1.27, +2.86% in both genders combined. A joinpoint was found in 2007 with Annual Percentage Change (APC) 1998–2007 of +0.16%, 95% CI -0.94, +1.28%, and 2007–2015 of +4.24%, 95% CI +2.87, +5.63%. Highest AAPC was found in the age group 20–39 years. In the Swedish Cancer Register the age-standardized incidence rate per 100,000 increased for brain tumors, ICD-code 193.0, during 1998–2015 with AAPC in men +0.49%, 95% CI +0.05, +0.94%, and in women +0.33%, 95% CI -0.29, +0.45%. The cases with brain tumor of unknown type lack morphological examination. Brain tumor diagnosis was based on cytology/histopathology in 83% for men and in 87% for women in 1980. This frequency increased to 90% in men and 88% in women in 2015. During the same time period CT and MRI imaging techniques were introduced and morphology is not always necessary for diagnosis. If all brain tumors based on clinical diagnosis with CT or MRI had been reported to the Cancer Register the frequency of diagnoses based on cytology/histology would have decreased in the register. The results indicate underreporting of brain tumor cases to the Cancer Register. The real incidence would be higher. Thus, incidence trends based on the Cancer Register should be used with caution. Use of wireless phones should be considered in relation to the change of incidence rates.

http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0185461

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Recent advances in the effects of microwave radiation on brains

Wei-Jia Zhi, Li-Feng Wang, Xiang-Jun Hu. Recent advances in the effects of microwave radiation on brains. Military Medical Research. December 2017, 4:29. Published online: 21 September 2017.

Abstract

This study concerns the effects of microwave on health because they pervade diverse fields of our lives. The brain has been recognized as one of the organs that is most vulnerable to microwave radiation. Therefore, in this article, we reviewed recent studies that have explored the effects of microwave radiation on the brain, especially the hippocampus, including analyses of epidemiology, morphology, electroencephalograms, learning and memory abilities and the mechanisms underlying brain dysfunction. However, the problem with these studies is that different parameters, such as the frequency, modulation, and power density of the radiation and the irradiation time, were used to evaluate microwave radiation between studies. As a result, the existing data exhibit poor reproducibility and comparability. To determine the specific dose-effect relationship between microwave radiation and its biological effects, more intensive studies must be performed.

Open Access Review Paper: https://link.springer.com/article/10.1186/s40779-017-0139-0

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Mobile Phone Use and The Risk of Headache: A Systematic Review and Meta-analysis of Cross-sectional Studies

Wang J, Su H1, Xie W, Yu S. Mobile Phone Use and The Risk of Headache: A Systematic Review and Meta-analysis of Cross-sectional Studies. Sci Rep. 2017 Oct 3;7(1):12595. doi: 10.1038/s41598-017-12802-9.

Abstract

Headache is increasingly being reported as a detrimental effect of mobile phone (MP) use. However, studies aimed to investigate the association between MP use and headache yielded conflicting results. To assess the consistency of the data on the topic, we performed a systematic review and meta-analysis of the available cross-sectional studies. Published literature from PubMed and other databases were retrieved and screened, and 7 cross-sectional studies were finally included in this meta-analysis. The pooled odds ratio (OR) and 95% confidence interval (CI) were calculated. We found that the risk of headache was increased by 38% in MP user compared with non-MP user (OR, 1.38; 95% CI, 1.18-1.61, $p < 0.001$). Among MP users, the risk of headache was also increased in those who had longer daily call duration (2-15 min vs. <2 min: OR, 1.62; 95% CI, 1.34-1.98, $p < 0.001$; >15 min vs. <2 min: OR, 2.50; 95% CI, 1.76-3.54, $p < 0.001$) and higher daily call frequency (2-4 calls vs. <2 calls: OR, 1.37; 95% CI, 1.07-1.76, $p < 0.001$; >4 calls vs. <2 calls: OR, 2.52; 95% CI, 1.78-3.58, $p < 0.001$). Our data indicate that MP use is significantly associated with headache, further epidemiologic and experimental studies are required to affirm and understand this association.

https://www.ncbi.nlm.nih.gov/pubmed/28974725

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Effects of electromagnetic waves emitted from 3G+wi-fi modems on human semen analysis

Kamali K, Atarod M, Sarhadi S, Nikbakht J, Emami M, Maghsoudi R, Salimi H, Fallahpour B, Kamali N, Momtazan A, Ameli M. Effects of electromagnetic waves emitted from 3G+wi-fi modems on human semen analysis. Urologia. 2017 Sep 14:0. doi: 10.5301/uj.5000269.

Abstract

OBJECTIVE: The purpose of this study was to evaluate the effects of 3G+wifi modems on human sperm quality.A total of 40 semen specimens were gathered between March and September 2015, from healthy adult men.

METHODS: The sperm samples were divided into two groups - 3G+wi-fi exposed and unexposed groups. In the unexposed group, the specimens were shielded by aluminum foil in three layers and put into an incubator at a temperature of 37°C for 50 minutes. The exposed group was positioned in another room in an incubator at a temperature of 37°C for 50 minutes. A 3G+wi-fi modem was put into the same incubator and a laptop computer was connected to the modem and was downloading for the entire 50 minutes.Semen analysis was done for each specimen and comparisons between parameters of the two groups were done by using Kolmogorov-Smirnov study and a paired t-test.

RESULTS: Mean percentage of sperm with class A and B motility were not significantly different in two groups ($p = 0.22$ and 0.54, respectively). In class C, it was significantly lower in the exposed group ($p = 0.046$), while in class D it was significantly higher ($p = 0.022$). Velocity curvilinear, velocity straight line, velocity average path, mean angular displacement, lateral displacement and beat cross frequency were significantly higher in the unexposed group. The limitation was the in vitro design.

CONCLUSIONS: Electromagnetic waves (EMWs) emitted from 3G+wi-fi modems cause a significant decrease in sperm motility and velocity, especially in non-progressive motile sperms. Other parameters of semen analysis did not change significantly.EMWs, which are used in communications worldwide, are a suspected cause of male infertility. Many studies evaluated the effects of cell phones and wi-fi on fertility. To our knowledge, no study has yet been done to show the effects of EMWs emitted from 3G+wi-fi modems on fertility.Our study revealed a significant decrease in the quality of human semen after exposure to EMWs emitted from 3G+wi-fi modems.

https://www.ncbi.nlm.nih.gov/pubmed/28967061

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Electromagnetic fields in neonatal incubators: the reasons for an alert

Bellieni CV, Nardi V, Buonocore G, Di Fabio S, Pinto I, Verrotti A. Electromagnetic fields in neonatal incubators: the reasons for an alert. J Matern Fetal Neonatal Med. 2017 Oct 8:1-11. doi: 10.1080/14767058.2017.1390559.

Abstract

BACKGROUND: Neonatal incubators are important tools for sick newborns in the first few days of life. Nevertheless, their electric engine, often very close to the newborn's body, emits electromagnetic fields (EMF) to which newborns are exposed. Aim of this paper is to review the available literature on EMF exposure in incubators, and the effects of such exposures on newborns that have been investigated.

METHODS: We carried out a systematic review of studies about EMF emissions produced by incubators, using Medline and Embase databases from 1993 to 2017.

RESULTS: We retrieved 15 papers that described the EMF exposure in incubators and their biological effects on babies. EMF levels in incubators appear to be between 2 and 100 mG, depending on the distance of the mattress from the electric engine. In some cases they exceed this range. These values interfere with melatonin production or with vagal tone. Even caregivers are exposed to high EMF, above 200 mG, when working at close contact with the incubators.

CONCLUSION: EMF have been described as potentially hazardous for human health, and values reported in this review are an alert to prevent babies' and caregivers' exposure when close to the incubators. A precautionary approach should be adopted in future incubator design, to prevent high exposures of newborns in incubators and of caregivers as well.

https://www.ncbi.nlm.nih.gov/pubmed/28988507

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Cellphone electromagnetic radiation damages the testicular ultrastructure of male rats

Gao XH, Hu HR, Ma X2, Chen J, Zhang GH. [Cellphone electromagnetic radiation damages the testicular ultrastructure of male rats]. [Article in Chinese]. Zhonghua Nan Ke Xue. 2016 Jun;22(6):491-495.

Abstract

OBJECTIVE: To investigate the influence of cellphone electromagnetic radiation (CER) on the testicular ultrastructure and the apoptosis of spermatogenic cells in male rats.atability, feasibility, applicability, and controllability in the construction of experimental animal models, we compared the major anatomic features of the penis of 20 adult beagle dogs with those of 10 adult men. Using microsurgical techniques, we performed cross-transplantation of the penis in the 20 (10 pairs) beagle dogs and observed the survival rate of the transplanted penises by FK506+MMF+MP immune induction. We compared the relevant indexes with those of the 10 cases of microsurgical replantation of the amputated penis.

METHODS: Thirty adult male SD rats were equally randomized into a 2 h CER, a 4 h CER, and a normal control group, the former two groups exposed to 30 days of 900 MHz CER for 2 and 4 hours a day, respectively, while the latter left untreated. Then the changes in the ultrastructure of the testis tissue were observed under the transmission electron microscope and the apoptosis of the spermatogenic cells was determined by TUNEL.

RESULTS: Compared with the normal controls, the rats of the 2 h CER group showed swollen basement membrane of seminiferous tubules, separated tight junction of Sertoli cells, increased cell intervals, apparent vacuoles and medullization in some mitochondria, and increased apoptosis of spermatogenic cells, mainly the apoptosis of primary spermatocytes ($P<0.05$). In comparison with the 2 h CER group, the animals of the 4 h CER group exhibited swollen basement membrane of seminiferous tubules, more separated tight junction of Sertoli cells, wider cell intervals, incomplete membrane of spermatogonial cells, fragments of cytoplasm, nuclear pyknosis and notch, slight dilation of perinuclear space, abnormalities of intracellular mitochondria with vacuoles, fuzzy structure, and fusion or disappearance of some cristae, and increased damage of mitochondria and apoptosis of spermatogenic cells, including the apoptosis of spermatogonial cells, primary spermatocytes, and secondary spermatocytes ($P<0.05$).

CONCLUSIONS: CER can damage the testicular ultrastructure and increase the apoptosis of spermatogenic cells of the male rat in a time-dependent manner, and the apoptosis of spermatogenic cells may be associated with the damage to mitochondria.

https://www.ncbi.nlm.nih.gov/pubmed/28963835

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Cardiovascular disease: Time to identify emerging environmental risk factors

Bandara P, Weller S. Cardiovascular disease: Time to identify emerging environmental risk factors. Eur J Prev Cardio. October 3, 2017.

No Abstract

Excerpts

In our latest review, 242 RF-EMR studies that investigated experimental endpoints related to oxidative stress (OS)16 were identified. A staggering 216 (89%) of them found significant effects related to OS, similar to a previous review.17 These are being further analysed following presentation at the recent Australasian Radiation Protection Society conference.18 Mostly in-vivo animal studies and in-vitro studies have demonstrated increased markers of endogenous OS and/or affected antioxidant levels in different tissue/cell types upon exposure to RF-EMR. Some studies have further demonstrated amelioration of RF-induced OS upon treatment with various antioxidants. Limited human studies at this stage complement these studies demonstrating OS and/or reduced antioxidant status upon acute radiofrequency exposure under experimental settings,19 in mobile phone users20 and residents near mobile phone base stations.21 Renowned physical scientists have recently presented experimental evidence and a theoretical explanation on how low-intensity RF-EMR can generate OS .22

OS is known to be implicated in CVD 23,24 and therefore RF-EMR, a new ubiquitous environmental exposure, may contribute to CVD by maintaining chronic OS, and thereby causing oxidative damage to cellular constituents and altering signal transduction pathways.

Although a few western countries have recently taken steps to reduce public exposure to RF-EMR, particularly of children, such as discouraging the use of wireless devices by children and banning/restricting WiFi in schools, 38,39 there is largely inaction at this stage. Intriguingly, a professor in public health at the University of California recently went to court and accessed the cell phone safety ‘fact sheet’ (on health risks with instructions to reduce exposure) prepared by the Californian Department of Public Health.40 It is reported that this document, originally prepared in 2009 and revised 27 times up to 2014, was abandoned due to influences from vested interests. Meanwhile in France, a physician took legal action to access data from government testing of mobile phones 41 revealing that most phones would not even pass the entirely thermally based (tissue heating) current exposure standards if held directly against the body, such as in a garment pocket.

It is clearly time to investigate the potential role of RF-EMR exposure from common wireless device use on CVD. Noting that existing research findings are influenced by the funding source, 42 fresh directives are necessary for objective high quality research to expand current primary and secondary prevention strategies. 43

http://journals.sagepub.com/doi/full/10.1177/2047487317734898

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Nonlinearity, coherence and complexity: Biophysical aspects related to health and disease

Foletti A, Brizhik L. Nonlinearity, coherence and complexity: Biophysical aspects related to health and disease. Electromagnetic Biology and Medicine. Published online 22 Sep 2017.

Abstract

Biological organisms are complex open dissipative systems whose dynamical stability is sustained due to the exchange of matter, energy and information. Dynamical stability occurs through a number of mechanisms that sustain efficient adaptive dynamics. Such properties of living matter can be the consequence of a self-consistent state of matter and electromagnetic field (EMF). Based on the soliton model of charge transport in redox processes, we describe a possible mechanism of the origin of endogenous EMF and coherence. Solitons are formed in polypeptides due to electron–lattice interaction. Solitons experience periodical potential barrier, as a result of which their velocity oscillates in time, and, hence, they emit electromagnetic radiation (EMR). Under the effect of such radiation from all other solitons, the synchronization of their dynamics takes place, which significantly increases the intensity of the general EMF. The complex structure of biological molecules, such as helical structure, is not only important for "structure-function" relations, but also the source of the stability of biophysical processes, e.g. effectiveness of energy and charge transport on macroscopic distances. Such a complex structure also provides the framework for the spatiotemporal structure of the endogenous EMF. The highly hierarchical organization of living organisms is a manifestation of their complexity, even at the level of simple unicellular organisms. This complexity increases the dynamical stability of open systems and enhances the possibility of information storage and processing. Our findings provide a qualitative overview of a possible biophysical mechanism that supports health and disease adaptive dynamics.

https://www.ncbi.nlm.nih.gov/pubmed/28937829

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Simplified Assessment Method for Population RF Exposure Induced by a 4G Network

Huang Y, Wiart J. Simplified Assessment Method for Population RF Exposure Induced by a 4G Network. IEEE Journal of Electromagnetics, RF and Microwaves in Medicine and Biology. PP(99). 18 Sep 2017. DOI:10.1109/JERM.2017.2751751.

Abstract

This article presents a simplified method, based on surrogate modeling, to evaluate the day-to-day global population exposure to radio frequency (RF) electromagnetic fields (EMF) induced by a 4G network, from both uplink and downlink radio emissions in a typical urban city. The uncertainties of 4G-induced RF-EMF exposure of an entire population were characterized for the first time taking into account the variability linked to urban propagation environment, information and communication technology usage, EMF respectively from personal wireless devices and Evolved Node B (eNB), as well as uplink throughput. In addition, the study focuses on a sensitivity analysis in order to assess the influence of these parameters on RF-EMF exposure. Globally, results show that the 4G-induced RF-EMF exposure follows a Generalized Extreme Value distribution with an average value of 1.19×10 W/kg. Moreover, authors show that, contrary to what have been observed in the 3G-induced RF-EMF exposure, that is, the exposure is dominated by uplink radio emissions, results have highlighted the importance of received power density from eNB to the issue of 4G-induced RF-EMF exposure. In 4G, the

uplink exposure from mobiles accounts for only 25% of global exposure, resulting from the high speed of uplink throughput.

http://ieeexplore.ieee.org/document/8039247/

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Time-averaged Realistic Maximum Power Levels for Assessment of RF Exposure for 5G Radio Base Stations

Thors B, Furuskär A, Colombi D, Törnevik C. Time-averaged Realistic Maximum Power Levels for the Assessment of Radio Frequency Exposure for 5G Radio Base Stations using Massive MIMO. IEEE Access. PP(99), 18 Sep 2017.

Abstract

In this paper a model for time-averaged realistic maximum power levels for the assessment of radio frequency (RF) electromagnetic field (EMF) exposure for the fifth generation (5G) radio base stations (RBS) employing massive MIMO is presented. The model is based on a statistical approach and developed to provide a realistic conservative RF exposure assessment for a significant proportion of all possible downlink exposure scenarios (95th percentile) in-line with requirements in a recently developed International Electrotechnical Commission (IEC) standard for RF EMF exposure assessments of radio base stations (RBS). Factors such as RBS utilization, time-division duplex (TDD), scheduling time, and spatial distribution of users within a cell are considered. The model is presented in terms of a closed-form equation. For an example scenario corresponding to an expected 5G RBS product, the largest realistic maximum power level was found to be less than 15% of the corresponding theoretical maximum. For far-field exposure scenarios, this corresponds to a reduction in RF EMF limit compliance distance with a factor of about 2.6. Results are given for antenna arrays of different sizes and for scenarios with beamforming in both azimuth and elevation.

http://ieeexplore.ieee.org/document/8039290/

Excerpt

In this paper, a theoretical model was presented to estimate the time-averaged realistic maximum power levels for the assessment of RF EMF exposure for 5G Radio Base Stations using Massive MIMO. The model was based on realistic conservative assumptions of a 5G mobile communication system and made use of a statistical approach to distribute the transmitted energy within the cell to obtain results that may be used in context with the ‘actual maximum exposure conditions’ in the international RF EMF exposure assessment standard for radio base stations IEC 62232:2017.

A key parameter of the model is how the users are assumed to be distributed within the cell. For all UDS considered, the time-averaged realistic maximum power levels was found to be significantly below the theoretical maximum. Even for very large degrees of system utilization, the time-averaged realistic maximum was found to take values between 7% - 22% of the theoretical maximum. This translates to reduced compliance distances and may be used to facilitate installation of 5G RBS products. The obtained results provide valuable input to standardization of RF EMF exposure assessments in the vicinity of RBS.

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Magnetic field exposure to wireless charging stations for mobile phones

Fröhlich, J., Zahner, M. and Dürrenberger, G. (2017), Magnetic field exposure to wireless charging stations for mobile phones. Bioelectromagnetics. doi:10.1002/bem.22087

No Abstract

Excerpts

This brief communication presents measurement and simulation data about magnetic field levels of, and human exposure to, wireless charging devices for smart phones, respectively. Most transmitters for inductive charging operate within a frequency window from 110 up to 205 kHz. The highest instantaneous field levels can be measured in stand-by mode. Peak and rms values amount to a few 100 μT, which is above the reference level. However, simulation results showed that the basic restrictions (defined in terms of electric field levels, V/m, in tissue and power absorption, specific absorption rate [SAR]), were met. From a regulatory point of view, inductive charging systems for small electronic devices like cell phones comply with safety standards, but worst-case induced electrical fields may come close to basic restrictions. Therefore, maximum currents for all specific implementations have to be restricted.

Currently, inductive charging is the only commercialized wireless charging technology. In the near future, devices for resonant power transfer will be available, too. Two standards for inductive charging exist: Qi and AirFuel. Qi is dominating the market. Some key technical characteristics of the Qi inductive charging standard are given in Table 1.

Conclusion

The dosimetric characterization showed that inductive charging stations comply with basic restrictions recommended by ICNIRP and IEEE, albeit the incident magnetic flux densities exceed the reference values by factors of tens, roughly. For internal electric fields, the margin was below a factor of 10. For SAR, in contrast, the margin amounted to three orders of magnitude. The study (i) affirmed that checking basic restrictions in case of local exposures that exceed reference values is necessary; (ii) showed that **exposure levels of current smartphone wireless charging systems may exploit ICNIRP basic restrictions on induced electric fields up to 30%, roughly, and are far from recommended maximum SAR levels**; and (iii) indicated that increasing the allowed maximum power for charging systems (as already outlined in the standard) has to be carefully evaluated regarding instantaneous values of induced electric fields.

http://onlinelibrary.wiley.com/doi/10.1002/bem.22087/full

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Evaluation of the mobile phone electromagnetic radiation on serum iron parameters in rats

Çetkin M, Demirel C, Kızılkan N, Aksoy N, Erbağcı H. Evaluation of the mobile phone electromagnetic radiation on serum iron parameters in rats.
Afr Health Sci. 2017 Mar;17(1):186-190. doi: 10.4314/ahs.v17i1.23.

Abstract

BACKGROUND: Electromagnetic fields (EMF) created by mobile phones during communication have harmful effects on different organs.

OBJECTIVES: It was aimed to investigate the effects of an EMF created by a mobile phone on serum iron level, ferritin, unsaturated iron binding capacity and total iron binding capacity within a rat experiment model.

METHODS: A total of 32 male Wistar albino rats were randomly divided into the control, sham, mobile phone speech (2h/day) and stand by (12 h/day) groups. The speech and stand by groups were subjected to the EMF for a total of 10 weeks.

RESULTS: No statistically significant difference was observed between the serum iron and ferritin values of the rats in the speech and stand by groups than the control and sham groups (p>0.05). The unsaturated iron binding capacity and total iron capacity values of the rats in the speech and stand by groups were significantly lower in comparison to the control group (p<0.01).

CONCLUSION:It was found that exposure to EMF created by mobile phones affected unsaturated iron binding capacity and total iron binding capacity negatively.

Open Access Paper: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5636244/

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Electromagnetic fields with frequencies of 5, 60 and 120 Hz affect the cell cycle and viability of human fibroblast BJ in vitro

Koziorowska A, Romerowicz-Misielak M Filipek A, Koziorowski M. Electromagnetic fields with frequencies of 5, 60 and 120 Hz affect the cell cycle and viability of human fibroblast BJ in vitro. J Biol Regul Homeost Agents. 2017 Jul-Sep;31(3):725-730.

Abstract

The impact of electromagnetic field (EMF) on humans has been described in numerous studies, but many questions are still unanswered. The aim of the experiment described in this study was to evaluate the effect of EMF on the viability of human fibroblast BJ in vitro and the percentage of cells in different phases of the cell cycle (G1/G0, S, G2/M) after 2 hours of exposure to sinusoidal continuous and pulsed EMFs with frequency of 5 Hz, 60 Hz and 120 Hz at a magnetic induction of 2,5 mT. The viability of BJ cells exposed to an EMF was estimated immediately after completion of exposure and after 24 hours. Metabolic activity of cells was assessed by MTT assay and compared to a control culture not exposed to EMFs. Cell cycle analysis was performed by BrdU incorporation. The analysis of the viability demonstrated significant differences in field efficiency, depending on its nature. Exposure of cells to pulse EMFs resulted in a decrease in their viability for each of the analyzed frequencies. Reduced viability was maintained for a further 24 hours after the end of exposure of cells to pulsed EMF. In the case of continuous field, reduced BJ cell viability was observed only at the highest applied frequency - 120Hz, and this effect maintained for the next 24 hours. Although there was no significant effect on cell viability (metabolic activity) of cells immediately after exposure to continuous EMF with a frequency of 5Hz, a significant increase was observed after 24 hours of incubation.

https://www.ncbi.nlm.nih.gov/pubmed/28956424

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Activation of Signaling Cascades by Weak Extremely Low Frequency Electromagnetic Fields

Kapri-Pardes E, Hanoch T, Maik-Rachline G, Murbach M, Bounds PL, Kuster N, Seger R. Activation of Signaling Cascades by Weak Extremely Low Frequency Electromagnetic Fields. Cell Physiol Biochem. 2017 Oct 16;43(4):1. doi: 10.1159/000481977.

Abstract

BACKGROUND/AIMS: Results from recent studies suggest that extremely low frequency magnetic fields (ELF-MF) interfere with intracellular signaling pathways related to proliferative control. The mitogen-activated protein kinases (MAPKs), central signaling components that regulate essentially all stimulated cellular processes, include the extracellular signal-regulated kinases 1/2 (ERK1/2) that are extremely sensitive to extracellular cues. Anti-phospho-ERK antibodies serve as a readout for ERK1/2 activation and are able to detect minute changes in ERK stimulation. The objective of this study was to explore whether activation of ERK1/2 and other signaling cascades can be used as a readout for responses of a variety of cell types, both transformed and non-transformed, to ELF-MF.

METHODS: We applied ELF-MF at various field strengths and time periods to eight different cell types with an exposure system housed in a tissue culture incubator and followed the phosphorylation of MAPKs and Akt by western blotting.

RESULTS: We found that the phosphorylation of ERK1/2 is increased in response to ELF-MF. However, the phosphorylation of ERK1/2 is likely too low to induce ELF-MF-dependent proliferation or oncogenic transformation. The p38 MAPK was very slightly phosphorylated, but JNK or Akt were not. The effect on ERK1/2 was detected for exposures to ELF-MF strengths as low as 0.15 µT and was maximal at ~10 µT. We also show that ERK1/2 phosphorylation is blocked by the flavoprotein inhibitor diphenyleneiodonium, indicating that the response to ELF-MF may be exerted via NADP oxidase similar to the phosphorylation of ERK1/2 in response to microwave radiation.

CONCLUSIONS: Our results further indicate that cells are responsive to ELF-MF at field strengths much lower than previously suspected and that the effect may be mediated by NADP oxidase. However, the small increase in ERK1/2 phosphorylation is probably insufficient to affect proliferation and oncogenic transformation. Therefore, the results cannot be regarded as proof of the involvement of ELF-MF in cancer in general or childhood leukemia in particular.

https://www.ncbi.nlm.nih.gov/pubmed/29035881

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Geomagnetic storm under laboratory conditions: randomized experiment

Gurfinkel YI, Vasin AL, Pishchalnikov RY, Sarimov RM, Sasonko ML, Matveeva TA. Geomagnetic storm under laboratory conditions: randomized experiment. Int J Biometeorol. 2017 Oct 13. doi: 10.1007/s00484-017-1460-8.

Abstract

The influence of the previously recorded geomagnetic storm (GS) on human cardiovascular system and microcirculation has been studied under laboratory conditions. Healthy volunteers in lying position were exposed under two artificially created conditions: quiet (Q) and storm (S). The Q regime playbacks a noise-free magnetic field (MF) which is closed to the natural geomagnetic conditions on Moscow's latitude. The S regime playbacks the initially recorded 6-h geomagnetic storm which is repeated four times sequentially. The cardiovascular response to the GS impact was assessed by measuring capillary blood velocity (CBV) and blood pressure (BP) and by the analysis of the 24-h ECG recording. A storm-to-quiet ratio for the cardio intervals (CI) and the heart rate variability (HRV) was introduced in order to reveal the average over group significant differences of HRV. An individual sensitivity to the GS was estimated using the autocorrelation function analysis of the high-frequency (HF) part of the CI spectrum. The autocorrelation analysis allowed for detection a group of subjects of study which autocorrelation functions (ACF) react differently in the Q and S regimes of exposure.

https://www.ncbi.nlm.nih.gov/pubmed/29030697

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NTP Cell Phone Radiation Study

Evaluation of Genotoxicity of Cell Phone Radiation in Male & Female Rats & Mice Following Subchronic Exposure

Smith-Roe SL, Wyde, ME, Stout MD, Winters JW, Hobbs CA, Shepard KG, Green AS, Kissing GA, Tice RR, Bucher JR, Witt KL. Evaluation of the Genotoxicity of Cell Phone Radiofrequency Radiation in Male and Female Rats and Mice Following Subchronic Exposure. Presentation at at annual meeting of Environmental Mutagenesis and Genomics Society held in Raleigh, North Carolina from September 9-13, 2017.

I don't know if a paper or slides are available. The abstract for this presentation is available at http://bitly.com/NTPsaferemr

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Dosimetric Assessment for Mice & Rats Exposed in Reverberation Chambers for the Two-Year NTP Cancer Bioassay Study on Cell Phone Radiation

Gong, YJ, Capstick, MH; Kuehn, S ; Wilson, PF; Ladbury, JM ; Koepke, G; McCormick, DL ; Melnick, RL Kuster, N.Life-Time Dosimetric Assessment for Mice and Rats Exposed in Reverberation Chambers for the Two-Year NTP Cancer Bioassay Study on Cell Phone Radiation. IEEE Transactions on Electromagnetic Compatibility. 59(6):1798-1808. DOI: 10.1109/TEMC.2017.2665039. Dec 2017.

Abstract

In this paper, we present the detailed life-time dosimetry analysis for rodents exposed in the reverberation exposure system designed for the two-year cancer bioassay study conducted by the National Toxicology Program of the National Institute of Environmental Health Sciences. The study required the well-controlled and characterized exposure of individually housed, unrestrained mice at 1900 MHz and rats at 900 MHz, frequencies chosen to give best uniformity exposure of organs and tissues. The wbSAR, the peak spatial SAR,

and the organ specific SAR as well as the uncertainty and variation due to the exposure environment, differences in the growth rates, and animal posture were assessed. Compared to the wbSAR, the average exposure of the high-water-content tissues (blood, heart, lung) were higher by similar to 4 dB, while the low-loss tissues (bone and fat) were less by similar to 9 dB. The maximum uncertainty over the exposure period for the SAR was estimated to be <49% (k = 2) for the rodents whereas the relative uncertainty between the exposure groups was < 14% (k = 1). The instantaneous variation (averaged over 1 min) was < 13% (k = 1), which is small compared to other long term exposure research projects. These detailed dosimetric results empowers comparison with other studies and provides a reference for studies of long-term biological effects of exposure.

http://ieeexplore.ieee.org/abstract/document/7880616/

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A History of the International Commission on Non-Ionizing Radiation Protection

Repacholi MH. A History of the International Commission on Non-Ionizing Radiation Protection. Health Phys. 2017 Oct;113(4):282-300. doi: 10.1097/HP.0000000000000699.

Abstract

Concern about health risks from exposure to non-ionizing radiation (NIR) commenced in the 1950s after tracking radars were first introduced during the Second World War. Soon after, research on possible biological effects of microwave radiation in the former Soviet Union and the U.S. led to public and worker exposure limits being much lower in Eastern European than in Western countries, mainly because of different protection philosophies. As public concern increased, national authorities began introducing legislation to limit NIR exposures from domestic microwave ovens and workplace devices such as visual display units. The International Radiation Protection Association (IRPA) was formed in 1966 to represent national radiation protection societies. To address NIR protection issues, IRPA established a Working Group in 1974, then a Study Group in 1975, and finally the International NIR Committee (INIRC) in 1977. INIRC's publications quickly became accepted worldwide, and it was logical that it should become an independent commission. IRPA finally established the International Commission on Non-Ionizing Radiation Protection (ICNIRP), chartering its remit in 1992, and defining NIR as electromagnetic radiation (ultraviolet, visible, infrared), electromagnetic waves and fields, and infra- and ultrasound. ICNIRP's guidelines have been incorporated into legislation or adopted as standards in many countries. While ICNIRP has been subjected to criticism and close scrutiny by the public, media, and activists, it has continued to issue well-received, independent, science-based protection advice. This paper summarizes events leading to the formation of ICNIRP, its key activities up to 2017, ICNIRP's 25th anniversary year, and its future challenges.

https://www.ncbi.nlm.nih.gov/pubmed/28846587

Excerpts

"At the Budapest meeting, Repacholi advised that since he had established the International EMF Project at WHO, and as ICNIRP was now working closely with this project, it was a conflict of interest for him to remain as Chairman or as a member of ICNIRP. As such, he resigned."

"While the independence of ICNIRP members is clearly required in its Charter and Statutes, it had become an issue of public and political interest in some countries. At its meeting in Bordeaux (September 2003), it was decided that a conflict of interest declaration by all current and new members should not only be kept on file but also posted on ICNIRP's website. A "Declaration of Personal Interest" completed by all Commission and Scientific Expert Group members is now posted on the ICNIRP website as a demonstration of the independence of its members, openness and transparency. These declarations of personal interest were made more stringent following discussions at the annual meeting in Thessaloniki (Greece, June 2013) and more detailed information was required from Commission and Scientific Expert Group members."

"Recommendations on exposure limits have been and continue to be based purely on the science and only minor changes or fine-tuning to these limits have been necessary over the years. Many national authorities have adopted ICNIRP guidelines into their own guidance or legislation. The stability of the limits over many years, because there has not been any research providing evidence of harm from exposures below the guideline limits, provides reassurance to national authorities about the adequacy of the protection the limits provide."

"ICNIRP members have taken a leading role in assisting WHO's International EMF Project with its first systematic review of the scientific literature to determine whether there are any health consequences from exposure to radiofrequency fields. The results and conclusions of this Environmental Health Criteria monograph will form a basis for the updated ICNIRP guidelines on high frequency EMF. An important aspect of this WHO review is that, not only WHO Task Group members, but all members of any working groups contributing to each chapter, including ICNIRP members, must complete a form detailing any conflict of interest for review and approval by the WHO Legal Department.Given the huge amount of work this systematic review involves, it is anticipated that this monograph should now be published in 2018. Much of ICNIRP's future work will be done in collaboration with WHO's EMF Project."

"ICNIRP published its general philosophy of NIR protection 15 y ago (ICNIRP 2002), but this needs updating and more detail added. ICNIRP is currently working on this update since it views the protection principles as fundamental to the development of all its guidelines and statements. In addition, such principles provide consistency in protection for future publications."

"Possible health effects of EMF have been of concern for a long time and so ICNIRP has been subjected to significant public and political scrutiny. To its credit, by steadfastly remaining a purely scientific Commission and not entering the politics of NIR issues, ICNIRP has successfully weathered all storms to become the most recognized agency for producing independent authoritative advice on NIR protection issues."

"The authors declare no conflicts of interest."

My note: In recent years, many professional journals require authors to disclose conflicts of interest (COIs). However, it is extremely rare that anyone discloses their COIs. Thus, this requirement which relies on self reporting COIs has been largely a sham.

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Increasing levels of saliva alpha amylase in electrohypersensitive (EHS) patients

Andrianome S, Hugueville L, de Seze R, Selmaoui B.Increasing levels of saliva alpha amylase in electrohypersensitive (EHS) patients.Int J Radiat Biol. 2017 Aug;93(8):841-848. doi: 10.1080/09553002.2017.1325971. Epub 2017 May 17.

Abstract

PURPOSE: To assess the level of various salivary and urinary markers of patients with electromagnetic hypersensitivity (EHS) and to compare them with those of a healthy control group.

MATERIALS AND METHODS: We analyzed samples from 30 EHS individuals and a matched control group of 25 individuals (non-EHS) aged between 22 and 66. We quantified cortisol both in saliva and urine, alpha amylase (sAA), immunoglobulin A and C Reactive Protein levels in saliva and neopterin in urine (uNeopterin).

RESULTS: sAA was found to be significantly higher ($p < 0.005$) in the EHS group. uNeopterin and sAA analysis showed a significant difference based on the duration of EHS.

CONCLUSION: Higher levels of sAA in EHS participants may suggest that the sympathetic adrenal medullar system is activated. However, most of the analyzed markers of the immune system, sympathetic activity and circadian rhythm did not vary significantly in the EHS group. There is a trend to the higher levels of some variables in subgroups according to the EHS duration.

https://www.ncbi.nlm.nih.gov/pubmed/28466664

Excerpts

sAA activity was significantly different ($p < 0.0001$) between the control and EHS group. The EHS group showed a significantly higher level of sAA (Figure 2(a)).

Figure 2. Salivary concentration of α-amylase (a) and IgA (b) in the control (black line) and EHS group (grey line) during experimentation (from bedtime to 16:30 h). Data expressed as mean ± SEM. Significant difference between groups for α-amylase ($p < 0.0001$); significant effect of time for α-amylase ($p = 0.0001$) and IgA ($p < 0.0001$).

The mean of sIgA showed a tendency to be positively correlated with EHS duration ($r = 0.141$, $p = 0.010$); sAA was also slightly but positively correlated with EHS duration ($r = 0.254$, $p < 0.001$).

Besides, the salivary enzyme α-amylase has been proposed as a marker for the stress-induced activity of the sympathetic nervous system (SNS), or more precisely of the sympathetic adrenomedullary (SAM) system, which is also involved in the secretion of adrenaline and noradrenaline (Chatterton et al. 1996 Chatterton RT Jr, Vogelsong KM, Lu YC, Ellman AB, Hudgens GA. 1996. Salivary alpha-amylase as a measure of endogenous adrenergic activity. Clin Physiol. 16:433–448.[Crossref], [PubMed], [Google Scholar]; Rohleder & Nater 2009 Rohleder N, Nater UM. 2009. Determinants of salivary alpha-amylase in humans and methodological considerations. Psychoneuroendocrinology. 34:469–485.[Crossref], [PubMed], [Web of Science ®], [Google Scholar]). Unlike cortisol, saliva alpha amylase levels were found to be significantly higher in the EHS group, in comparison to the control group. The question that arises here is whether this change in α-amylase activity was a result of outside exposure to EMF or simply a consequence of chronic stress.

.. in the present study, sAA levels were shown to be constantly elevated in EHS individuals, even during their stay (from 09:00 to 16:30 h) in the EMF-shielded room in our laboratory. The role of EMF on the increase of AA is still to be proven. However, our results indicated that the EHS population seems to have higher levels of sAA than the control group. And the cause of this increase is to be yet determined.

Moreover, a significant and positive correlation was shown between sAA levels and the duration of EHS. Indeed, the longer the duration of EHS, the higher the level of sAA. This may suggest that the longer they are EHS, the more they react. One may speculate that this could be due to a degraded system in patients presenting EHS for a long time.

Besides, a study has shown that exposure to radiofrequency electromagnetic fields (RF-EMF) emitted by mobile phone base stations affected salivary α-amylase in healthy participants (Augner et al. 2010 Augner C, Hacker GW, Oberfeld G, Florian M, Hitzl W, Hutter J, Pauser G. 2010. Effects of exposure to GSM mobile phone base station signals on salivary cortisol, alpha-amylase, and immunoglobulin A. Biomed Environ Sci BES. 23:199–207.[Crossref], [PubMed], [Web of Science ®], [Google Scholar]). In addition, a study of people living next to phone base stations, self-declaring base-station neighbors (distance to base station ≤100 m), had higher levels of α-amylase accompanied by a higher general strain (Augner & Hacker 2009 Augner C, Hacker GW. 2009. Are people living next to mobile phone base stations more strained? Relationship of health concerns, self-estimated distance to base station, and psychological parameters. Indian J Occup Environ Med. 13:141–145.[Crossref], [PubMed], [Google Scholar]; Augner et al. 2010 Augner C, Hacker GW, Oberfeld G, Florian M, Hitzl W, Hutter J, Pauser G. 2010. Effects of exposure to GSM mobile phone base station signals on salivary cortisol, alpha-amylase, and immunoglobulin A. Biomed Environ Sci BES. 23:199–207.[Crossref], [PubMed], [Web of Science ®], [Google Scholar]). This may suggest that people self-reporting EHS could share similarities with this population, but whether this is due to actual exposure to EMF or to other underlying factors is not clear. In our study, unfortunately, recordings of exposure field density before entering the study (outside the experimental lab) were not available.

In summary, an exploration of selected and measurable markers of EHS was conducted in our study to understand this condition. Our finding indicates that markers of the circadian rhythm and immune system were not affected in EHS compared to non-EHS individuals. Our results suggest different profiles of EHS according to the duration of the syndrome. Furthermore, the mechanism underlying the higher expression of α-amylase should be focused on. These findings could be new elements in the understanding, explanation and comprehension of the physiopathology of EHS.

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Maternal cell phone use in early pregnancy & child's language, communication & motor skills at 3 & 5 years: Norwegian mother child cohort study

Papadopoulou E, Haugen M, Schjølberg S, Magnus P, Brunborg G, Vrijheid M, Alexander J. Maternal cell phone use in early pregnancy and child's language, communication and motor skills at 3 and 5 years: the Norwegian mother and child cohort study (MoBa). BMC Public Health. 2017 Sep 5;17(1):685. doi: 10.1186/s12889-017-4672-2.

Abstract

BACKGROUND: Cell phone use during pregnancy is a public health concern. We investigated the association between maternal cell phone use in pregnancy and child's language, communication and motor skills at 3 and 5 years.

METHODS: This prospective study includes 45,389 mother-child pairs, participants of the MoBa, recruited at mid-pregnancy from 1999 to 2008. Maternal frequency of cell phone use in early pregnancy and child language, communication and motor skills at 3 and 5 years, were assessed by questionnaires. Logistic regression was used to estimate the associations.

RESULTS: No cell phone use in early pregnancy was reported by 9.8% of women, while 39%, 46.9% and 4.3% of the women were categorized as low, medium and high cell phone users. Children of cell phone user mothers had 17% (OR = 0.83, 95% CI: 0.77, 0.89) lower adjusted risk of having low sentence complexity at 3 years, compared to children of non-users. The risk was 13%, 22% and 29% lower by low, medium and high maternal cell phone use. Additionally, children of cell phone users had lower risk of low motor skills score at 3 years, compared to children of non-users, but this association was not found at 5 years. We found no association between maternal cell phone use and low communication skills.

CONCLUSIONS: We reported a decreased risk of low language and motor skills at three years in relation to prenatal cell phone use, which might be explained by enhanced maternal-child interaction among cell phone users. No evidence of adverse neurodevelopmental effects of prenatal cell phone use was reported.

https://www.ncbi.nlm.nih.gov/pubmed/28870201

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Use of non-ionizing electromagnetic fields for the treatment of cancer

Jimenez H, Blackman C, Lesser G, Debinski W, Chan M, Sharma S, Watabe K, Lo HW, Thomas A, Godwin D, Blackstock W, Mudry A, Posey J, O'Connor R, Brezovich I, Bonin K, Kim-Shapiro D, Barbault A, Pasche B. Use of non-ionizing electromagnetic fields for the treatment of cancer. Front Biosci (Landmark Ed). 2018 Jan 1;23:284-297.

Abstract

Cancer treatment and treatment options are quite limited in circumstances such as when the tumor is inoperable, in brain cancers when the drugs cannot penetrate the blood-brain-barrier, or when there is no tumor-specific target for generation of effective therapeutic antibodies. Despite the fact that electromagnetic fields (EMF) in medicine have been used for therapeutic or diagnostic purposes, the use of non-ionizing EMF for cancer treatment is a new emerging concept. Here we summarize the history of EMF from the 1890's to the novel and new innovative methods that target and treat cancer by non-ionizing radiation.

https://www.ncbi.nlm.nih.gov/pubmed/28930547

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Efficacy and Safety of Treating Glioblastoma With Tumor-Treating Fields Therapy

Saria MG, Kesari S. Efficacy and Safety of Treating Glioblastoma With Tumor-Treating Fields Therapy. Clin J Oncol Nurs. 2016 Oct 1;20(5):S9-S13. doi: 10.1188/16.CJON.S1.9-13.

Abstract

BACKGROUND: Glioblastoma (GBM) is a highly aggressive astrocytoma with a dismal prognosis. Since 1976, only three chemotherapeutic agents have been approved for the treatment of GBM. Tumor-treating fields (TTFields) therapy, delivered via a noninvasive device, is a new therapy approved for use in patients with recurrent GBM and in combination with temozolomide for the treatment of newly diagnosed GBM.

OBJECTIVES: This article reviews the mechanism of action and findings from preclinical and clinical studies supporting the use of TTFields for patients with newly diagnosed and recurrent GBM.

METHODS: This article provides an overview of published literature on the efficacy and safety of treating GBM with TTFields.

FINDINGS: For the first time in more than a decade, patients with GBM have a noninvasive treatment option that has been shown to increase progression-free survival and overall survival with minimal adverse events.

https://www.ncbi.nlm.nih.gov/pubmed/27668388

Excerpts

Compared with historic cancer treatment modalities, TTFields have an innovative mechanism of action. Nonbiochemical and nonablative, TTFields use frequency-specific, low-intensity, alternating electric fields to disrupt structures within the cancer cell during mitosis, leading to apoptosis. Specifically, TTFields technology takes advantage of the special characteristics, geometric shape, and the rate of dividing cancer cells, which make them susceptible to the effects of TTFields. TTFields alter tumor cell polarity at an intermediate frequency (100–300 kHz). The frequency used for TTFields is specific to the target cell type (e.g., 200 kHz for gliomas). TTFields have been shown to disrupt the normal assembly of the microtubule spindle by exerting directional forces on polar intracellular elements, such as macromolecules and organelles. These processes lead to physical disruption of the cell membrane and to programmed cell death (Giladi et al., 2015) (see Figure 1).

The pivotal, randomized phase III study leading to the FDA approval of Optune for recurrent GBM and the subsequent prospective, multicenter, open-label, randomized, controlled trial leading to the approval of Optune for patients with newly diagnosed GBM demonstrate that the addition of TTFields to maintenance TMZ chemotherapy significantly improves survival without increasing toxicities in patients with glioblastoma. The introduction of the second-generation device, which weighs about 50% less than the original device, is expected to improve GBM patient compliance. Trials are evaluating the safety and efficacy of TTFields in low-grade gliomas, solid tumor brain metastases, non-small cell lung cancer, pancreatic cancer, and other solid malignancies.

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Evaluation of Electromagnetic Exposure During 85 kHz Wireless Power Transfer for Electric Vehicles

SangWook Park. Evaluation of Electromagnetic Exposure During 85 kHz Wireless Power Transfer for Electric Vehicles. IEEE Transactions on Magnetics. Volume: PP, Issue: 99. Sep 1, 2017. 10.1109/TMAG.2017.2748498

Abstract

The external fields in the proximity of electric vehicle (EV) wireless power transfer (WPT) systems requiring high power may exceed the limits of international safety guidelines. This study presents dosimetric results of an 85 kHz WPT system for electric vehicles. A WPT system for charging EVs is designed and dosimetry for the system is evaluated for various exposure scenarios: a human body in front of the WPT system without shielding, with shielding, with alignment and misalignment between transmitter and receiver, and with a metal plate on the system for vehicle mimic floor pan. The minimum accessible distances in compliance are investigated for various transmitting powers. The maximum allowable transmitting power are also investigated with the limits of international safety guidelines and the dosimetric results.

http://ieeexplore.ieee.org/document/8024022/

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Effect of 2G and 3G Cell Phone Radiation on Developing Liver of Chick Embryo - Comparative Study

D'Silva MH, Swer RT, Anbalagan J, Rajesh B. Effect of Radiofrequency Radiation Emitted from 2G and 3G Cell Phone on Developing Liver of Chick Embryo - A Comparative Study. J Clin Diagn Res. 2017 Jul;11(7):AC05-AC09. doi: 10.7860/JCDR/2017/26360.10275. Epub 2017 Jul 1.

Abstract

INTRODUCTION: The increasing scientific evidence of various health hazards on exposure of Radiofrequency Radiation (RFR) emitted from both the cell phones and base stations have caused significant media attention and public discussion in recent years. The mechanism of interaction of RF fields with developing tissues of children and fetuses may be different from that of adults due to their smaller physical size and variation in tissue electromagnetic properties. The present study may provide an insight into the basic mechanisms by which RF fields interact with developing tissues in an embryo.

AIM: To evaluate the possible tissue and DNA damage in developing liver of chick embryo following chronic exposure to Ultra-High Frequency/Radiofrequency Radiation (UHF/RFR) emitted from 2G and 3G cell phone.

MATERIALS AND METHODS: Fertilized chick embryos were incubated in four groups. Group A-experimental group exposed to 2G radiation (60 eggs), Group B- experimental group exposed to 3G radiation (60 eggs), Group C- sham exposed control group (60 eggs) and Group D- control group (48 eggs). On completion of scheduled duration, the embryos were collected and processed for routine histological studies to check structural changes in liver. The nuclear diameter and karyorrhexis changes of hepatocytes were analysed using oculometer and square reticule respectively. The liver procured from one batch of eggs from all the four groups was subjected to alkaline comet assay technique to assess DNA damage. The results were compared using one-way ANOVA test.

RESULTS: In our study, the exposure of developing chick embryos to 2G and 3G cell phone radiations caused structural changes in liver in the form of dilated sinusoidal spaces with haemorrhage, increased vacuolations in cytoplasm, increased nuclear diameter and karyorrhexis and significantly increased DNA damage.

CONCLUSION: The chronic exposure of chick embryo liver to RFR emitted from 2G and 3G cell phone resulted in various structural changes and DNA damage. The changes were more pronounced in 3G experimental group. Based on these findings it is necessary to create awareness among public about the possible ill effects of RFR exposure from cell phone.

Open Access: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5583901/

Excerpts

The first four batches (48 eggs) were grouped as control (Group–D) and they were incubated without any external factors interfering with their developmental process. Next five batches (60 eggs) were treated as sham exposed group (Group-C). They were incubated along with a popular brand cell phone with the SAR of 0.310 watts/kilogram hung from above with 5 cm distance separating the egg and kept in null status (switched off)....

The experimental group, Group–A (exposed to 2G cell phone radiation) and Group–B (exposed to 3G cell phone radiation), were also incubated (60+60 eggs) in a similar manner with the cell phone kept in silent operative mode with head phone plugged in (switched on). This arrangement ensured that the cell phone got activated automatically each time it received a call and the intensity of radio frequency waves were measured using radiofrequency meter (RF meter, Less EMF Inc, USA) [Table/Fig-1].

A popular brand cell phone hand set and a service provider were used for network connection for both 2G and 3G exposure. For exposure activation, the cell phone was rung from another cell phone for duration of three minutes each, every half an hour, with the first exposure given at 12th hour of incubation (4.30 am-4.30 pm). The total exposure for a 12 hour period was 75 minutes followed by 12 hour of exposure-free period. This was repeated daily up to 12th day of incubation.

From our experimental outcome, we conclude that the chronic exposure of chick embryo liver to RFR emitted from 2G and 3G cell phone resulted in various structural changes and DNA damage. The changes were more pronounced in 3G experimental group. Many researchers now opine that cell phones may turn out to be the cigarettes of 21st century as their effects or interactions with biological tissues on long term exposure are yet to be explored especially in foetuses and children. Hence, children and pregnant women should use the cell phone with caution. Introduction of new generation phones, 4G and 5G, open a vast potential for future research and whether these changes observed due to RFR exposure are reversible or not on withdrawing the exposure is another arena which warrants further research.

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Effects of Combined Exposure to Microwave and Heat on Gene Expression and Sperm Parameters in Mice

Gohari FA, Saranjam B, Asgari M, Omidi L, Ekrami H, Moussavi-Najarkola SA.An Experimental Study of the

Effects of Combined Exposure to Microwave and Heat on Gene Expression and Sperm Parameters in Mice. J Hum Reprod Sci. 2017 Apr-Jun;10(2):128-134. doi: 10.4103/jhrs.JHRS_136_16.

Abstract

OBJECTIVES: Separate exposure to microwaves (MWs) or heat had effects on expression levels of Bax and Bcl-2 and sperm parameters in studied group.

AIMS: The objectives of this research were to determine the effects of separate and combined exposure to 900-MHz MW (as representative of cell phone radiation) and heat on gene expression and spermogram of male mice.

SETTINGS AND DESIGN: This experimental animal study was conducted in the school of public health.

MATERIALS AND METHODS: The study was done on 12 male mice randomly divided into four groups (21-23 g): control, test group 1 with separate exposure to 900-MHz MW, test group 2 with separate exposure to hot and sultry climate, and test group 3 with simultaneous whole body exposures to 900-MHz MW and hot and sultry climate. In all studied groups, gene expression and sperm parameters were measured.

RESULTS: Tissue samples in all test groups showed integrity of the seminiferous tubule followed by all types of germ line cells. Significant increases in the number of dead sperms in mice with separate exposure to heat were observed in comparison with the other studied groups ($P < 0.05$). The ratio of Bax expression was elevated to 0.015 ± 0.006 in mice after combined exposures to 900-MHz MW and heat.

CONCLUSION: Separate and combined exposure to 900-MHz MW and heat may induce adverse effects on sperm parameters and gene expression of studied male mice.

https://www.ncbi.nlm.nih.gov/pubmed/28904503

Note: limited statistical power -- 12 mice randomly divided into 4 groups

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Residential magnetic fields exposure and childhood leukemia: a population-based case-control study in California

Kheifets L, Crespi CM, Hooper C, Cockburn M, Amoon AT, Vergara XP. Residential magnetic fields exposure and childhood leukemia: a population-based case-control study in California. Cancer Causes Control. 2017 Sep 12. doi: 10.1007/s10552-017-0951-6. [Epub ahead of print]

Abstract

PURPOSE: Studies have reported an increased risk of childhood leukemia associated with exposure to magnetic fields. We conducted a large records-based case-control study of childhood leukemia risk and exposure to magnetic fields from power lines in California.

METHODS: The study included 5,788 childhood leukemia cases (born in and diagnosed in California 1986-2008) matched to population-based controls on age and sex. We calculated magnetic fields at birth addresses using geographic information systems, aerial imagery, historical information on load and phasing, and site visits.

RESULTS: Based on unconditional logistic regression controlling for age, sex, race/ethnicity, and socioeconomic status using subjects geocoded to a basic standard of accuracy, we report a slight risk deficit in two intermediate exposure groups and a small excess risk in the highest exposure group (odds ratio of 1.50

(95% confidence interval [0.70, 3.23])). Subgroup and sensitivity analyses as well as matched analyses gave similar results. All estimates had wide confidence intervals.

CONCLUSION: Our large, statewide, record-based case-control study of childhood leukemia in California does not in itself provide clear evidence of risk associated with greater exposure to magnetic fields from power lines, but could be viewed as consistent with previous findings of increased risk.

https://www.ncbi.nlm.nih.gov/pubmed/28900736

Excerpts

Over 35 epidemiologic studies have investigated the association of childhood leukemia with residential low-frequency magnetic fields or physical surrogates of magnetic fields [1]. Three pooled analyses have found an increased risk of childhood leukemia for relatively high estimated residential magnetic field exposure [2, 3, 4]. The consistent association found between childhood leukemia and average magnetic field exposure above 0.3–0.4 μT could be due to chance, selection bias, misclassification, other factors which confound the association, or true causal relationship. As explanation for both individual results and pooled efforts is lacking, selection bias seems as the most likely explanation, but uncertainty remains and other explanations outlined above are possible. This study aims to address this uncertainty by minimizing bias, misclassification, and chance.

The California Power Line Study is funded by the Electric Power Research Institute.

The authors declare no conflicts of interest.

[The estimates of leukemia risk for 0.4 or greater microTesla exposure ranged from 1.48 - 1.55 (all p-values > .25). There were only 17 cases and 11 controls in this subgroup so the study has limited statistical power.]

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Power frequency magnetic field promotes a more malignant phenotype in neuroblastoma cells via redox-related mechanisms

Falone S, Santini S Jr, Cordone V, Cesare P, Bonfigli A, Grannonico M, Di Emidio G, Tatone C, Cacchio M, Amicarelli F. Power frequency magnetic field promotes a more malignant phenotype in neuroblastoma cells via redox-related mechanisms.Sci Rep. 2017 Sep 13;7(1):11470. doi: 10.1038/s41598-017-11869-8.

Abstract

In accordance with the classification of the International Agency for Research on Cancer, extremely low frequency magnetic fields (ELF-MF) are suspected to promote malignant progression by providing survival advantage to cancer cells through the activation of critical cytoprotective pathways. Among these, the major antioxidative and detoxification defence systems might be targeted by ELF-MF by conferring cells significant resistance against clinically-relevant cytotoxic agents. We investigated whether the hyperproliferation that is induced in SH-SY5Y human neuroblastoma cells by a 50 Hz, 1 mT ELF magnetic field was supported by improved defence towards reactive oxygen species (ROS) and xenobiotics, as well as by reduced vulnerability against both H2O2 and anti-tumor ROS-generating drug doxorubicin. ELF-MF induced a proliferative and survival advantage by activating key redox-responsive antioxidative and detoxification cytoprotective pathways that are associated with a more aggressive behavior of neuroblastoma cells. This was coupled with the upregulation of the major sirtuins, as well as with increased signaling activity of the erythroid 2-related nuclear transcription factor 2 (NRF2). Interestingly, we also showed that the exposure to 50 Hz MF as low as 100 μT may still be able to alter behavior and responses of cancer cells to clinically-relevant drugs.

https://www.ncbi.nlm.nih.gov/pubmed/28904402

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Modified health effects of non-ionizing EMR combined with other agents reported in the biomedical literature

Kostoff RN, Lau CGY. Modified health effects of non-ionizing electromagnetic radiation combined with other agents reported in the biomedical literature. In C.D. Geddes (ed.), Microwave Effects on DNA and Proteins. Switzerland: Springer, pp. 97-158.DOI 10.1007/978-3-319-50289-2. 2017.

Abstract

Ionizing and non-ionizing electromagnetic field (EMF) radiation, either stand-alone or in combination with other agents, exert health effects on biological systems. The present chapter examines the scope of non-ionizing EMF radiation combined effects; i.e., identifies effects on biological systems from combined exposure to non-ionizing electromagnetic fields/radiation and at least one other agent. Only articles in which the presence of non-ionizing EMF radiation had some effect (beneficial or adverse) on the biological system were selected. A comprehensive and novel query was developed using an iterative hybrid approach, whereby articles related by common text and by citation linkages were retrieved. This retrieved literature was: (1) clustered algorithmically into 32 biomedical sub-themes (assigned by the authors); (2) grouped through factor analysis into 32 factors; and (3) subsequently grouped manually (by the authors) into an effects-based taxonomy. The common principles within each thematic cluster/group that accounted for the combined effects were identified. Non-ionizing EMF radiation plays a supportive role in a wide range of beneficial and adverse effects. Major beneficial effects include (1) accelerated healing of wounds and injuries in concert with other agents and (2) treatment of cancer by combining chemotherapy with radiation. Major adverse effects, on the other hand, include (1) enhanced carcinogenesis, (2) enhanced cellular or genetic mutations, and (3) teratogenicity. It should be noted that community consensus (unanimity among papers published in peer-reviewed journals) does not exist on these potential effects, either beneficial or adverse, although there is substantial credible scientific evidence supporting the above effects (as described in this chapter).

Open access chapter: http://stip.gatech.edu/wp-content/uploads/2017/03/371048_1_En_4_Chapter_OnlinePDF.pdf

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Multiple sclerosis and environmental risk factors: a case-control study in Iran

Abbasi M, Nabavi SM, Fereshtehnejad SM, Jou NZ, Ansari I, Shayegannejad V, Mohammadianinejad SE, Farhoudi M, Noorian A, Razazian N, Abedini M, Faraji F. Multiple sclerosis and environmental risk factors: a case-control study in Iran. Neurol Sci. 2017 Aug 10. doi: 10.1007/s10072-017-3080-9.

Abstract

Studies have shown an increase in the incidence of MS in Iran. The aim of our study was to evaluate the relationship between environmental exposure and MS in Iran. This case-control study was conducted on 660 MS patients and 421 controls. Many environmental factors are compared between the two groups. Our findings demonstrated that prematurity ([OR = 4.99 (95% CI 1.34-18.68), P = 0.017]), history of measles and mumps ([OR = 1.60 (95% CI 1.05-2.45), P = 0.029; OR = 1.85 (95% CI 1.22-2.78), P = 0.003, respectively]), breast feeding [OR = 2.90 (95% CI 1.49-5.65), P = 0.002], head trauma in childhood ([OR = 8.21 (95% CI 1.56-

43.06), P = 0.013]), vaccination in adulthood ([OR = 4.57 (95% CI 1.14-18.41), P = 0.032, respectively]), migraine ([OR = 3.50 (95% CI 1.61-7.59), P = 0.002]), family history of MS, IBD, migraine, and collagen vascular diseases ([OR = 2.73 (95% CI 1.56-4.78), P < 0.001], [OR = 3.14 (95% CI 1.460-6.78), P = 0.004; OR = 3.18 (95% CI 1.83-5.53), P < 0.001; OR = 1.81 (95% CI 1.03-3.20), P = 0.040, respectively]), stressful events ([OR = 32.57 (95% CI 17.21-61.64), P < 0.001]), and **microwave exposure ([OR = 3.55 (95% CI 2.24-5.63)**, P ≤0.001]) were more in the MS group. Sun exposure ([OR = 0.09 (95% CI 0.02-0.38), P = 0.001]), dairy and calcium consumption ([OR = 0.44 (95% CI 0.27-0.71), P = 0.001]), diabetes mellitus ([OR = 0.11 (95% CI 0.01-00.99), P = 0.049], and complete vaccination during childhood appeared to decreased MS risk. Our results investigated many risk factors and protective factors in Iran.

https://www.ncbi.nlm.nih.gov/pubmed/28799006

Excerpts

[44.3% of the MS cases used a microwave oven more than 3 times a week compared to 19.9% of the controls (adjusted OR = 3.55, 95% CI= 2.24 - 5.63)].

Conclusions
It seems that the increase in MS prevalence is due to environmental factors. As a result of disability and high cost, prevention of environmental risk factors is important. The result demonstrated that the most modifiable risk factors in Iranian population were stressful event and microwave exposure. Also, the most protective modifiable factors were sun exposure and calcium supplement consumption. However, more studies are required to evaluate the potential risk factors in a geographical area such as Iran with increasing prevalence in MS.

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Human exposure to pulsed fields in the frequency range from 6 to 100 GHz

Laakso I, Morimoto R, Heinonen J, Jokela K, Hirata A. Human exposure to pulsed fields in the frequency range from 6 to 100 GHz. Phys Med Biol. 2017 Aug 9;62(17):6980-6992. doi: 10.1088/1361-6560/aa81fe.

Abstract

Restrictions on human exposure to electromagnetic waves at frequencies higher than 3-10 GHz are defined in terms of the incident power density to prevent excessive temperature rise in superficial tissue. However, international standards and guidelines differ in their definitions of how the power density is interpreted for brief exposures. This study investigated how the temperature rise was affected by exposure duration at frequencies higher than 6 GHz. Far-field exposure of the human face to pulses shorter than 10 s at frequencies from 6 to 100 GHz was modelled using the finite-difference time-domain method. The bioheat transfer equation was used for thermal modelling. We investigated the effects of frequency, polarization, exposure duration, and depth below the skin surface on the temperature rise. The results indicated limitations in the current human exposure guidelines and showed that radiant exposure, i.e. energy absorption per unit area, can be used to limit temperature rise for pulsed exposure. The data are useful for the development of human exposure guidelines at frequencies higher than 6 GHz.

https://www.ncbi.nlm.nih.gov/pubmed/28791963

Excerpts

Figure 2 shows that the hotspot locations depend on the frequency and polarization and often appear in and around fine structures such as the eyelids. However, they can also appear in other locations, most notably in the eyes and cheeks. Future studies should investigate the differences in the absorption pattern and temperature rise in multiple anatomically different individuals. The investigation should also take into account the extent of opening between the eyelids,

.. our results showed that relatively long exposure averaging times used in current ICNIRP guidelines may not provide adequate protection in the case of brief, intense pulsed exposure (figure 4). An additional limit defined for the maximum radiant exposure could provide protection from short pulse exposure. It is important to note that the effect of exposure duration diminishes as the frequency decreases (figure 5). Therefore, separate consideration for pulsed exposure is relevant only at frequencies higher than 10 GHz.

In conclusion, this study addressed the issue of pulsed exposure, which is currently treated differently in different international guidelines and standards. The results showed the effects of non-uniform energy absorption, exposure duration, and frequency on the temperature rise, and are useful for the development of human exposure guidelines at frequencies higher than 6 GHz.

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Assessment of fetal exposure to 4G LTE tablet in realistic scenarios: Effect of position, gestational age and frequency

Chiaramello E, Parazzini M, Fiocchi S, Ravazzani P, Wiart J. Assessment of fetal exposure to 4G LTE tablet in realistic scenarios: Effect of position, gestational age and frequency. IEEE Journal of Electromagnetics, RF and Microwaves in Medicine and Biology. PP:90. 2017.

Abstract

The continuous development of Radio-Frequency (RF) devices used in every-day life highlights the need of conducting appropriate health risk assessment due to Radio- Frequency Electromagnetic Fields (RF-EMF) exposure, especially for the fetal exposure in realistic scenarios. In this study, we used stochastic dosimetry, an approach that combines electromagnetic computational techniques and statistics, to assess the fetal exposure to a 4G LTE tablet in realistic scenarios, assessing the influence of the position of the tablet, the gestational age of the fetus and the frequency of the emitting antenna. Results showed that the exposure in terms of Specific Absorption Rate (SAR) was within the limits of the ICNIRP 1998 general public Guidelines in all the considered scenarios. The position of the tablet was very influential for the induced SAR in the fetus, resulting in Quartile Coefficient of Dispersion always higher than 40%. The level of exposure for the later pregnancy was found to be higher than those for the early pregnancy. As to the effect of the emitting frequency of the tablet, we found that the higher the frequency, the lower the induced SAR in the fetus.

http://ieeexplore.ieee.org/document/8000304/

Excerpt

Fig.2 shows, as example, some preliminary results referred to the exposure of the 9-months GA fetus to the 4G LTE tablet in a generic position among those described in Fig.1. All the reported SAR values have been normalized to a radiated power equal to 1 W. In this specific position, among all fetal tissues, adrenal gland, gallbladder and kidney showed SARWT values slightly higher than 5 mW/kg. Considering the pSAR1gT values, among all tissues skin, small intestine, muscle and kidney showed values higher than 10 mW/kg (with maximum of 22 mW/kg in the skin tissue).

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Nature relatedness is connected with modern health worries and electromagnetic hypersensitivity

Dömötör Z, Szemerszky R, Köteles F. Nature relatedness is connected with modern health worries and electromagnetic hypersensitivity. J Health Psychol. 2017 Mar 1:1359105317699681. doi:

10.1177/1359105317699681.

Abstract

Although nature relatedness is considered a positive characteristic, its relationship to constructs involving worries about the negative effects of artificial environmental factors is also feasible. A questionnaire assessing modern health worries, electrosensitivity, somatosensory amplification, spirituality, and nature relatedness was completed by 510 individuals. Nature relatedness was related to electrosensitivity, modern health worries, and spirituality. In a binary logistic regression analysis, somatosensory amplification, modern health worries, and nature relatedness were associated with electrosensitivity, and nature relatedness moderated the connection between modern health worries and electrosensitivity. In naive representations, "natural" might be associated with health, whereas "modern" and "artificial" evoke negative associations.

https://www.ncbi.nlm.nih.gov/pubmed/28810440

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Thermal mapping on male genital and skin tissues of laptop thermal sources and electromagnetic interaction

Safari M, Mosleminiya N, Abdolali A. Thermal mapping on male genital and skin tissues of laptop thermal sources and electromagnetic interaction. Bioelectromagnetics. 2017 Aug 11. doi: 10.1002/bem.22068.
Abstract

Since the development of communication devices and expansion of their applications, there have been concerns about their harmful health effects. The main aim of this study was to investigate laptop thermal effects caused by exposure to electromagnetic fields and thermal sources simultaneously; propose a nondestructive, replicable process that is less expensive than clinical measurements; and to study the effects of positioning any new device near the human body in steady state conditions to ensure safety by U.S. and European standard thresholds. A computer simulation was designed to obtain laptop heat flux from SolidWorks flow simulation. Increase in body temperature due to heat flux was calculated, and antenna radiation was calculated using Computer Simulation Technology (CST) Microwave Studio software. Steady state temperature and specific absorption rate (SAR) distribution in user's body, and heat flux beneath the laptop, were obtained from simulations. The laptop in its high performance mode caused 420 (W/m2) peak two-dimensional heat flux beneath it. The cumulative effect of laptop in high performance mode and 1 W antenna radiation resulted in temperatures of 42.9, 38.1, and 37.2 °C in lap skin, scrotum, and testis, that is, 5.6, 2.1, and 1.4 °C increase in temperature, respectively. Also, 1 W antenna radiation caused 0.37 × 10-3 and 0.13 × 10-1**.**

https://www.ncbi.nlm.nih.gov/pubmed/28799651

Excerpts

Findlay and Dimbylow [2010] carried out one such study on SAR in the body of a sitting 10-year-old at 2.4 and 5 GHz. They found maximum peak localized three-dimensional (3D) SAR of 3.99 × 10−3 (W/kg) in the torso area.

It should be specified that this study only considered thermal effects on men; however, laptop antenna could have non-thermal effects on the user's body or pregnant women, including DNA fraction [Nagaoka et al., 2007; Zoppetti et al., 2011; Avendano et al., 2012], but such non-thermal effects are not considered in the present paper.

Since maximum allowed power consumption for an array of antennas designed for this purpose is 1 W and there were two antennas, each one consumed up to 0.5 W of power. However, in normal conditions, Wireless Local Area Network (WLAN) antennas can radiate using only 10 mW [Guterman et al., 2009].

It should be noted that the given values of SAR were normalized to 1 W peak antenna power output, while typically a WLAN antenna radiates about 10 mW; therefore, for a real world operating system, maximum SAR of 0.37×10^{-3} and 0.18×10^{-3} (W/kg) is expected for 2 and 1 active antennas, respectively, which are 10^4 times lower than the European safety limit (2 W/kg) [IEEE Standard for Safety Levels with Respect to Humans, 2005].

Also, maximum SAR of 0.13×10^{-3} (W/kg) is expected for a WLAN antenna radiation power of about 10 mW operating at 5 GHz, which is still lower than safety limits.

... maximum temperature on surface of scrotum skin of the laptop user in the studied position was 38.1 °C, which was 2.1 °C higher than normal temperature in absence of the laptop in the simulation.

It can be inferred from the aforementioned works that increase in scrotal temperature can result in reduction of sperm motility, which consequently enhances the probability of infertility, lessens sperm production, decreases sperm concentration by 56% [Hjollund et al., 2002], increases ROS, and negatively affects sperm morphology, increasing the number of sperm with physical dimensions different from those of normal sperm.

A method of simulating thermal mapping of positioning laptop on laps of an adult man was developed. To tackle this problem, we exploited computer simulation and, to make the simulation close to the actual problem, we created 3D models of an actual laptop (Sony FW 590 Gab), antennas, and human phantom with inhomogeneous body, large number of tissues, and dispersion properties. We employed a commercial laptop Wi-Fi antenna at 2.4 GHz and a dipole antenna at 5 GHz, thermal sources with radiation powers, and human body voxel consisting of 97 tissues which were described previously. In the simulation, maximum SAR in human body was calculated 0.37×10^{-3} and 0.13×10^{-1} (W/kg) at 2.4 and 5 GHz, respectively, which was negligible according to IEEE standards; thus, the major calculated temperature elevation was due to laptop thermal sources. The temperature in glans penis, lap skin, lap muscles, and testes increased up to 37.8, 42.9, 38.8, and 37.2 °C, respectively, which was in line with clinical studies of thermal effect. Hence, the proposed method can be replicated for other scenarios. It is worth noting that the presented result cannot be easily generalized to other devices or human models. However, the whole method is replicable for similar phenomena. The recommended subject for future works can be used with the presented method for determining the effect of laptop and other devices on adult pregnant women and similar cases.

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Comparative analysis of downlink signal levels emitted by GSM 900, GSM 1800, UMTS, and LTE base stations

Ibrani M, Hamiti E, Ahma L, Halili R, Dragusha B. Comparative analysis of downlink signal levels emitted by GSM 900, GSM 1800, UMTS, and LTE base stations. Ad Hoc Networking Workshop (Med-Hoc-Net), 2017 16th Annual Mediterranean.28-30 June 2017.

Abstract

Determination of exposure levels is considered as one of the parameters of planning and optimization of green cellular networks. While moving towards 5G technology and standardization, the results of comparative exposure levels induced by 2G, 3G and 4G networks are of interest. We present the results of in-situ determination of downlink signal levels [jn Kosovo] emitted by GSM 900, GSM 1800, UMTS, and LTE networks in urban areas. The measurements are conducted with calibrated spectrum analyzer NARDA SRM 3006 at outdoor and indoor spots, including LOS and NLOS positions. The highest measured value is 2.82 V/m registered in outdoor LOS position for GSM 900. The results of comparative research highlight GSM 900 as the biggest contributor to the overall cellular systems downlink signal level, followed with UMTS, GSM 1800

and LTE. Obtained results are compared with the ICNIRP reference levels as well as with downlink signal levels emitted by cellular systems in other countries.

http://ieeexplore.ieee.org/document/8001655/

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Cancer occurrences in laboratory rats from exposure to RF and microwave radiation

Lin JC. Cancer Occurrences in Laboratory Rats from Exposure to RF and Microwave Radiation. IEEE Journal of Electromagnetics, RF and Microwaves in Medicine and Biology. Aug 2, 2017. PP:99.

Health effects of radio frequency (RF) and microwave radiation have been a subject of scientific inquiry and public interest of late because of widespread global usage of mobile communication devices by billions of people everywhere. A minute increase in health risks such as cancer from RF radiation might lead to significant consequences for health of the general public. A recent U.S. government announcement of discovery of rare cancers in rats exposed to RF radiation is an important occurrence. Note that any new or single report should not be viewed in isolation. The U.S. government project was organized to confront the weaknesses of prior laboratory rodent studies on the potential of RF exposure to impact human health such as cancer in controlled environments. Indeed, several published reports on animal cancer investigations involving prolonged exposures to RF radiation are contentious and perplexing. The discrepancies have presented ambiguity in assessing public health threats from RF exposure. It is the objective of this review to provide a critical and analytical synopsis and assessment on current progress in cancers in rats exposed, lifelong, to RF and microwave radiation. Its focus is on laboratory studies involving cancer production and promotion, and survival of experimental rats. Of special interest is carcinogenesis in the head—cancer development in the head. The question of whether RF exposure from wireless and mobile devices and systems poses a health risk would likely remain equivocal and controversial for some time to come.

http://ieeexplore.ieee.org/document/8000308/

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Mobile phone (1800MHz) radiation impairs female reproduction in mice through stress induced inhibition of ovarian & uterine activity

Shahin S, Singh SP, Chaturvedi CM. Mobile Phone (1800MHz) Radiation Impairs Female Reproduction in Mice, Mus musculus, through Stress Induced Inhibition of Ovarian and Uterine Activity. Reprod Toxicol. 2017 Aug 2. pii: S0890-6238(17)30167-3. doi: 10.1016/j.reprotox.2017.08.001. [Epub ahead of print]

Highlights

• Mice exposed to mobile phone radiation (MPR) in different operative modes.
• Ovarian & uterine histopathology, steroidogenesis & stress parameters were checked.
• Degenerative changes & reduced follicle count were observed in MPR exposed ovary.
• MPR resulted significant decrease in ovarian steroidogenic proteins & sex steroids.
• MPR induced oxidative & nitrosative stress impairs reproductive functions in mice.

Abstract

Present study investigated the long-term effects of mobile phone (1800MHz) radiation in stand-by, dialing and receiving modes on the female reproductive function (ovarian and uterine histo-architecture, and steroidogenesis) and stress responses (oxidative and nitrosative stress). We observed that mobile phone radiation induces significant elevation in ROS, NO, lipid peroxidation, total carbonyl content and serum corticosterone coupled with significant decrease in antioxidant enzymes in hypothalamus, ovary and uterus of mice. Compared to control group, exposed mice exhibited reduced number of developing and mature follicles as well as corpus lutea. Significantly decreased serum levels of pituitary gonadotrophins (LH, FSH), sex steroids (E2 and P4) and expression of SF-1, StAR, P-450scc, 3β-HSD, 17β-HSD, cytochrome P-450 aromatase, ER-α and ER-β were observed in all the exposed groups of mice, compared to control. These findings suggest that mobile phone radiation induces oxidative and nitrosative stress, which affects the reproductive performance of female mice.

https://www.ncbi.nlm.nih.gov/pubmed/28780396

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The effects of electromagnetic radiation (2450 MHz wireless devices) on the heart and blood tissue: role of melatonin

Gumral N, Saygin M, Asci H, Uguz AC, Celik O, Doguc DK, Savas HB, Comlekci S.The effects of electromagnetic radiation (2450 MHz wireless devices) on the heart and blood tissue: role of melatonin. Bratisl Lek Listy. 2016;117(11):665-671. doi: 10.4149/BLL_2016_128.

Abstract

OBJECTIVE: This study was designed to investigate the effects of 2450 MHz EMR on the heart and blood in rat and possible ameliorating effects of melatonin.

MATERIAL AND METHOD: Thirty-two female Wistar Albino rats were randomly grouped (by eight in each group) as follows: Group I: cage-control group (dimethysulfoxide (DMSO), 10mg/kg/day i.p. without stress and EMR. Group II: sham-control rats stayed in restrainer without EMR and DMSO (10mg/kg/day i.p.). Group III: rats exposed to 2450 MHz EMR. Group IV: treated group rats exposed to 2450 MHz EMR+melatonin (MLT) (10mg/kg/day i.p.).

RESULTS: In the blood tissue, there was no significant difference between the groups in respect of erythrocytes GSH, GSH-Px activity, plasma LP level and vitamin A concentration ($p > 0.05$). However, in the Group IV, erythrocytes' LP levels ($p < 0.05$) were observed to be significantly decreased while plasma vitamin C, and vitamin E concentrations ($p < 0.05$) were found to be increased when compared to Group III. In the heart tissues, MDA and NO levels significantly increased in group III compared with groups I and II ($p < 0.05$). Contrary to these oxidant levels, CAT and SOD enzyme activities decreased significantly in group III compared with groups I and II (p 0.05). Besides, MLT treatment lowered the MDA and NO levels compared with group III.

DISCUSSION: In conclusion, these results demonstrated that contrary to its effect on the heart, the wireless (2450 MHz) devices cause slight oxidative-antioxidative changes in the blood of rats, and a moderate melatonin supplementation may play an important role in the antioxidant system (plasma vitamin C and vitamin E). However, further investigations are required to clarify the mechanism of action of the applied 2450 MHz EMR exposure (Tab. 3, Fig. 1, Ref. 49).

https://www.ncbi.nlm.nih.gov/pubmed/28125893

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Effect of 2G and 3G cell phone radiation on developing liver of chick embryo – A comparative study

Mary Hydrina D'Silva MH, Swer RT, Anbalagan J, Rajesh B. Effect of Radiofrequency Radiation Emitted from 2G and 3G Cell Phone on Developing Liver of Chick Embryo – A Comparative Study. J Clinical Diagnostic Research. 11(7):AC05-AC09. Jul 2017

Introduction: The increasing scientific evidence of various health hazards on exposure of Radiofrequency Radiation (RFR) emitted from both the cell phones and base stations have caused significant media attention and public discussion in recent years. The mechanism of interaction of RF fields with developing tissues of children and fetuses may be different from that of adults due to their smaller physical size and variation in tissue electromagnetic properties. The present study may provide an insight into the basic mechanisms by which RF fields interact with developing tissues in an embryo.

Aim: To evaluate the possible tissue and DNA damage in developing liver of chick embryo following chronic exposure to ultra-high frequency/radiofrequency radiation (UHF/RFR) emitted from 2G and 3G cell phone.

Materials and Methods: Fertilized chick embryos were incubated in four groups. Group A-experimental group exposed to 2G radiation (60 eggs), Group B- experimental group exposed to 3G radiation (60 eggs), Group C-sham exposed control group (60 eggs) and Group D– control group (48 eggs). On completion of scheduled duration, the embryos were collected and processed for routine histological studies to check structural changes in liver. The nuclear diameter and karyorrhexic changes of hepatocytes were analysed using oculometer and square reticule respectively. The liver procured from one batch of eggs from all the four groups was subjected to alkaline comet assay technique to assess DNA damage. The results were compared using one-way ANOVA test.

Results: In our study, the exposure of developing chick embryos to 2G and 3G cell phone radiations caused structural changes in liver in the form of dilated sinusoidal spaces with haemorrhage, increased vacuolations in cytoplasm, increased nuclear diameter and karyorrhexis and significantly increased DNA damage.

Conclusion: The chronic exposure of chick embryo liver to RFR emitted from 2G and 3G cell phone resulted in various structural changes and DNA damage. The changes were more pronounced in 3G experimental group. Based on these findings it is necessary to create awareness among public about the possible ill effects of RFR exposure from cell phone.

http://www.jcdr.net/article_abstract.asp?issn=0973-709x&year=2017&month=July&volume=11&issue=7&page=AC05-AC09&id=10275

Excerpts

The experimental group, Group–A (exposed to 2G cell phone radiation) and Group–B (exposed to 3G cell phone radiation), were also incubated (60+60 eggs) in a similar manner with the cell phone kept in silent operative mode with head phone plugged in (switched on). This arrangement ensured that the cell phone got activated automatically each time it received a call ...

A popular brand cell phone hand set and a service provider were used for network connection for both 2G and 3G exposure. For exposure activation, the cell phone was rung from another cell phone for duration of three minutes each, every half an hour, with the first exposure given at 12th hour of incubation (4.30 am-4.30 pm). The total exposure for a 12 hour period was 75 minutes followed by 12 hour of exposure-free period. This was repeated daily up to 12th day of incubation.

From our experimental outcome, we conclude that the chronic exposure of chick embryo liver to RFR emitted from 2G and 3G cell phone resulted in various structural changes and DNA damage. The changes were more pronounced in 3G experimental group. Many researchers now opine that cell phones may turn out to be the cigarettes of 21st century as their effects or interactions with biological tissues on long term exposure are yet to be explored especially in foetuses and children. Hence children and pregnant women should use the cell phone with caution. Introduction of new generation phones, 4G and 5G, open a vast potential for future research and whether these changes observed due to RFR exposure are reversible or not on withdrawing the exposure is another arena which warrants further research.

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Disturbing honeybees' behavior with EMF: a methodology

Danial Favre. Disturbing honeybees' behavior with electromagnetic waves: A methodology.J Behav 2(2): 1010 (2017).

Abstract

Mobile phone companies and policy makers point to studies with contradictory results and usually claim that there is a lack of scientific proof of adverse effects of electromagnetic fields on animals. The present perspective article describes an experiment on bees, which clearly shows the adverse effects of electromagnetic fields on these insects' behavior. The experiment should be reproduced by other researchers so that the danger of man-made electromagnetism (for bees, nature and thus humans) ultimately appears evident to anyone.

https://www.jscimedcentral.com/Behavior/behavior-2-1010.php

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Effect of DECT cordless phone radiation on exposed, laboratory cultivated maize plants

Stefia AL, Margaritis LH, Christodoulakis NS. The effect of the non-ionizing radiation on exposed, laboratory cultivated maize (Zea mays L.) plants. Flora. 223: 23-20. Aug 2017. https://doi.org/10.1016/j.flora.2017.05.008

Highlights

- Young corn plants exposed to long term radiation from a DECT base-unit.
- No biomass reduction was observed for the exposed plants, after two weeks.
- Photosynthetic pigment content seems unaltered.
- After two weeks, mesophyll chloroplast structure seems not to be affected.
- Bundle sheath chloroplasts severely affected, apprehending repression of a major advantage.

Abstract

A series of experiments was carried out to investigate possible structural or biochemical effects on young *Zea mays* plants after a long-term exposure to non-ionizing, continuous radiation emitted from the base unit of a cordless DECT system. Exposed plants, compared to their normal counterparts, do not seem to be affected concerning their sprouting potential, biomass production for both the above ground part and the root, leaf structure, photosynthetic pigment content and their absorbance. The structural profile of the exposed plants seems almost identical to those of the control ones. Biomass production, photosynthetic pigments, leaf structure and chloroplast arrangement do not differ in exposed plants. What seems to be affected is the structure of the chloroplasts accommodated in the bundle sheath cells of the exposed leaves. They suffer a slight swelling of their thylakoids and an undulation of some of the thylakoid membranes. Scarcely a disruption of chloroplast envelope can be observed.

http://www.sciencedirect.com/science/article/pii/S0367253017332176

Excerpts

In the middle of one of the two cages, the base unit of a DECT telephone apparatus (General, Model 123) was appropriately positioned (Fig. 2). The DECT base was in a 24 h a day, 7 days a week, pulsed transmission mode, at 1882 MHz, as described elsewhere (Margaritis et al., 2014) while the light/dark programme of the chamber was adjusted to a 16/8 cycle (Stefi et al., 2016, 2017).

Radiation was measured in the two cages, while the DECT device was transmitting within one of them, with a NARDA SRM3000 (Germany) spectrum analyzer. The corresponding electrical field intensity (average and peak), in each experimental setup, was measured for a 6-min period according to ICNIRP (1998) guidelines as in Table 1. Supplementary, low precision measurements were made in the control cage with a broadband field meter (TES-92, 50 MHz–3.5 GHz, Electromagnetic radiation detector – TES Electrical Electronic Corp. Taipei, Taiwan, R.O.C.) at the value of 490.1 mV/m. In the nearby cage (exposed), radiation reached the value of 27.46 V/m (27.460 mV/m, at 1882 MHz) (55 fold higher).

Concluding, we could say that non-ionizing radiation emitted from devices of everyday use such as mobile phones, DECT phones, tablets, Wi-Fi routers etc, can by no means be considered as “innocent”. Our current results, recent papers for the effects on Arabidopsis thaliana and Gossypium hirsutum (Stefi et al., 2016, 2017), numerous reports from epidemiological researches correlating exposure and clinical disorders such as sleep disorders on children that use mobile phone before sleep (Van den Bulck 2007), promotion of lymphomas and leukemias in adults and children (Hardell et al., 2014) are serious reasons for further consideration.

Moreover, the effects of non-ionizing electromagnetic radiation on behavior (Divan et al., 2012), cardiovascular system (Celik and Hascalik 2004), reproduction and development (Margaritis et al., 2014), oxidative stress induction (Esmekaya et al., 2011; Manta et al., 2014), memory deficits (Fragopoulou et al., 2010, Ntzouni et al., 2011) and cancer provocation (Hardell and Carlberg 2009), strongly support the aspect that the problem is far more than serious and public anxiety seems justified.

Taking in to account that:

• The function of the C_4 chloroplasts is uniquely associated with the function of stomata (Ghannoum, 2008).
• Stomata of *Z. mays* are of the dumbbell – shape type. This type of stomata appears only in Graminae and is unique in structure and function.
• The total yield in our experiments was almost similar for both control and exposed plants.
• The photosynthetic pigment content, as measured with the UV/Vis Specol photometer, was more or less similar in both control and exposed plants.
• Taking into consideration that maize plants are fully mature and pistillate female flowers appear after about two months while corns are harvested three months after sprouting,
We may conclude that the differences between control and exposed plants are negligible in spite of the significant structural deformations of the agranal BSC chloroplasts. Moreover, stomatal function seems not to be affected and photosynthesis (even the C_4) not to be disturbed by radiation, until this stage of the plant’s life. Finally, we may point out that the deformations observed in the chloroplasts may affect the mature plant by suspending the great advantage of the C_4 photosynthesis.

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Effect of DECT cordless phone radiation on exposed, laboratory cultivated upland cotton plants

Stefi AL, Margaritis LH, Christodoulakis NS. The effect of the non ionizing radiation on exposed, laboratory cultivated upland cotton (Gossypium hirsutum L.) plants. Flora: Morphology, Distribution, Functional Ecology of Plants [Internet]. 2017;226:55 - 64.

Abstract

A series of experiments was carried out to investigate possible structural or biochemical alterations in Gossypium hirsutum plants after a long term (21 days) exposure to non ionizing radiation (1882 MHz) emitted from the base unit of a cordless DECT system. Exposed plants, compared to the negative (matched) controls, seem to be seriously affected. Notably lower biomass production for the above ground part and the root was

recorded. Reduction of the photosynthetic pigments and severe damage of the chloroplast structure were also observed. It seems that non ionizing radiation can be noxious for plant life functions.

https://www.scopus.com/record/display.uri?eid=2-s2.0-84997817372&doi=10.1016%2fj.flora.2016.11.009&origin=inward&txGid=2a0c5f11e55ffcd3b656cd415c1041ac

Excerpt

[same exposure setup as the maize study]

The effect of the non-ionizing radiation at the microwave band, on the Gossypium hirsutum young plants, after a long termexposure, can be considered as significant. The disastrous effect on chloroplast structure, the reduction of the photosynthetic pigments and the suppression of the photosynthetic potential, are the main causes for the significant reduction of the primary productivity. Moreover, a serious effect on the underground part of the plant was recorded but this cannot be evaluated yet.

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The aftermath of long-term exposure to non-ionizing radiation on laboratory cultivated pine plants

Stefi AL, Margaritis LH, Christodoulakis NS. The aftermath of long-term exposure to non-ionizing radiation on laboratory cultivated pine plants (Pinus halepensis M.). Flora. 234: 173-186. September 2017. https://doi.org/10.1016/j.flora.2017.07.016

Highlights

• Young pine plants exposed to long term radiation from a DECT base-unit.
• Significant biomass reduction was observed for the exposed plants, after seven weeks.
• Photosynthetic pigment content decreased in the exposed leaves.
• Cotyledon, leaf, stem and root structure seem unaffected.
• Many mesophyll cells severely affected with extensive damages to their chloroplasts.

Abstract

Sprouts of Pinus halepensis were incubated and cultured in the laboratory under controlled conditions to investigate their response to a long-term exposure to continuous, non-ionizing radiation emitted from the base unit of a cordless DECT system. Exposed plants, compared to their control counterparts, seem to be affected since they exhibit lower sprouting potential, minor fresh weight and biomass for both the above ground part and the root, reduction of their photosynthetic pigments and significantly increased ROS levels. Cotyledon, juvenile leaf, primary shoot and root structure seem similar in both control and exposed plants. What seems to be affected is the structure of chloroplasts in the exposed leaves. Many cells of the exposed leaves possess severely deformed chloroplasts with dilated or destructed thylakoid membranes although disruption of chloroplast envelopes was not observed.

http://www.sciencedirect.com/science/article/pii/S0367253017332760

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Impact of RFR on DNA damage & antioxidants in peripheral blood lymphocytes of humans residing in the vicinity of mobile phone base stations

Zothansiama, Zosangzuali M, Lalramdinpuii M, Jagetia GC. Impact of radiofrequency radiation on DNA damage and antioxidants in peripheral blood lymphocytes of humans residing in the vicinity of mobile phone base stations. Electromagn Biol Med. 2017 Aug 4:1-11. doi: 10.1080/15368378.2017.1350584.

Abstract

Radiofrequency radiations (RFRs) emitted by mobile phone base stations have raised concerns on its adverse impact on humans residing in the vicinity of mobile phone base stations. Therefore, the present study was envisaged to evaluate the effect of RFR on the DNA damage and antioxidant status in cultured human peripheral blood lymphocytes (HPBLs) of individuals residing in the vicinity of mobile phone base stations and comparing it with healthy controls.

The study groups matched for various demographic data including age, gender, dietary pattern, smoking habit, alcohol consumption, duration of mobile phone use and average daily mobile phone use.

The RF power density of the exposed individuals was significantly higher ($p < 0.0001$) when compared to the control group. The HPBLs were cultured and the DNA damage was assessed by cytokinesis blocked micronucleus (MN) assay in the binucleate lymphocytes. The analyses of data from the exposed group ($n = 40$), residing within a perimeter of 80 meters of mobile base stations, showed significantly ($p < 0.0001$) higher frequency of micronuclei (MN) when compared to the control group, residing 300 meters away from the mobile base station/s.

The analysis of various antioxidants in the plasma of exposed individuals revealed a significant attrition in glutathione (GSH) concentration ($p < 0.01$), activities of catalase (CAT) ($p < 0.001$) and superoxide dismutase (SOD) ($p < 0.001$) and rise in lipid peroxidation (LOO) when compared to controls. Multiple linear regression analyses revealed a significant association among reduced GSH concentration ($p < 0.05$), CAT ($p < 0.001$) and SOD ($p < 0.001$) activities and elevated MN frequency ($p < 0.001$) and LOO ($p < 0.001$) with increasing RF power density.

https://www.ncbi.nlm.nih.gov/pubmed/28777669

My note: All of the recorded RFR power density values in this study were well below the Federal Communication Commission's maximum permissible exposure limits in the U.S. for the general population. These limits are are 6,000 mW/m^2 [milliwatts per square meter] for 900 MHz and 10,000 mW/m^2 for 1800 MHz radiofrequency radiation. In contrast, the highest recorded value in this study was 7.52 mW/m^2 of RFR. The "exposed individuals" who resided within 80 meters of a cell antenna received an average of 5.00 mW/m^2 of RFR in their bedrooms.

To see excerpts from this study and related research: **Cell Tower Health Effects** or **http://bit.ly/saferemrcelltower**

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Mobile phone RF exposure has no effect on DNA double strand breaks in human lymphocytes

Danese E, Lippi G, Buonocore R, Benati M, Bovo C, Bonaguri C, Salvagno GL, Brocco G, Roggenbuck D, Montagnana M. Mobile phone radiofrequency exposure has no effect on DNA double strand breaks (DSB) in human lymphocytes. Ann Transl Med. 2017 Jul;5(13):272. doi: 10.21037/atm.2017.04.35.

Abstract

BACKGROUND: The use of mobile phones has been associated with an increased risk of developing certain

type of cancer, especially in long term users. Therefore, this study was aimed to investigate the potential genotoxic effect of mobile phone radiofrequency exposure on human peripheral blood mononuclear cells in vitro.

METHODS: The study population consisted in 14 healthy volunteers. After collection of two whole blood samples, the former was placed in a plastic rack, 1 cm from the chassis of a commercial mobile phone (900 MHz carrier frequency), which was activated by a 30-min call. The second blood sample was instead maintained far from mobile phones or other RF sources. The influence of mobile phone RF on DNA integrity was assessed by analyzing γ-H2AX foci in lymphocytes using immunofluorescence staining kit on AKLIDES.

RESULTS: No measure of γ-H2AX foci was significantly influenced by mobile phone RF exposure, nor mobile phone exposure was associated with significant risk of genetic damages in vitro (odds ratio comprised between 0.27 and 1.00).

CONCLUSIONS: The results of this experimental study demonstrate that exposure of human lymphocytes to a conventional 900 MHz RF emitted by a commercial mobile phone for 30 min does not significantly impact DNA integrity.

https://www.ncbi.nlm.nih.gov/pubmed/28758098

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Effects of Long-Term Exposure to 60 GHz Millimeter-Wavelength Radiation on Genotoxicity & Heat Shock Protein Expression of Cells Derived from Human Eye

Koyama S, Narita E, Shimizu Y, Suzuki Y, Shiina T, Taki M, Shinohara N, Miyakoshi J.Effects of Long-Term Exposure to 60 GHz Millimeter-Wavelength Radiation on the Genotoxicity and Heat Shock Protein (Hsp) Expression of Cells Derived from Human Eye. Int J Environ Res Public Health. 2016 Aug 8;13(8). pii: E802. doi: 10.3390/ijerph13080802.

Abstract

Human corneal epithelial (HCE-T) and human lens epithelial (SRA01/04) cells derived from the human eye were exposed to 60 gigahertz (GHz) millimeter-wavelength radiation for 24 h. There was no statistically significant increase in the micronucleus (MN) frequency in cells exposed to 60 GHz millimeter-wavelength radiation at 1 mW/cm² compared with sham-exposed controls and incubator controls. The MN frequency of cells treated with bleomycin for 1 h provided positive controls. The comet assay, used to detect DNA strand breaks, and heat shock protein (Hsp) expression also showed no statistically significant effects of exposure. These results indicate that exposure to millimeter-wavelength radiation has no effect on genotoxicity in human eye cells.

https://www.ncbi.nlm.nih.gov/pubmed/27509516

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RF EMF exposure in everyday microenvironments in Europe: A systematic literature review

Sagar S, Dongus S, Schoeni A, Roser K, Eeftens M, Struchen B, Foerster M, Meier N, Adem S, Röösli M. Radiofrequency electromagnetic field exposure in everyday microenvironments in Europe: A systematic literature review. J Expo Sci Environ Epidemiol. 2017 Aug 2. doi: 10.1038/jes.2017.13.

Abstract

The impact of the introduction and advancement in communication technology in recent years on exposure level of the population is largely unknown. The main aim of this study is to systematically review literature on the distribution of radiofrequency electromagnetic field (RF-EMF) exposure in the everyday environment in Europe and summarize key characteristics of various types of RF-EMF studies conducted in the European countries.

We systematically searched the ISI Web of Science for relevant literature published between 1 January 2000 and 30 April 2015, which assessed RF-EMF exposure levels by any of the methods: spot measurements, personal measurement with trained researchers and personal measurement with volunteers.

Twenty-one published studies met our eligibility criteria of which 10 were spot measurements studies, 5 were personal measurement studies with trained researchers (microenvironmental), 5 were personal measurement studies with volunteers and 1 was a mixed methods study combining data collected by volunteers and trained researchers. RF-EMF data included in the studies were collected between 2005 and 2013. The mean total RF-EMF exposure for spot measurements in European "Homes" and "Outdoor" microenvironments was 0.29 and 0.54 V/m, respectively. In the personal measurements studies with trained researchers, the mean total RF-EMF exposure was 0.24 V/m in "Home" and 0.76 V/m in "Outdoor". In the personal measurement studies with volunteers, the population weighted mean total RF-EMF exposure was 0.16 V/m in "Homes" and 0.20 V/m in "Outdoor". Among all European microenvironments in "Transportation", the highest mean total RF-EMF 1.96 V/m was found in trains of Belgium during 2007 where more than 95% of exposure was contributed by uplink.

Typical RF-EMF exposure levels are substantially below regulatory limits. We found considerable differences between studies according to the type of measurements procedures, which precludes cross-country comparison or evaluating temporal trends. A comparable RF-EMF monitoring concept is needed to accurately identify typical RF-EMF exposure levels in the everyday environment.

https://www.ncbi.nlm.nih.gov/pubmed/28766560

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Measurement of the environmental broadband electromagnetic waves in a mid-size European city

Fernández-García R, Gil I. Measurement of the environmental broadband electromagnetic waves in a mid-size European city. Environ Res. 2017 Jul 26;158:768-772. doi: 10.1016/j.envres.2017.07.040.

Abstract

In this paper, the level of exposure to broadband radiofrequency electromagnetic field in a mid-size European city was evaluated in accordance with the International Commission on Non-ionizing Radiation Protection guidelines from 1998. With the aim to analyse all the potential electromagnetic waves present in the city up to 18GHz, a total of 271 locations distributed along Terrassa (Spain) have been measured. To show the results in an easy-to-interpret way by the citizen, the results have been represented in a set of raster maps. The measurement results obtained showed that the electromagnetic wave measured in all broadband frequency range along the city is much lower than the safety level according to the international regulations for both public and occupational sectors.

https://www.ncbi.nlm.nih.gov/pubmed/28755561

Excerpts

... according to the World Health Organization, due to the ubiquitous source of RF radiation the percentage of all people being exposed to RF electromagnetic radiation is rapidly approaching the percentage exposed to polluted air (Lin, 2016) and therefore, more research must be devoted to this crucial issue. In addition, it is necessary to extend the RF-EMF exposure assessment to broadband frequency measurements including fields beyond 6 GHz. This fact will be mandatory in the future because of the deployment of new wireless standards such as the fifth-generation mobile communication systems (5G) (Colombi et al., 2015; Zhao et al., 2015).

The electric field measurements have been carried out by means of the electromagnetic field meter *Wavecontrol SMP2* and a *WPF18* broadband isotropic probe to assess the radioelectric environment and all the potential hand-made radiofrequency sources. The probe has a broadband frequency range from 300 kHz to 18 GHz with a measurement range from 0.5 V/m to 250 V/m. The electromagnetic sensor is based on a diode technology and it presents a sensitivity of 0.5 V/m with a resolution lower than 5%, a dynamic range of 54 dB and a linearity of ± 0.5 dB. The measurement equipment has been calibrated according to the ISO 17025 standard. The equipment is able to cover all the potential non-ionizing electromagnetic emissions in the environment from 300 kHz to 18 GHz....

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Are electromagnetic fields in incubators a risk factor for autism?

Bellieni CV, Buonocore G. Acta Paediatr. Are electromagnetic fields in incubators a risk factor for autism? 2017 Jul 22. doi: 10.1111/apa.14001.

Abstract

Hugo Lagercrantz recently argued (1) that a possible cause of infantile autism was the unnatural isolation that babies experienced in neonatal incubators. Atypical brain connectivity has been detected in children with autism and it is possible that this may be also due to environmental factors, including the lack of physiological stimuli that is typically found in the incubator environment. We suggest that also another factor may expose babies in incubators to the risk of developing autistic traits and that is the high electromagnetic fields (EMF) produced by the incubator's electric engine.

https://www.ncbi.nlm.nih.gov/pubmed/28734102

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Report from the BioEM2017: Annual meeting of BEMS & EBEA

Dariusz Leszczynski. Report from the BioEM2017: Annual meeting of BEMS & EBEA, Hangzhou, China, June 5-9, 2017.

https://betweenrockandhardplace.files.wordpress.com/2017/07/report-from-bioem2017.pdf

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Effects of short and long term EMF exposure on the human hippocampus

Omur Gulsum Deniz, Suleyman Kaplan, Mustafa Bekir Selçuk, Murat Terzi, Gamze Altun, Kıymet Kübra Yurt, Kerim Aslan, Devra Davis. Effects of short and long term electromagnetic fields exposure on the human hippocampus. Journal of Microscopy and Ultrastructure, In Press, Corrected Proof, Available online 13 July 2017.

Highlights

• This pilot investigation of female medical students finds that electromagnetic fields exposure does not alter the volume of the human hippocampus.

• Widespread use of mobile phones among medical students results in a low level of concentration in the present study.
• Prolonged use of mobile phones can lead to a decline in the ability to suppress stimuli.

Abstract

The increasing use of mobile phones may have a number of physiological and psychological effects on human health. Many animal and human studies have reported various effects on the central nervous system and cognitive performance from of exposure to electromagnetic fields (EMF) emitted by mobile phones. The aim of the present study was to evaluate the effects of mobile phones on the morphology of the human brain and on cognitive performance using stereological and spectroscopic methods and neurocognitive tests.

Sixty healthy female medical school students aged 18–25 years were divided into a low exposure group (30 subjects, <30 min daily use by the head) and high exposure group (30 subjects, >90 min daily use by the head). Magnetic resonance images (MRI) of the brain analysed on OsiriX 3.2.1 workstation. Neuropsychological tests were performed for each subject. In addition, three dominant specific metabolites were analysed, choline at 3.21 ppm, creatine at 3.04 ppm and N-acetyl aspartate at 2.02 ppm. Analysis of the spectroscopic results revealed no significant difference in specific metabolites between the groups ($p > 0.05$). There was also no significant difference in terms of hippocampal volume between the groups ($p > 0.05$). In contrast, the results of the stroop and digit span (backward) neurocognitive tests of high exposure group for evaluating attention were significantly poorer from low exposure group ($p < 0.05$). Based on these results, we conclude that a lack of attention and concentration may occur in subjects who talk on mobile phones for longer times, compared to those who use phones relatively less.

http://www.sciencedirect.com/science/article/pii/S2213879X17300524

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Monte Carlo simulations of skin exposure to electromagnetic field from 10 GHz to 1 THz

Sasaki K, Mizuno M, Wake K, Watanabe S. Monte Carlo simulations of skin exposure to electromagnetic field from 10 GHz to 1 THz.
Phys Med Biol. 2017 Jul 25. doi: 10.1088/1361-6560/aa81fc.

Abstract

In this study, we present an assessment of human-body exposure to an electromagnetic eld at frequencies ranging from 10 GHz to 1 THz. The energy absorption and temperature elevation were assessed by solving boundary value problems of the one-dimensional Maxwell equations and a bioheat equation for a multilayer plane model. Dielectric properties were measured in vitro at frequencies of up to 1 THz at body temperature. A Monte Carlo simulation was conducted to assess variations of the transmittance into a skin surface and temperature elevation inside a body by considering the variation of the tissue thickness due to individual differences among human bodies. Furthermore, the impact of the dielectric properties of adipose tissue on temperature elevation, for which large discrepancies between our present measurement results and those in past works were observed, was also examined. We found that the dielectric properties of adipose tissue do not impact on temperature elevation at frequencies over 30 GHz. The potential risk of skin burn was discussed on the basis of the temperature elevation in millimeter-wave and terahertz-wave exposure. Furthermore, the consistency of the basic restrictions in the international guidelines set by ICNIRP was discussed.

https://www.ncbi.nlm.nih.gov/pubmed/28742056

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Electromagnetic fields may act via calcineurin inhibition to suppress immunity, thereby increasing risk

for opportunistic infection: Conceivable mechanisms of action

Doyon, PR, Johansson O. Electromagnetic fields may act via calcineurin inhibition to suppress immunity, thereby increasing risk for opportunistic infection: Conceivable mechanisms of action. Med Hypotheses. 106:71-87. Sep 2017. https://doi.org/10.1016/j.mehy.2017.06.028Get rights and content

Abstract

While a good number of studies have demonstrated that modern, man-made ambient electromagnetic fields can have both stimulatory and inhibitory effect on immune system function, the precise mechanisms have yet to be completely elucidated. It is hypothesized here that, depending on the parameters, one of the means by which long-term electromagnetic field exposure has the potential to eventually lead to immunosuppression is via downstream inhibition of the enzyme calcineurin — a protein phosphatase, which activates the T-cells of the immune system and can be blocked by pharmaceutical agents.

Calcineurin is the target of a class of pharmaceuticals called calcineurin inhibitors (e.g., cyclosporine, pimecrolimus and tacrolimus). When organ transplant recipients take such pharmaceuticals to prevent or suppress organ transplant rejection, one of the major side effects is immunosuppression leading to increased risk of opportunistic infection: e.g., fungal, viral (Epstein-Barr virus, cytomegalovirus), atypical bacterial (Nocardia, Listeria, mycobacterial, mycoplasma), and parasitic (e.g., toxoplasmosis) infections.

Frequent anecdotal reports, as well as a number of scientific studies, have shown that electromagnetic field exposures may indeed produce the same effect: a weakened immune system leading to an increase in the same or similar opportunistic infections: i.e., fungal, viral, atypical bacterial, and parasitic infections.

Furthermore, numerous research studies have shown that man-made electromagnetic fields have the potential to open voltage-gated calcium channels, which can in turn produce a pathological increase of intracellular calcium, leading downstream to the pathological production of a series of reactive oxygen species. Finally, there are a number of research studies demonstrating the inhibition of calcineurin by a pathological production of reactive oxygen species.

Hence, it is hypothesized here that exposures to electromagnetic fields have the potential to inhibit immune system response by means of an eventual pathological increase in the influx of calcium into the cytoplasm of the cell, which induces a pathological production of reactive oxygen species, which in turn can have an inhibitory effect on calcineurin. Calcineurin inhibition leads to immunosuppression, which in turn leads to a weakened immune system and an increase in opportunistic infection.

http://www.sciencedirect.com/science/article/pii/S0306987717301718

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Biochemical & pathological changes in male rat kidney & bladder following exposure to continuous 900-MHz EMF on postnatal days 22-59

Türedi S, Kerimoğlu G, Mercantepe T, Odacı E. Biochemical and pathological changes in the male rat kidney and bladder following exposure to continuous 900-MHz electromagnetic field on postnatal days 22-59. Int J Radiat Biol. 2017 Jul 27:1-10. doi: 10.1080/09553002.2017.1350768.

Abstract

PURPOSE: To investigate the effect on male rat kidney and bladder tissues of exposure to 900-megahertz (MHz) electromagnetic field (EMF) applied on postnatal days 22-59, inclusive.

MATERIALS AND METHODS: Twenty-four male Sprague Dawley rats, aged 21 days, were used. These were

divided equally into one of three groups, control (CG), sham (SG) or EMF (EMFG). CG was not exposed to any procedure. SG rats were kept inside a cage, without being exposed to the effect of EMF, for 1 h a day on postnatal days 22-59, inclusive. EMFG rats were exposed to continuous 900-MHz EMF for 1 h a day under the same conditions as those for the SG rats. Rats were sacrificed on postnatal day 60, and the kidney and bladder tissues were removed. Tissues were stained with hematoxylin and eosin (H&E) and Masson trichrome for histomorphological evaluation. The TUNEL method was used to assess apoptosis. Transmission electron microscopy (TEM) was also used for the kidney tissue. Oxidant/antioxidant parameters were studied in terms of biochemical values.

RESULTS: The findings showed that tissue malondialdehyde increased in EMFG compared to CG and SG in both kidney ($p = 0.004$ and $p = 0.004$, respectively) and bladder tissue ($p = 0.004$, $p = 0.006$, respectively), while catalase and glutathione levels decreased compared to CG ($p = 0.004$; $p = 0.004$, respectively) and SG ($p = 0.004$; $p = 0.004$, respectively). In the EMF group, pathologies such as dilatation and vacuolization in the distal and proximal tubules, degeneration in glomeruli and an increase in cells tending to apoptosis were observed in kidney tissue. In bladder tissue, degeneration in the transitional epithelium and stromal irregularity and an increase in cells tending to apoptosis were observed in EMFG. Additionally, EMFG samples exhibited glomerular capillary degeneration with capillary basement membranes under TEM.

CONCLUSIONS: We conclude that continuous exposure to the effect of 900-MHz EMF for 1 h a day on postnatal days 22-59, inclusive, causes an increase in oxidative stress and various pathological changes in male rat kidney and bladder tissues.

https://www.ncbi.nlm.nih.gov/pubmed/28747141

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Anxiety-like behavioural effects of ELF EMF in rats

Djordjevic NZ, Paunović MG, Peulić AS.Anxiety-like behavioural effects of extremely low-frequency electromagnetic field in rats. Environ Sci Pollut Res Int. 2017 Jul 29. doi: 10.1007/s11356-017-9710-1.

Abstract

In recent years, extremely low-frequency electromagnetic field (ELF-EMF) has received considerable attention for its potential biological effects. Numerous studies have shown the role of ELF-EMF in behaviour modulation. The aim of this study was to investigate the effect of short-term ELF-EMF (50 Hz) in the development of anxiety-like behaviour in rats through change hypothalamic oxidative stress and NO. Ten adult male rats (Wistar albino) were divided in two groups: control group-without exposure to ELF-EMF and experimental group-exposed to ELF-EMF during 7 days. After the exposure, time open field test and elevated plus maze were used to evaluate the anxiety-like behaviour of rats. Upon completion of the behavioural tests, concentrations of superoxide anion ($O_2^{\cdot -}$), nitrite (NO_2^-, as an indicator of NO) and peroxynitrite ($ONOO^-$) were determined in the hypothalamus of the animals. Obtained results show that ELF-EMF both induces anxiety-like behaviour and increases concentrations of $O_2^{\cdot -}$ and NO, whereas it did not effect on $ONOO^-$ concentration in hypothalamus of rats. In conclusion, the development of anxiety-like behaviour is mediated by oxidative stress and increased NO concentration in hypothalamus of rats exposed to ELF-EMF during 7 days.

https://www.ncbi.nlm.nih.gov/pubmed/28756602

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Influence of electromagnetic pulse on the offspring sex ratio of male BALB/c mice

Li JH, Jiang DP, Wang YF, Yan JJ, Guo QY, Miao X, Lang HY, Xu SL, Liu JY, Guo GZ.Influence of electromagnetic pulse on the offspring sex ratio of male BALB/c mice. Environ Toxicol Pharmacol. 2017 Jun

21;54:155-161. doi: 10.1016/j.etap.2017.06.015. [Epub ahead of print]

Abstract

Public concern is growing about the exposure to electromagnetic fields (EMF) and its effect on male reproductive health. Detrimental effect of EMF exposure on sex hormones, reproductive performance and sex-ratio was reported. The present study was designed to clarify whether paternal exposure to electromagnetic pulse (EMP) affects offspring sex ratio in mice. 50 male BALB/c mice aged 5-6 weeks were exposed to EMP daily for 2 weeks before mated with non-exposed females at 0d, 7d, 14d, 21d and 28d after exposure. Sex hormones including total testosterone, LH, FSH, and GnRH were detected using radioimmunoassay. The sex ratio was examined by PCR and agarose gel electrophoresis. The results of D0, D21 and D28 showed significant increases compared with sham-exposed groups. The serum testosterone increased significantly in D0, D14, D21, and D28 compared with sham-exposed groups (p<0.05). Overall, this study suggested that EMP exposure may lead to the disturbance of reproductive hormone levels and affect the offspring sex ratio.

https://www.ncbi.nlm.nih.gov/pubmed/28735146

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Hore PJ, Mouritsen H. The Radical-Pair Mechanism of Magnetoreception.Annu Rev Biophys. 2016 Jul 5;45:299-344. doi: 10.1146/annurev-biophys-032116-094545.

Abstract

Although it has been known for almost half a century that migratory birds can detect the direction of the Earth's magnetic field, the primary sensory mechanism behind this remarkable feat is still unclear. The leading hypothesis centers on radical pairs-magnetically sensitive chemical intermediates formed by photoexcitation of cryptochrome proteins in the retina. Our primary aim here is to explain the chemical and physical aspects of the radical-pair mechanism to biologists and the biological and chemical aspects to physicists. In doing so, we review the current state of knowledge on magnetoreception mechanisms. We dare to hope that this tutorial will stimulate new interdisciplinary experimental and theoretical work that will shed much-needed additional light on this fascinating problem in sensory biology.

https://www.ncbi.nlm.nih.gov/pubmed/27216936

Bolte P et al. Localisation of the Putative Magnetoreceptive Protein Cryptochrome 1b in the Retinae of Migratory Birds and Homing Pigeons. PLoS One. 2016 Mar 8;11(3):e0147819. doi: 10.1371/journal.pone.0147819.

Abstract

Cryptochromes are ubiquitously expressed in various animal tissues including the retina. Some cryptochromes are involved in regulating circadian activity. Cryptochrome proteins have also been suggested to mediate the primary mechanism in light-dependent magnetic compass orientation in birds. Cryptochrome 1b (Cry1b) exhibits a unique carboxy terminus exclusively found in birds so far, which might be indicative for a specialised function. Cryptochrome 1a (Cry1a) is so far the only cryptochrome protein that has been localised to specific cell types within the retina of migratory birds. Here we show that Cry1b, an alternative splice variant of Cry1a, is also expressed in the retina of migratory birds, but it is primarily located in other cell types than Cry1a. This could suggest different functions for the two splice products. Using diagnostic bird-specific antibodies (that allow for a precise discrimination between both proteins), we show that Cry1b protein is found in the retinae of migratory European robins (Erithacus rubecula), migratory Northern Wheatears (Oenanthe oenanthe) and pigeons (Columba livia). In all three species, retinal Cry1b is localised in cell types which have been discussed as potentially well suited locations for magnetoreception: Cry1b is observed in the cytosol of ganglion cells,

displaced ganglion cells, and in photoreceptor inner segments. The cytosolic rather than nucleic location of Cry1b in the retina reported here speaks against a circadian clock regulatory function of Cry1b and it allows for the possible involvement of Cry1b in a radical-pair-based magnetoreception mechanism.

https://www.ncbi.nlm.nih.gov/pubmed/26953791

Bazalova O et al. Cryptochrome 2 mediates directional magnetoreception in cockroaches.Proc Natl Acad Sci U S A. 2016 Feb 9;113(6):1660-5. doi: 10.1073/pnas.1518622113.

Abstract

The ability to perceive geomagnetic fields (GMFs) represents a fascinating biological phenomenon. Studies on transgenic flies have provided evidence that photosensitive Cryptochromes (Cry) are involved in the response to magnetic fields (MFs). However, none of the studies tackled the problem of whether the Cry-dependent magnetosensitivity is coupled to the sole MF presence or to the direction of MF vector. In this study, we used gene silencing and a directional MF to show that mammalian-like Cry2 is necessary for a genuine directional response to periodic rotations of the GMF vector in two insect species. Longer wavelengths of light required higher photon fluxes for a detectable behavioral response, and a sharp detection border was present in the cyan/green spectral region. Both observations are consistent with involvement of the FADox, FAD(•-) and FADH(-) redox forms of flavin. The response was lost upon covering the eyes, demonstrating that the signal is perceived in the eye region. Immunohistochemical staining detected Cry2 in the hemispherical layer of laminal glia cells underneath the retina. Together, these findings identified the eye-localized Cry2 as an indispensable component and a likely photoreceptor of the directional GMF response. Our study is thus a clear step forward in deciphering the in vivo effects of GMF and supports the interaction of underlying mechanism with the visual system.

https://www.ncbi.nlm.nih.gov/pubmed/26811445

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World Health Organization, radiofrequency radiation and health - a hard nut to crack (Review)

Hardell L. World Health Organization, radiofrequency radiation and health - a hard nut to crack (Review). International Journal of Oncology. Published online on: June 21, 2017. https://doi.org/10.3892/ijo.2017.4046

Abstract

In May 2011 the International Agency for Research on Cancer (IARC) evaluated cancer risks from radiofrequency (RF) radiation. Human epidemiological studies gave evidence of increased risk for glioma and acoustic neuroma. RF radiation was classified as Group 2B, a possible human carcinogen. Further epidemiological, animal and mechanistic studies have strengthened the association. In spite of this, in most countries little or nothing has been done to reduce exposure and educate people on health hazards from RF radiation. On the contrary ambient levels have increased. In 2014 the WHO launched a draft of a Monograph on RF fields and health for public comments. It turned out that five of the six members of the Core Group in charge of the draft are affiliated with International Commission on Non-Ionizing Radiation Protection (ICNIRP), an industry loyal NGO, and thus have a serious conflict of interest. Just as by ICNIRP, evaluation of non-thermal biological effects from RF radiation are dismissed as scientific evidence of adverse health effects in the Monograph. This has provoked many comments sent to the WHO. However, at a meeting on March 3, 2017 at the WHO Geneva office it was stated that the WHO has no intention to change the Core Group.

Open Access Paper: https://www.spandidos-publications.com/10.3892/ijo.2017.4046

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Use of cell phones and brain tumors: a true association?

Mortazavi, S.A.R., Mortazavi, G. & Mortazavi, S.M.J. Letter to the Editor: Use of cell phones and brain tumors: a true association? Neurol Sci (2017). doi:10.1007/s10072-017-3055-x.

Dear Editor:

With great interest, we have read the editorial by Beghi entitled "Use of cell phones and brain tumors: a true association?" that is published in the journal of Neurol Sci 2017 doi: 10.1007/s10072-017-2992-8 [1]. In this article, the author confirms the lack of robust evidence of association between use of cell phones and brain tumors. However, Beghi mentions that absence of evidence does not necessarily mean that there is no any association. The editorial authored by Beghi addresses a very challenging issue. However, this editorial cannot be considered as a good contribution in the field of radiofrequency exposure and cancer. Over the past several years, our team has conducted several studies on the possible association of exposure to radiofrequency electromagnetic fields (RF-EMFs) and adverse health effects. Beghi claims that the findings of case–control studies have not been confirmed by cohort studies "First of all, the positive results of some case–control studies have not been confirmed by cohort studies. Case–control studies, even when methodologically robust, cannot replace cohort studies in confirming or disproving an association between a given exposure and a disease. ….In this context, none of the cohort studies found an increased risk of brain tumors in people exposed to cell phones." Although what he claims about the advantages of cohort studies seems to be right, his conclusion is problematic. Beghi does not mention that the number of cohort studies conducted on this topic so far is drastically low and all of these studies had some basic limitations. Therefore, the absence of cohort-proven findings does not necessarily mean that there is no detrimental effect. In this light, as free radical formation after exposure to RF-EMF is confirmed in many studies, even without firm conclusions from cohort studies, these exposures should be limited.

Furthermore, Beghi claims that "Second, the increased risk of brain tumors in case–control studies, if proven, is at best modest and, as brain tumors are rare diseases, the total number of tumors appears only slightly increased." It is worth mentioning that a systematic review and meta-analysis recently published by Yang et al. could not find a link between mobile phone use of any duration and the odds of high-grade glioma. However, there was a 2.22 times greater odds of the occurrence of low-grade glioma for long-term mobile phone use (OR = 2.22, 95% CI = 1.69–2.92) [2]. Beghi also claims that a clear dose–response effect has never been confirmed. Over the past several years, our team has conducted several studies on the possible association of RF-EMFs and adverse health effects. Mortazavi et al. have also recently addressed the shortcoming of some of the papers claiming lack of association between exposure to RF-EMF and cancer. They have provided evidence showing that exposure to RF-EMFs, at least at high levels and long durations, can increase the risk of cancer [3]. Substantial evidence now indicates that the current controversy regarding the carcinogenesis of RF-EMFs might be caused by the lack of accurate information regarding the magnitude of exposure to RF-EMFs which possibly plays a basic role in RF-induced carcinogenesis [4]. We have also provided evidence which shows that, in a similar pattern with ionizing radiation, the carcinogenesis of non-ionizing RF-EMF may have a nonlinear J-shaped dose–response relationship [4].

https://www.ncbi.nlm.nih.gov/pubmed/28689225

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Use of mobile and cordless phones and change in cognitive function: a prospective cohort analysis of Australian primary school children

Bhatt CR, Benke G, Smith CL, Redmayne M, Dimitriadis C, Dalecki A, Macleod S, Sim MR, Croft RJ, Wolfe R, Kaufman J, Abramson MJ Use of mobile and cordless phones and change in cognitive function: a prospective cohort analysis of Australian primary school children. Environ Health. 2017 Jun 19;16(1):62. doi: 10.1186/s12940-017-0250-4.

Abstract

BACKGROUND: Some previous studies have suggested an association between children's use of mobile phones (MPs)/cordless phones (CPs) and development of cognitive function. We evaluated possible longitudinal associations between the use of MPs and CPs in a cohort of primary school children and effects on their cognitive function.

METHODS: Data on children's socio-demographics, use of MPs and CPs, and cognitive function were collected at baseline (2010-2012) and follow-up (2012-2013). Cognitive outcomes were evaluated with the CogHealth™ test battery and Stroop Color-Word test. The change in the number of MP/CP voice calls weekly from baseline to follow-up was dichotomized: "an increase in calls" or a "decrease/no change in calls". Multiple linear regression analyses, adjusting for confounders and clustering by school, were performed to evaluate the associations between the change in cognitive outcomes and change in MP and CP exposures.

RESULTS: Of 412 children, a larger proportion of them used a CP (76% at baseline and follow-up), compared to a MP (31% at baseline and 43% at follow-up). Of 26 comparisons of changes in cognitive outcomes, four demonstrated significant associations. The increase in MP usage was associated with larger reduction in response time for response inhibition, smaller reduction in the number of total errors for spatial problem solving and larger increase in response time for a Stroop interference task. Except for the smaller reduction in detection task accuracy, the increase in CP usage had no effect on the changes in cognitive outcomes.

CONCLUSION: Our study shows that a larger proportion of children used CPs compared to MPs. We found limited evidence that change in the use of MPs or CPs in primary school children was associated with change in cognitive function.

https://www.ncbi.nlm.nih.gov/pubmed/28629417

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Patterns of cellular phone use among young people in 12 countries: Implications for RF exposure

Langer CE, de Llobet P, Dalmau A, Wiart J, Goedhart G, Hours M, et al. (32 authors). Patterns of cellular phone use among young people in 12 countries: Implications for RF exposure. Environ Int. 2017 Jun 29;107:65-74. doi: 10.1016/j.envint.2017.06.002.

Highlights

• Number and duration of calls varied by sex, age range, and socioeconomic status
• Laterality and hands-free use were less influenced by user characteristics
• Country of origin explained most of the variance in number and duration of calls, as well as SMS and data/Wi-Fi

Abstract

Characterizing exposure to radiofrequency (RF) fields from wireless telecommunications technologies during childhood and adolescence is a research priority in investigating the health effects of RF. The Mobi-Expo study aimed to describe characteristics and determinants of cellular phone use in 534 young people (10-24years) in 12 countries. The study used a specifically designed software application installed on smartphones to collect data on the use of wireless telecommunications devices within this age group. The role of gender, age, maternal education, calendar period, and country was evaluated through multivariate models mutually

adjusting for all variables. Call number and duration were higher among females compared to males (geometric mean (GM) ratio 1.17 and 1.42, respectively), among 20-24year olds compared to 10-14year olds (GM ratio 2.09 and 4.40, respectively), and among lowest compared to highest social classes (GM ratio 1.52 and 1.58, respectively). The number of SMS was higher in females (GM ratio 1.46) and the middle age group (15-19year olds: GM ratio 2.21 compared to 10-14year olds) and decreased over time. Data use was highest in the oldest age group, whereas Wi-Fi use was highest in the middle age group. Both data and Wi-Fi use increased over time. Large differences in the number and duration of calls, SMS, and data/Wi-Fi use were seen by country, with country and age accounting for up to 50% of the variance. Hands-free and laterality of use did not show significant differences by sex, age, education, study period, or country. Although limited by a convenience sample, these results provide valuable insights to the design, analysis, and interpretation of future epidemiological studies concerning the health effects of exposure resulting from cellular phone use in young people. In addition, the information provided by this research may be used to design strategies to minimize RF exposure.

https://www.ncbi.nlm.nih.gov/pubmed/28668725

Excerpts

Participants made on average 30.6 calls per week (median 20.9) and spent 60.8 min per week making or receiving calls (median 34.3; Table 2).

A total of 248 (46.4%) subjects had usable data for laterality. For these participants, 18.8% of total call time was “hands-free” on average (median 10.6%), i.e. using the speaker phone, a hands-free kit, or holding the phone away from the head (Table 2). Out of the total call time near the head (not “hands-free”), participants used the phone on the right side of the head in 63.8% of the time on average (median 70.8% - Table 2). With respect to gender, there was no statistically significant difference between males and females for hands-free usage, although females tended to speak somewhat less on their right-hand side (68% in males versus 61% in females, adj OR 0.75; 95% CI 0.54, 1.03).

Overall, UMTS (3G) was the most commonly used communication protocol with 37% of voice calls occurring using UMTS. HSDPA (3G transitional) was the next most common, with 32% of voice calls. UMTS was the most common communication protocol in Canada, France, Greece, Italy, and The Netherlands (80%, 30%, 36%, 41%, and 55%, respectively) (Fig. 2). In contrast, HSDPA was the most common network in Australia, Germany, Israel, Japan, New Zealand, and Spain (69%, 36%, 68%, 51%, 46%, and 33%, respectively). The most common network in Korea was “other” (43%). GPRS and EDGE (both 2G transitional) were not commonly used in any of the countries during our study period; use ranged from 0% (Japan and Korea) to 32% (The Netherlands) GPRS and 22% (France and Germany) EDGE, respectively.

In comparison with our findings, CEFALO, a study among 7–19 year old children and adolescents investigating possible associations between cellular phone use and brain tumors, had a much lower level of phone use among controls during a period from early 2004 through mid-2008 (Aydin et al., 2011). The top quartile of controls had a cumulative lifetime use of 2638 calls and 144 h spent on voice calls. Using the mean number and duration of calls, it would take the participants in our study less than three years to reach the lifetime use of the highest quartile of CEFALO controls.

First, the handset is not near the head for the full call duration, but rather for about 83% of the time. In addition to intentional hands-free device or speaker phone usage, this is explained by other hands-free use such as answering and ending a call. Furthermore, the time spent with the phone on one side of the head was not as high as the 90% assigned to the self-reported predominant side within the RF dose algorithm used in the INTERPHONE study (Cardis et al., 2011a), but that was a study of older adults.

A major limitation of this study is that it is a convenience sample, limiting the generalizability of the results. Given that most of the volunteers were found through friends and/or colleagues of the research team, the education level and in turn socioeconomic status is likely higher than that of the general population.

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Functional brain MRI in patients complaining of EHS after long term exposure to EMF

Heuser G, Heuser SA. Functional brain MRI in patients complaining of electrohypersensitivity after long term exposure to electromagnetic fields. Rev Environ Health. 2017 Jul 5.

Abstract

INTRODUCTION: Ten adult patients with electromagnetic hypersensitivity underwent functional magnetic resonance imaging (fMRI) brain scans. All scans were abnormal with abnormalities which were consistent and similar. It is proposed that fMRI brain scans be used as a diagnostic aid for determining whether or not a patient has electromagnetic hypersensitivity. Over the years we have seen an increasing number of patients who had developed multi system complaints after long term repeated exposure to electromagnetic fields (EMFs). These complaints included headaches, intermittent cognitive and memory problems, intermittent disorientation, and also sensitivity to EMF exposure. Regular laboratory tests were within normal limits in these patients. The patients refused to be exposed to radioactivity. This of course ruled out positron emission tomography (PET) and single-photon emission computed tomography (SPECT) brain scanning. This is why we ordered fMRI brain scans on these patients. We hoped that we could document objective abnormalities in these patients who had often been labeled as psychiatric cases.

MATERIALS AND METHODS: Ten patients first underwent a regular magnetic resonance imaging (MRI) brain scan, using a 3 Tesla Siemens Verio MRI open system. A functional MRI study was then performed in the resting state using the following sequences: A three-dimensional, T1-weighted, gradient-echo (MPRAGE) Resting state network. The echo-planar imaging (EPI) sequences for this resting state blood oxygenation level dependent (BOLD) scan were then post processed on a 3D workstation and the independent component analysis was performed separating out the various networks. Arterial spin labeling. Tractography and fractional anisotropy.

RESULTS: All ten patients had abnormal functional MRI brain scans. The abnormality was often described as hyper connectivity of the anterior component of the default mode in the medial orbitofrontal area. Other abnormalities were usually found. Regular MRI studies of the brain were mostly unremarkable in these patients.

CONCLUSION: We propose that functional MRI studies should become a diagnostic aid when evaluating a patient who claims electrohypersensitivity (EHS) and has otherwise normal studies. Interestingly, the differential diagnosis for the abnormalities seen on the fMRI includes head injury. It turns out that many of our patients indeed had a history of head injury which was then followed sometime later by the development of EHS. Many of our patients also had a history of exposure to potentially neurotoxic chemicals, especially mold. Head injury and neurotoxic chemical exposure may make a patient more vulnerable to develop EHS.

https://www.ncbi.nlm.nih.gov/pubmed/28678737

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An off-the-shelf meter for measuring body amperage: A new gold standard for epidemiologic studies?

Milham S. An off-the-shelf meter for measuring body amperage: A new gold standard for epidemiologic studies? Electromagn Biol Med. 2017 Jun 26:1. doi: 10.1080/15368378.2017.1336101.

No Abstract (letter)

https://www.ncbi.nlm.nih.gov/pubmed/28650676

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Effects of folic acid on rat kidney exposed to 900 MHz EMR

Ömür Gülsüm Deniz, Elfide Gizem Kıvrak, Arife Ahsen Kaplan, Berrin Zuhal Altunkaynak. Effects of folic acid on rat kidney exposed to 900 MHz electromagnetic radiation. Journal of Microscopy and Ultrastructure. Available online 17 June 2017.

Highlights

• The kidneys of adult male rats were investigated after exposure to 900-MHz electromagnetic radiation.
• Folic acid exhibited protective effects in the kidney against the side-effects of electromagnetic radiation exposure.
• Changes in volume and numbers of glomeruli in the kidney were analyzed using unbiased stereological methods.

Abstract

Because of increased use of cell phones, the purpose of this study was to investigation of the oxidative damage caused by electromagnetic radiation (EMR) emitted by cell phones and histological and morphometrical determination of the possible protective role of folic acid (FA) in preventing the detrimental effects of EMR on the kidney. Twenty-four adult male Wistar albino rats were divided into control (Cont), EMR, EMR + FA and FA groups, each containing six rats. The EMR and EMR + FA groups were exposed to EMR for 60 min a day over a period of 21 days, while no EMR exposure was applied to the Cont and FA groups. The source of the EMR was an EMR device which emits a digital signal producing 900-MHz frequency radiation. The generator connected to a one-monopole antenna was used in this study and the rats were placed in the plexiglass restrainer at an equal distance from the monopole antenna. Following the experimental period, and after tissue processing, a physical disector-Cavalieri method combination was applied to the sections. The mean volume of the cortex, medulla, proximal and distal tubules increased significantly in the EMR groups compared to the Cont group ($p < 0.01$). Contrarily, the total number of glomeruli in the EMR group decreased compared to the Cont group ($p < 0.01$). The protective effects of FA was observed in the kidney ($p < 0.05$).

In conclusion, the 900-MHz EMR leads to kidney damage. FA may exhibit a protective effect against the adverse effects of EMR exposure in terms of the total number of glomeruli.

http://www.sciencedirect.com/science/article/pii/S2213879X17300500

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Changes in locomotor activity in mice due to low-intensity microwaves amplitude modulated in the EEG spectral domain

Eeghem VV, Arfani AE, Anthoula A, Walrave L, Pourkazemi A, Bentea E, Demuyser T, Smolders I, Stiens J. Selective changes in locomotor activity in mice due to low-intensity microwaves amplitude modulated in the EEG spectral domain. Neuroscience. 2017 Jul 4. pii: S0306-4522(17)30461-X. doi: 10.1016/j.neuroscience.2017.06.056.

Abstract

Despite the numerous benefits of microwave applications in our daily life, microwaves were associated with diverse neurological complaints such as headaches and impaired sleep patterns, and changes in the electroencephalogram (EEG). To which extent microwaves influence the brain function remains unclear. This

exploratory study assessed the behavior and neurochemistry in mice immediately or 4 weeks after a 6-day exposure to low-intensity 10 GHz microwaves with an amplitude modulation (AM) of 2 or 8 Hz. These modulation frequencies of 2 and 8 Hz are situated within the delta and theta-alpha frequency bands in the EEG spectrum and are associated with sleep and active behavior, respectively. During these experiments, the specific absorbance rate was 0.3 W/kg increasing the brain temperature with 0.23°C. For the first time, exposing mice to 8 Hz AM significantly reduced locomotor activity in an open field immediately after exposure which normalized after 4 weeks. This in contrast to 2 Hz AM which didn't induce significant changes in locomotor activity immediately and 4 weeks after exposure. Despite this difference in motor behavior, no significant changes in striatal dopamine and DOPAC levels and DOPAC/dopamine turnover nor in cortical glutamate concentrations were detected. In all cases, no effects on motor coordination on a rotarod, spatial working memory, anxiety nor depressive-like behavior were observed. The outcome of this study indicates that exposing mice to low-intensity 8 Hz AM microwaves can alter the locomotor activity in contrast to 2 Hz AM which did not affect the tested behaviors.

https://www.ncbi.nlm.nih.gov/pubmed/28687311

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Influence of RF EMF from 3rd-generation cellular phones on fertilization and embryo development in mice (W-CDMA study)

Suzuki S, Okutsu M, Suganuma R, Komiya H, Nakatani-Enomoto S, Kobayashi S, Ugawa Y, Tateno H, Fujimori K.Influence of radiofrequency-electromagnetic waves from 3rd-generation cellular phones on fertilization and embryo development in mice. Bioelectromagnetics. 2017 Jun 19. doi: 10.1002/bem.22063.

Abstract

The purpose of this study was to evaluate the effects of 3rd-generation (3G) cellular phone radiofrequency-electromagnetic wave (RF-EMW) exposure on fertilization and embryogenesis in mice. Oocytes and spermatozoa were exposed to 3G cellular phone RF-EMWs, 1.95 GHz wideband code division multiple access, at a specific absorption rate of 2 mW/g for 60 min, or to sham exposure. After RF-EMW exposure, in vitro fertilization and intracytoplasmic sperm injection were performed. Rates of fertilization, embryogenesis (8-cell embryo, blastocyst), and chromosome aberration were compared between the combined spermatozoa and oocyte groups: both exposed, both non-exposed, one exposed, and the other non-exposed. Rates of fertilization, embryogenesis, and blastocyst formation did not change significantly across the four groups. Considering that the degree of exposure in the present study was ≥100 times greater than daily exposure of human spermatozoa and even greater than daily exposure of oocytes, the present results indicate safety of RF-EMW exposure in humans.

https://www.ncbi.nlm.nih.gov/pubmed/28628221

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The Effects of Exposure to Low Frequency EMF on Male Fertility

Darbandi M, Darbandi S, Agarwal A, Henkle R, Sadeghi MR. The Effects of Exposure to Low Frequency Electromagnetic Fields on Male Fertility. Altern Ther Health Med. 2017 Jun 23. pii: AT5423.

Abstract

Context • People are increasingly exposed to low frequency (LF) electromagnetic fields (EMFs), mainly from electricity distribution networks and electronic devices. Critics of this widespread exposure believe that it can have detrimental effects on the human body. On the other hand, many in vivo and in vitro studies have claimed that low frequency electromagnetic therapy can function as a form of alternative medicine and that therapists

can treat disease by applying electromagnetic radiation or pulsed EMFs to the body or cells. It is not yet entirely clear, however, whether LF-EMF is beneficial or harmful.
Objectives • This study aimed to examine the effects of LF-EMFs on men's reproductive functions, according to the types of waveform and the frequency and duration of exposure.
Design • The study reviewed all available research, both human and animal, on the effects of LF-EMFs on male reproductive functions, covering the literature from January 1978 to June 2016. The documents were obtained from PubMed, Science Direct, and Google Scholar, and any article that was irrelevant or a duplicate was excluded. A total of 61 articles were found, and 27 articles were reviewed.
Setting • This project was performed at the Avicenna Research Center (Tehran, Iran).
Participants • Literature included human and animal studies conducted on rabbits, mice, rats, and boars.
Intervention • Among these studies, any article that was irrelevant, a duplicate, or published with duplicate data was excluded. At the end, 27 articles were checked.
Outcome Measures • Outcome measures included testing related to reproductive organ weights, reproductive endocrinal hormones, fetal development, and spermatogenesis as well as sperm motility, morphology, and vitality.
Results • The reviewed studies provided contradictory results that were highly dependent on the exposure parameters, such as the shape and frequency of wave, intensity, duration, and timing of the exposure.
Conclusions • LF-EMF at 15 Hz with a peak intensity of 8 Gauss, with a square waveform of 50 Hz frequency and a duration of a few hours or less can have a positive effect on sperm quality, motility, and fertility. Exposures at other frequencies either had no effects on the sperm's performance and quality or held biological hazard for cells. It appears that there is still little understanding of how EMF affects cellular functions. Therefore, more standardized and controlled studies should be carried out to understand the effects of EMF on the body.

https://www.ncbi.nlm.nih.gov/pubmed/28646801

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Proteomic Analysis of the Effect of ELF-EMF With Different Intensities in SH-SY5Y Neuroblastoma Cell Line

Rezaie-Tavirani M, Hasanzadeh H, Seyyedi S, Zali H.Proteomic Analysis of the Effect of Extremely Low-Frequency Electromagnetic Fields (ELF-EMF) With Different Intensities in SH-SY5Y Neuroblastoma Cell Line.J Lasers Med Sci. 2017 Spring;8(2):79-83. doi: 10.15171/jlms.2017.14.

Abstract

Introduction: During the last 3 decades, human is exposed to extremely low frequency electromagnetic fields (ELF-EMF) emitted by power lines and electronic devices. It is now well accepted that ELF-EMF are able to produce a variety of biological effects, although the molecular mechanism is unclear and controversial. Investigation of different intensities effects of 50 Hz ELF-EMF on cell morphology and protein expression is the aim of this study.
Methods: SH-SY5Y human neuroblastoma cell line was exposed to 0.5 and 1 mT 50 Hz (ELF-EMF) for 3 hours. Proteomics techniques were used to determine the effects of these fields on protein expression. Bioinformatic and statistical analysis of proteomes were performed using Progensis SameSpots software.
Results: Our results showed that exposure to ELF-EMF changes cell morphology and induces a dose-dependent decrease in the proliferation rate of the cells. The proteomic studies and bioinformatic analysis indicate that exposure to 50 Hz ELF-EMF leads to alteration of cell protein expression in both dose-dependent and intensity dependent manner, but the later is more pronounced.
Conclusion: Our data suggests that increased intensity of ELF-EMF may be associated with more alteration in cell protein expression, as well as effect on cell morphology and proliferation

https://www.ncbi.nlm.nih.gov/pubmed/28652900

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The bee, the flower, and the electric field: electric ecology and aerial electroreception

Clarke D, Morley E, Robert D. The bee, the flower, and the electric field: electric ecology and aerial electroreception. J Comp Physiol A Neuroethol Sens Neural Behav Physiol. 2017 Jun 24. doi: 10.1007/s00359-017-1176-6.

Abstract

Bees and flowering plants have a long-standing and remarkable co-evolutionary history. Flowers and bees evolved traits that enable pollination, a process that is as important to plants as it is for pollinating insects. From the sensory ecological viewpoint, bee-flower interactions rely on senses such as vision, olfaction, humidity sensing, and touch. Recently, another sensory modality has been unveiled; the detection of the weak electrostatic field that arises between a flower and a bee. Here, we present our latest understanding of how these electric interactions arise and how they contribute to pollination and electroreception. Finite-element modelling and experimental evidence offer new insights into how these interactions are organised and how they can be further studied. Focusing on pollen transfer, we deconstruct some of the salient features of the three ingredients that enable electrostatic interactions, namely the atmospheric electric field, the capacity of bees to accumulate positive charge, and the propensity of plants to be relatively negatively charged. This article also aims at highlighting areas in need of further investigation, where more research is required to better understand the mechanisms of electrostatic interactions and aerial electroreception.

https://www.ncbi.nlm.nih.gov/pubmed/28647753

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Biological effects related to geomagnetic activity and possible mechanisms

Krylov VV. Biological effects related to geomagnetic activity and possible mechanisms. Bioelectromagnetics. 2017 Jun 21. doi: 10.1002/bem.22062. [Epub ahead of print]

Abstract

This review presents contemporary data on the biological effects of geomagnetic activity. Correlations between geomagnetic indices and biological parameters and experimental studies that used simulated geomagnetic storms to detect possible responses of organisms to these events in nature are discussed. Possible mechanisms by which geomagnetic activity influences organisms are also considered. Special attention is paid to the idea that geomagnetic activity is perceived by organisms as a disruption of diurnal geomagnetic variation. This variation, in turn, is viewed by way of a secondary zeitgeber for biological circadian rhythms. Additionally, we discuss the utility of cryptochrome as a biological detector of geomagnetic storms. The possible involvement of melatonin and protein coding by the CG8198 gene in the biological effects of geomagnetic activity are discussed. Perspectives for studying mechanisms by which geomagnetic storms affect organisms are suggested.

https://www.ncbi.nlm.nih.gov/pubmed/28636777

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Mobile phone use and risk for intracranial tumors and salivary gland tumors - A meta-analysis

Bortkiewicz A, Gadzicka E, Szymczak W. Mobile phone use and risk for intracranial tumors and salivary gland tumors - A meta-analysis. Int J Occup Med Environ Health. 2017 Feb 21;30(1):27-43. doi:

10.13075/ijomeh.1896.00802. Epub 2017 Feb 13.

Abstract

Results of epidemiological studies on the association between use of mobile phone and brain cancer are ambiguous, as well as the results of 5 meta-analysis studies published to date. Since the last meta-analysis (2009), new case-control studies have been published, which theoretically could affect the conclusions on this relationship. Therefore, we decided to perform a new meta-analysis. We conducted a systematic review of multiple electronic data bases for relevant publications. The inclusion criteria were: original papers, case-control studies, published till the end of March 2014, measures of association (point estimates as odds ratio and confidence interval of the effect measured), data on individual exposure. Twenty four studies (26 846 cases, 50 013 controls) were included into the meta-analysis. A significantly higher risk of an intracranial tumor (all types) was noted for the period of mobile phone use over 10 years (odds ratio (OR) = 1.324, 95% confidence interval (CI): 1.028-1.704), and for the ipsilateral location (OR = 1.249, 95% CI: 1.022-1.526). The results support the hypothesis that long-term use of mobile phone increases risk of intracranial tumors, especially in the case of ipsilateral exposure. Further studies are needed to confirm this relationship.

Excerpts

The results obtained in the random effects model indicated that there was a significant relationship between mobile phone use for longer than 10 years and the risk of intracranial tumors (OR = 1.46, 95% CI: 1.07–1.98).

Because OR is significantly greater than 1 (OR = 1.25, 95% CI: 1.04–1.52), we can conclude that there is a significant relationship between the time from the first regular use of mobile phone of 10 years or more and the risk of intracranial tumors.

Since OR is greater than 1 (OR = 1.29, 95% CI: 1.06–1.57), there is a significant relationship between ipsilateral use of mobile phone and the risk of intracranial tumor.

We found a significant relationship between:
— all intracranial tumors and all phone types; ipsilateral exposure;
— all intracranial tumors and all phone types, when the time of mobile phone use was not shorter than 10 years;
— all intracranial tumors and all phone types when the time from the first regular use of mobile phone was 10 years or more.

We are not able to compare our results with reference to different kinds of intracranial tumors (glioma, meningioma, acoustic neuroma) in relation to time of using mobile phones. A reliable analysis was not feasible because, in our opinion, the number of original works is too small.

Conclusions
Our results support the hypothesis that long-term (over 10 years) use of mobile phones increases the risk of intracranial tumors, especially in the case of ipsilateral exposure. The same conclusions are valid for the work by Davis et al. (2013) [45], who reviewed papers on the association between the use of wireless (mobile and cordless) phones and intracranial tumors. Those authors stress that the risk of tumors in people who have used the phone for periods longer than 10 years is significantly elevated. In people who had started using the phone on a regular basis before they were 20 years old, the risk of ipsilateral glioma was found to be fourfold higher. Hardell et al. (2013) [46] stress the significance of the "lifetime exposure dose." For an exposure of ≥ 1640 h, the risk of ipsilateral acoustic neuroma is 2.55 (95% CI: 1.5–4.4).

These results are in concordance with the conclusion of the expert panel for the International Agency for Research on Cancer (IARC), that cell phones are possibly carcinogenic (Group 2B) [47]. More research is needed to confirm that electromagnetic fields emitted by mobile phones are carcinogenic to humans.

Open Access Paper: http://bit.ly/2m8Amwt

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Mobile phone use and risk of brain tumours: a systematic review of association between study quality, source of funding, and research outcomes

Prasad M, Kathuria P, Nair P, Kumar A, Prasad K. Mobile phone use and risk of brain tumours: a systematic review of association between study quality, source of funding, and research outcomes. Neurol Sci. 2017 Feb 17. doi: 10.1007/s10072-017-2850-8. [Epub ahead of print]

Abstract

Mobile phones emit electromagnetic radiations that are classified as possibly carcinogenic to humans. Evidence for increased risk for brain tumours accumulated in parallel by epidemiologic investigations remains controversial. This paper aims to investigate whether methodological quality of studies and source of funding can explain the variation in results. PubMed and Cochrane CENTRAL searches were conducted from 1966 to December 2016, which was supplemented with relevant articles identified in the references. Twenty-two case control studies were included for systematic review. Meta-analysis of 14 case-control studies showed practically no increase in risk of brain tumour [OR 1.03 (95% CI 0.92-1.14)]. However, for mobile phone use of 10 years or longer (or >1640 h), the overall result of the meta-analysis showed a significant 1.33 times increase in risk. The summary estimate of government funded as well as phone industry funded studies showed 1.07 times increase in odds which was not significant, while mixed funded studies did not show any increase in risk of brain tumour. Metaregression analysis indicated that the association was significantly associated with methodological study quality ($p < 0.019$, 95% CI 0.009-0.09). Relationship between source of funding and log OR for each study was not statistically significant ($p < 0.32$, 95% CI 0.036-0.010). We found evidence linking mobile phone use and risk of brain tumours especially in long-term users (≥10 years). Studies with higher quality showed a trend towards high risk of brain tumour, while lower quality showed a trend towards lower risk/protection.

https://www.ncbi.nlm.nih.gov/pubmed/28213724

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Non-ionizing radiation (NIR): Evaluating safety

Martin Blank. Non-ionizing radiation (NIR): Evaluating safety. Environmental Pollution. 222:153. March 2017. http://dx.doi.org/10.1016/j.envpol.2016.12.063.

No Abstract.

Excerpt

... the divisions of the EM spectrum were created by engineers and physicists who set frequency boundaries that did not take biological factors into account. It is clear that stress protein synthesis is stimulated across the ranges of the spectrum. If the public is to be protected, safety standards should be based on measurable properties that relate to protective biological mechanisms, rather than the less sensitive thermal criterion.

http://www.sciencedirect.com/science/article/pii/S0269749116328159

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Mobile phone types and SAR characteristics of the human brain

Lee AK, Hong SE, Kwon JH, Choi HD, Cardis E. Mobile phone types and SAR characteristics of the human brain.Phys Med Biol. 2017 Mar 7;62(7):2741-2761. doi: 10.1088/1361-6560/aa5c2d. [Epub ahead of print]

Abstract

Mobile phones differ in terms of their operating frequency, outer shape, and form and location of the antennae, all of which affect the spatial distributions of their electromagnetic field and the level of electromagnetic absorption in the human head or brain. For this paper, the specific absorption rate (SAR) was calculated for four anatomical head models at different ages using 11 numerical phone models of different shapes and antenna configurations. The 11 models represent phone types accounting for around 86% of the approximately 1400 commercial phone models released into the Korean market since 2002. Seven of the phone models selected have an internal dual-band antenna, and the remaining four possess an external antenna. Each model was intended to generate an average absorption level equivalent to that of the same type of commercial phone model operating at the maximum available output power. The 1 g peak spatial SAR and ipsilateral and contralateral brain-averaged SARs were reported for all 11 phone models. The effects of the phone type, phone position, operating frequency, and age of head models on the brain SAR were comprehensively determined.

https://www.ncbi.nlm.nih.gov/pubmed/28267685

Excerpts

Both the psSAR in the brain and the brain hemisphere-averaged SAR were analyzed for the four anatomical head models and 11 representative phone models. The head models used are Eartha and Billie (8 and 11 year-old females), and Louis and Duke (14 and 34 year-old males) from IT'IS. The 11 phone models include bar, slider, and flip types operating at 835 and 1850
MHz (1765 MHz for some of the flip-type models) ....

• Phone positions and SAR. The gap in the psSAR between the cheek and tilt positions is small in the brain compared to that in the SAM phantom. Flip-type phone models with an external antenna (M8h, M8w, M9h, and M9w) generated higher SAR levels at the left position than at the right position for both frequencies.
• Frequency and SAR. Both the psSAR and the brain hemisphere-averaged SAR are higher at low frequency (835 MHz) than at high frequency (1850 or 1765 MHz). This seems to be because the electromagnetic energy penetrates deeper and is deposited in a larger 'hot spot' area at lower frequency.
• Phone types and SAR. ...The closer the antenna is located to the receiver of the phone, the higher the SAR that seems to appear in the brain. The variability in the psSAR in the brain is much higher between the different phone types than between the different head models. It suggests that it is crucial for study subjects to report exact information on the phone models used for proper exposure assessments in epidemiological studies.
• Laterality of brain hemisphere-averaged SAR. The contralateral brain-averaged SAR level of some models such as M7 and M8 at low frequency is comparable to their ipsilateral brain-averaged SAR at high frequency.
• Age-related changes in SAR. Both the psSAR (tables 2 and 3) and the brain hemisphere-averaged SAR (figures 11 and 12) seem to be strongly influenced by the distance between the head (or auricle) surface and the surface of the temporal lobe of the brain; the temporal lobe of Eartha is the farthest away from the phone body out of all of head models, and Eartha showed the lowest 1 g psSAR and lowest ipsilateral brain-averaged SAR for most of the cases considered. Overall, the variability in the brain SAR of the four head models in this study did not form a consistent pattern with age.

It is impossible to obtain the proper amount of global information regarding the outer shape, antenna location, operating frequency, and detailed SAR values because the SAR-compliance process for mobile phones varies by country. The phone models used in this paper cover the phone types of around 86% of all commercial models released onto the Korean market
since 2002. The closer the antenna is located to the receiver of the phone, the higher the SAR is generally produced in the human brain. The maximum difference in psSAR in the brain between the numerical phone

models amounted to around 12 dB. The results suggest that it is very important for all subjects to report exact information on the phone models they use if
accurate exposure levels are to be obtained in epidemiological studies ....

The issue of whether children are more sensitive to EMF emitted from mobile phones has been a hot topic among many researchers over the past two decades. In this study, a maximum psSAR variability of 5.6 dB was shown between the four head models, but was not dependent on age. To generate representative head models, the anatomical morphology of the human head at different ages and for both genders is being statistically investigated using MR images of hundreds of Koreans from early childhood to adult. The resultant statistical figures will become the foundation for detecting age-related influences on the SAR.
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On the averaging area for incident power density for human exposure limits at frequencies over 6 GHz

Hashimoto Y, Hirata A, Morimoto R, Aonuma S, Laakso I, Jokela K, Foster K. On the averaging area for incident power density for human exposure limits at frequencies over 6 GHz. Phys Med Biol. 2017 Feb 8. doi: 10.1088/1361-6560/aa5f21.

Abstract

Incident power density is used as the dosimetric quantity to specify the restrictions on human exposure to electromagnetic fields at frequencies above 3 or 10 GHz in order to prevent excessive temperature elevation at the body surface. However, international standards and guidelines have different definitions for the size of the area over which the power density should be averaged. This study reports computational evaluation of the relationship between the size of the area over which incident power density is averaged and the local peak temperature elevation in a multi-layer model simulating a human body. Three wave sources are considered in the frequency range from 3 to 300 GHz: an ideal beam, a half-wave dipole antenna, and an antenna array. One-dimensional analysis shows that averaging area of 20 mm × 20 mm is a good measure to correlate with the local peak temperature elevation when the field distribution is nearly uniform in that area. The averaging area is different from recommendations in the current international standards/guidelines, and not dependent on the frequency. For a non-uniform field distribution, such as a beam with small diameter, the incident power density should be compensated by multiplying a factor that can be derived from the ratio of the effective beam area to the averaging area. The findings in the present study suggest that the relationship obtained using the one-dimensional approximation is applicable for deriving the relationship between the incident power density and the local temperature elevation.

https://www.ncbi.nlm.nih.gov/pubmed/28176675

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A Technical Approach to the Evaluation of Radiofrequency Radiation Emissions from Mobile Telephony Base Stations

Buckus R, Strukčinskienė B, Raistenskis J, Stukas R, Šidlauskienė A, Čerkauskienė R, Isopescu DN, Stabryla J, Cretescu I. A Technical Approach to the Evaluation of Radiofrequency Radiation Emissions from Mobile Telephony Base Stations. Int J Environ Res Public Health. 2017 Mar 1;14(3). pii: E244. doi: 10.3390/ijerph14030244.

Abstract

During the last two decades, the number of macrocell mobile telephony base station antennas emitting radiofrequency (RF) electromagnetic radiation (EMR) in residential areas has increased significantly, and therefore much more attention is being paid to RF EMR and its effects on human health. Scientific field measurements of public exposure to RF EMR (specifically to radio frequency radiation) from macrocell mobile

telephony base station antennas and RF electromagnetic field (EMF) intensity parameters in the environment are discussed in this article. The research methodology is applied according to the requirements of safety norms and Lithuanian Standards in English (LST EN). The article presents and analyses RF EMFs generated by mobile telephony base station antennas in areas accessible to the general public. Measurements of the RF electric field strength and RF EMF power density were conducted in the near- and far-fields of the mobile telephony base station antenna. Broadband and frequency-selective measurements were performed outside (on the roof and on the ground) and in a residential area. The tests performed on the roof in front of the mobile telephony base station antennas in the near-field revealed the presence of a dynamic energy interaction within the antenna electric field, which changes rapidly with distance. The RF EMF power density values on the ground at distances of 50, 100, 200, 300, 400, and 500 m from the base station are very low and are scattered within intervals of 0.002 to 0.05 μW/cm². The results were compared with international exposure guidelines (ICNIRP).

https://www.ncbi.nlm.nih.gov/pubmed/28257069

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Effect of Base Transceiver Station waves on some immunological and hematological factors in exposed persons

Taheri M, Roshanaei G, Ghaffari J, Rahimnejad S, Khosroshahi BN, Aliabadi M, Eftekharian MM. The effect of Base Transceiver Station waves on some immunological and hematological factors in exposed persons. Hum Antibodies. 2017;25(1-2):31-37. doi: 10.3233/HAB-160303.

Abstract

BACKGROUND: Since the number of mobile subscribers has significantly increased in recent years, the installation and deployment of Base Transceiver Station (BTS) antennas sending and receiving signals has become common and inevitable in different regions.

OBJECTIVE: In this study, we have tried to evaluate the effect of the waves on some immunological and hematological parameters in exposed individuals. In this study, the exposed and non-exposed individuals were used as the test and control groups, respectively.

METHODS: The test group was healthy people who resided in the vicinity of the Base Transceiver Station (BTS) antenna and received the maximum of radiation. The control group was selected from the healthy individuals that were matched with the exposed group by age. They resided in a distance of Base Transceiver Station (BTS) antenna and received the minimum of radiation. After stating complete explanations and obtaining the consent, the venous blood samples were taken from them. Then, CBC and the level of cytokines including IL-4, IL-10 and interferon γ were performed on the samples and the results were analyzed by SPSS software.

RESULTS: In the test group, the whole number of white blood cells, the level of hematocrit, percent of monocytes, eosinophils and basophils were significantly lower than the control group. The number of red blood cells, their average volume and the mean concentration of hemoglobin were notably higher than the controls. There was not observed a significant difference between the two groups in hemoglobin, its mean concentration, platelet count, percent of lymphocytes and neutrophils as well as serum levels of cytokines IL-4, IL-10 and interferon γ .

CONCLUSIONS: It seems that radiation of mobile phone antennas influenced the blood and immune systems, but further study should be done to exactly determine the targets.

https://www.ncbi.nlm.nih.gov/pubmed/27911288

Also see: http://bit.ly/1cXH1B4

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A study on the effect of prolonged mobile phone use on pure tone audiometry thresholds of medical students of Sikkim

Das S, Chakraborty S, Mahanta B. A study on the effect of prolonged mobile phone use on pure tone audiometry thresholds of medical students of Sikkim. J Postgrad Med. 2017 Mar 3. doi: 10.4103/0022-3859.201419. [Epub ahead of print]

Abstract

INTRODUCTION: Mobile phones have become indispensable for daily activities, and people are exposed to them from an early age. There is, however, concern about the harmful effect of the electromagnetic radiation emitted from the mobile phones.

OBJECTIVE: The objective of the study was to study the effect of mobile phone on average pure tone audiometry (PTA) threshold of the person and to study the changes in the pure tone threshold at high frequencies such as 2 kHz, 4 kHz, and 8 kHz among the students with prolonged exposure to mobile phones.

METHODOLOGY: A cross-sectional study was conducted among the medical students who have been using mobile phones for the past 5 years. The effect of mobile phones on the PTA threshold in the exposed ear and the nonexposed ear was assessed.

RESULTS: The study shows that there is a significant difference in average air conduction (AC) and bone conduction (BC) hearing threshold among the exposed and the nonexposed ears ($P < 0.05$). A significant rise of both AC and BC threshold at individual frequencies between the exposed and the nonexposed ear is also noted in this study.

CONCLUSION: The study conducted shows changes in the hearing threshold of the exposed ear when compared with the nonexposed ear. There are however lot of unanswered questions which provide an interesting avenue for further research. Till concrete evidence is available the only feasible way to control its exposure is to limit the duration of usage of mobile phones.

https://www.ncbi.nlm.nih.gov/pubmed/28272071

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RF EMR from cell phone causes defective testicular function in male Wistar rats

Oyewopo AO, Olaniyi SK, Oyewopo CI, Jimoh AT. Radiofrequency electromagnetic radiation from cell phone causes defective testicular function in male Wistar rats. Andrologia. 2017 Mar 6. doi: 10.1111/and.12772. [Epub ahead of print]

Abstract

Cell phones have become an integral part of everyday life. As cell phone usage has become more widespread, concerns have increased regarding the harmful effects of radiofrequency electromagnetic radiation from these devices. The current study was undertaken to investigate the effects of the emitted radiation by cell phones on testicular histomorphometry and biochemical analyses. Adult male Wistar rats weighing 180-200 g were randomly allotted to control, group A (switched off mode exposure), group B (1-hr exposure), group C (2-hr exposure) and group D (3-hr exposure). The animals were exposed to radiofrequency electromagnetic radiation of cell phone for a period of 28 days. Histomorphometry, biochemical and histological investigations were carried out. The histomorphometric parameters showed no significant change ($p < .05$) in the levels of germinal epithelial diameter in all the experimental groups compared with the control group. There was no significant change ($p < .05$) in cross-sectional diameter of all the experimental groups compared with the control group. Group D rats showed a significant decrease ($p < .05$) in lumen diameter compared with group B rats. There was an uneven distribution of germinal epithelial cells in groups B, C and D. However, there was degeneration of the epithelia cells in group D when compared to the control and group B rats. Sera levels of malondialdehyde (MDA) and superoxide dismutase (SOD), which are markers of reactive oxygen species, significantly increased (MDA) and decreased (SOD), respectively, in all the experimental groups compared with the control group. Also sera levels of gonadotropic hormones (FSH, LH and testosterone) significantly decreased ($p < .05$) in groups C and D compared with the control group. The study demonstrates that chronic exposure to radiofrequency electromagnetic radiation of cell phone leads to defective testicular function that is associated with increased oxidative stress and decreased gonadotropic hormonal profile.

https://www.ncbi.nlm.nih.gov/pubmed/28261838

Also see: http://www.saferemr.com/2015/09/effect-of-mobile-phones-on-sperm.html

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Activation of autophagy at cerebral cortex and apoptosis at brainstem are differential responses to 835 MHz RF-EMF exposure

Kim JH, Yu DH, Kim HR. Activation of autophagy at cerebral cortex and apoptosis at brainstem are differential responses to 835 MHz RF-EMF exposure. Korean J Physiol Pharmacol. 2017 Mar;21(2):179-188. doi: 10.4196/kjpp.2017.21.2.179. Epub 2017 Feb 21.

Abstract

With the explosive increase in exposure to radiofrequency electromagnetic fields (RF-EMF) emitted by mobile phones, public concerns have grown over the last few decades with regard to the potential effects of EMF exposure on the nervous system in the brain. Many researchers have suggested that RF-EMFs can effect diverse neuronal alterations in the brain, thereby affecting neuronal functions as well as behavior. Previously, we showed that long-term exposure to 835 MHz RF-EMF induces autophagy in the mice brain. In this study, we explore whether short-term exposure to RF-EMF leads to the autophagy pathway in the cerebral cortex and brainstem at 835 MHz with a specific absorption rate (SAR) of 4.0 W/kg for 4 weeks. Increased levels of autophagy genes and proteins such as LC3B-II and Beclin1 were demonstrated and the accumulation of autophagosomes and autolysosomes was observed in cortical neurons whereas apoptosis pathways were up-regulated in the brainstem but not in the cortex following 4 weeks of RF exposure. Taken together, the present study indicates that monthly exposure to RF-EMF induces autophagy in the cerebral cortex and suggests that autophagic degradation in cortical neurons against a stress of 835 MHz RF during 4 weeks could correspond to adaptation to the RF stress environment. However, activation of apoptosis rather than autophagy in the brainstem is suggesting the differential responses to the RF-EMF stresses in the brain system.

https://www.ncbi.nlm.nih.gov/pubmed/28280411

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RF radiation induced genotoxic and carcinogenic effects on chickpea root tip cells

Sadaf Tabasum Qureshi, Sajjad Ahmed Memon, Abdul Rasool Abassi, Mahboob Ali Sial, Farooque Ali Bughio. Radiofrequency radiations induced genotoxic and carcinogenic effects on chickpea (Cicer arietinum L.) root tip cells. Saudi Journal of Biological Sciences. Published online Feb 11, 2017. http://dx.doi.org/10.1016/j.sjbs.2016.02.011

Abstract

Present study was under taken to predict the possible DNA damages (genotoxicity) and carcinogenicity caused by radiofrequency radiations (RF) to living tissue. Dry seeds of chickpea were treated with GSM cell phone (900 MHz) and laptop (3.31 GHz) as RF source for 24 and 48 h. Untreated seeds were used as (0 h) negative control and Gamma rays (250 Gray) as positive control. Plant chromosomal aberration assay was used as genotoxicity marker. All the treatment of RF inhibits seed germination percentage. 48 h laptop treatment has the most negative effect as compared to untreated control. A decrease was observed in mitotic index (M.I) and increase in abnormality index (A.I) with the increase in exposure duration and frequency in (Hz). Cell membrane damages were also observed only in 48 h exposure of cell phone and laptop (RF). Maximum nuclear membrane damages and ghost cells were again recorded in 48 h exposure of cell phone and laptop. The radiofrequency radiations (900 MHz and 3.31 GHz) are only genotoxic as they induce micronuclei, bi-nuclei, multi-nuclei and scattered nuclei but could be carcinogenic as 48 h incubation of RF induced fragmentation and ghost cells. Therefore cell phones and laptop should not be used unnecessarily to avoid possible genotoxic and carcinogenic effects.

Conclusion

It is concluded that radiofrequency radiations are genotoxic as they induced chromosomal aberrations in chickpea mitotic cells and the presence of ghost cells is clear indication of their carcinogenic potential. To avoid reported DNA damages in this work cell phones should always be used either for short duration or with hands-free for long duration and they should not be kept in pockets or near body. Laptops should not be used unnecessarily for enjoyment purpose. It must be placed on desk top rather lap to minimize their exposure to human body. Further assay of carcinogenity are recommended on mouse and human cell lines.

http://www.sciencedirect.com/science/article/pii/S1319562X16000589

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ELF-MF exposure affects the robustness of epigenetic programming during granulopoiesis

Manser M, Sater MR, Schmid CD, Noreen F, Murbach M, Kuster N, Schuermann D, Schär P. ELF-MF exposure affects the robustness of epigenetic programming during granulopoiesis. Sci Rep. 2017 Mar 7;7:43345. doi: 10.1038/srep43345.

Abstract

Extremely-low-frequency magnetic fields (ELF-MF) have been classified as "possibly carcinogenic" to humans on the grounds of an epidemiological association of ELF-MF exposure with an increased risk of childhood leukaemia. Yet, underlying mechanisms have remained obscure. Genome instability seems an unlikely reason as the energy transmitted by ELF-MF is too low to damage DNA and induce cancer-promoting mutations. ELF-MF, however, may perturb the epigenetic code of genomes, which is well-known to be sensitive to environmental conditions and generally deranged in cancers, including leukaemia. We examined the potential of ELF-MF to influence key epigenetic modifications in leukaemic Jurkat cells and in human CD34+ haematopoietic stem cells undergoing in vitro differentiation into the neutrophilic lineage. During granulopoiesis, sensitive genome-wide profiling of multiple replicate experiments did not reveal any statistically significant, ELF-MF-dependent alterations in the patterns of active (H3K4me2) and repressive (H3K27me3) histone marks nor in DNA methylation. However, ELF-MF exposure showed consistent effects on the reproducibility of these histone and DNA modification profiles (replicate variability), which appear to be of a stochastic nature but show preferences for the genomic context. The data indicate that ELF-MF exposure stabilizes active chromatin, particularly during the transition from a repressive to an active state during cell differentiation.

https://www.ncbi.nlm.nih.gov/pubmed/28266526

In conclusion, we report that ELF-MF exposure has no significant effect in a deterministic manner on the epigenetic landscapes of leukaemic and differentiating haematopoietic cells. However, our data indicate that ELF-MF exposure may influence the robustness of histone modification and DNA methylation patterning in the course of the global chromatin reorganization associated with neutrophilic differentiation. This, however, did not affect notably the overall dynamics and efficiency of granulopoiesis.

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Spontaneous magnetic alignment behaviour in free-living lizards

Diego-Rasilla FJ, Pérez-Mellado V, Pérez-Cembranos A. Spontaneous magnetic alignment behaviour in free-living lizards. Naturwissenschaften. 2017 Apr;104(3-4):13. doi: 10.1007/s00114-017-1439-7. Epub 2017 Mar 1.

Abstract

Several species of vertebrates exhibit spontaneous longitudinal body axis alignment relative to the Earth's magnetic field (i.e., magnetic alignment) while they are performing different behavioural tasks. Since magnetoreception is still not fully understood, studying magnetic alignment provides evidence for magnetoreception and broadens current knowledge of magnetic sense in animals. Furthermore, magnetic alignment widens the roles of magnetic sensitivity in animals and may contribute to shed new light on magnetoreception. In this context, spontaneous alignment in two species of lacertid lizards (Podarcis muralis and Podarcis lilfordi) during basking periods was monitored. Alignments in 255 P. muralis and 456 P. lilfordi were measured over a 5-year period. The possible influence of the sun's position (i.e., altitude and azimuth) and geomagnetic field values corresponding to the moment in which a particular lizard was observed on lizards' body axis orientation was evaluated. Both species exhibited a highly significant bimodal orientation along the north-northeast and south-southwest magnetic axis. The evidence from this study suggests that free-living lacertid lizards exhibit magnetic alignment behaviour, since their body alignments cannot be explained by an effect of the sun's position. On the contrary, lizard orientations were significantly correlated with geomagnetic field values at the time of each observation. We suggest that this behaviour might provide lizards with a constant directional reference while they are sun basking. This directional reference might improve their mental map of space to accomplish efficient escape behaviour. This study is the first to provide spontaneous magnetic alignment behaviour in free-living reptiles.

https://www.ncbi.nlm.nih.gov/pubmed/28251303

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Corporate Ties That Bind: An Examination of Corporate Manipulation and Vested Interest in Public Health. Martin J. Walker (Ed.). New York: Skyhorse Publishing. Mar 28, 2017. 24 chapters; 592 pp.

In the 21st century, corporations have worked their way into government and, as they become increasingly more powerful, arguments about their involvement with public health have become increasingly black and white. With corporations at the center of public health and environmental issues, everything chemical or technological is good, everything natural is bad; scientists who are funded by corporations are right and those who are independent are invariably wrong. There is diminishing common ground between the two opposed sides in these arguments.

Corporate Ties that Bind is a collection of essays written by influential academic scholars, activists, and epidemiologists from around the world that scrutinize the corporate reasoning, false science and trickery involving those, like in-house epidemiologists, who mediate the scientific message of organizations who attack and censure independent voices. This book addresses how the growth of corporatism is destroying liberal democracy and personal choice.

Whether addressing asbestos, radiation, PCBs, or vaccine regulation, the essays here address the dangers of trusting corporations and uncover the lengths to which corporations put profits before health.

Foreward: David O. Carpenter

Chapter 3: Lennart Hardell. A Battleground--From Phenoxyacetic Acids, Chlorphenyls and Dioxins to Mobile Phones--Cancer Risks, Greenwashing and Vested Interests

Chapter 10: Christian Blom. Escaping Electrosensitivity.

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Brief Report on the Gaps in the Knowledge about the Health Effects of the RF-EMF Exposures

Leszczynski D. Brief Report on the Gaps in the Knowledge about the Health Effects of the RF-EMF Exposures. unpublished paper. Mar 15, 2017.

https://betweenrockandhardplace.files.wordpress.com/2017/03/brief-report-on-gaps-in-the-knowledge.pdf

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Analysis of mobile phone use among young patients with brain tumors in Japan

Sato Y, Kojimahara N, Yamaguchi N. Analysis of mobile phone use among young patients with brain tumors in Japan. Bioelectromagnetics. 2017 Mar 24. doi: 10.1002/bem.22047.

Abstract

The purpose of this study was to clarify ownership and usage of mobile phones among young patients with brain tumors in Japan. The subjects of this study were patients with brain tumors diagnosed between 2006 and 2010 who were between the ages of 6 and 18 years. The target population for the analysis was 82 patients. Patients were divided into two groups: 16 patients who were mobile phone owners 1 year before diagnosis, and 66 patients who did not own mobile phones (non-owners). Using data on the mobile phone ownership rate obtained from three general-population surveys, we calculated the expected number of mobile phone owners. The three age-adjusted standardized ownership ratios were 0.83 (95% confidence interval [CI]: 0.56-1.22), 0.51 (95% CI: 0.24-1.04), and 0.75 (95% CI: 0.42-1.32). The mobile phone ownership prevalence among the young Japanese patients with brain tumors in the current study does not differ from available estimates for the general population of corresponding age. However, since the use of mobile phones among children is increasing annually, investigations into the health effects of mobile phone use among children should continue.

https://www.ncbi.nlm.nih.gov/pubmed/28342194

Note: This study has some major methodologic limitations including a small sample size. The study did not examine other sources of exposure to RF radiation (e.g., cordless phone use).

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Electronic control of gene expression and cell behaviour in Escherichia coli through redox signalling

Tschirhart T, Kim E, McKay R, Ueda H, Wu HC, Pottash AE, Zargar A, Negrete A, Shiloach J, Payne GF, Bentley WE. Electronic control of gene expression and cell behaviour in Escherichia coli through redox signalling. Nat Commun. 2017 Jan 17;8:14030. doi: 10.1038/ncomms14030.

Abstract

The ability to interconvert information between electronic and ionic modalities has transformed our ability to record and actuate biological function. Synthetic biology offers the potential to expand communication 'bandwidth' by using biomolecules and providing electrochemical access to redox-based cell signals and behaviours. While engineered cells have transmitted molecular information to electronic devices, the potential for bidirectional communication stands largely untapped. Here we present a simple electrogenetic device that uses redox biomolecules to carry electronic information to engineered bacterial cells in order to control transcription from a simple synthetic gene circuit. Electronic actuation of the native transcriptional regulator SoxR and transcription from the PsoxS promoter allows cell response that is quick, reversible and dependent on the amplitude and frequency of the imposed electronic signals. Further, induction of bacterial motility and population based cell-to-cell communication demonstrates the versatility of our approach and potential to drive intricate biological behaviours.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5247576/

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Exposure to radiofrequency radiation emitted from mobile phone jammers adversely affects the quality of human sperm

M.E. Parsanezhad, S.M.J. Mortazavi, T. Doohandeh, B. Namavar Jahromi1, H. Mozdarani, A. Zarei, M. Davari, S. Amjadi,
A. Soleimani, M. Haghani. Exposure to radiofrequency radiation emitted from mobile phone jammers adversely affects the quality of human sperm. International Journal of Radiation Research. 15(1). Jan 2017.

Abstract

Background: The health effect of rapidly increasing everyday exposure of humans to radiofrequency radiation is a major global concern. Mobile phone jammers prevent the mobile phones from receiving signals from base stations by interfering with authorized mobile carriers' services. In spite of the fact that mobile jammer use is illegal, they are occasionally used in offices,
shrines, conference rooms and cinemas. The purpose of this study was to investigate the biological effects of short term exposure of human sperm to radiofrequency radiation emitted from a commercial mobile phone jammer.

Materials and Methods: Fresh semen samples were obtained by masturbation from 50 healthy donors who had referred with their wives to Infertility Treatment Center at the Mother and Child Hospital, Shiraz University of Medical Sciences. Female problem was diagnosed as the reason for infertility in these couples. The semen sample of each participant was divided into 4 aliquots. The first aliquot was subjected to swim-up and exposed to jammer radiation. The second aliquot was not subjected to swimup but was exposed to jammer radiation. The third and fourth aliquots were not exposed to jammer radiation but only the 3rd aliquot was subjected to swim-up.

Results: Semen samples exposed to radiofrequency radiation showed a significant decrease in sperm motility and increase in DNA fragmentation.

Conclusion: Electromagnetic radiation in radiofrequency range emitted from mobile phone jammers may lead to decreased motility and increased DNA fragmentation in human semen. It can be concluded that mobile phone jamming might exert adverse reproductive health effects.

http://bit.ly/2nyVhck

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Pulsed or continuous EMF induce apoptotic signaling pathway in mouse spermatogenic cells in vitro and may affect male fertility

Solek P, Majchrowicz L, Bloniarz D, Krotoszynska E, Koziorowski M. Pulsed or continuous electromagnetic field induce p53/p21-mediated apoptotic signaling pathway in mouse spermatogenic cells in vitro and thus may affect male fertility. Toxicology. 2017 Mar 16. pii: S0300-483X(17)30092-6. doi: 10.1016/j.tox.2017.03.015. [Epub ahead of print]

Abstract

The impact of electromagnetic field (EMF) on the human health and surrounding environment is a common topic investigated over the years. A significant increase in the electromagnetic field concentration arouses public concern about the long-term effects of EMF on living organisms associated with many aspects. In the present study, we investigated the effects of pulsed and continuous electromagnetic field (PEMF/CEMF) on mouse spermatogenic cell lines (GC-1 spg and GC-2 spd) in terms of cellular and biochemical features in vitro. We evaluated the effect of EMF on mitochondrial metabolism, morphology, proliferation rate, viability, cell cycle progression, oxidative stress balance and regulatory proteins. Our results strongly suggest that EMF induces oxidative and nitrosative stress-mediated DNA damage, resulting in p53/p21-dependent cell cycle arrest and apoptosis. Therefore, spermatogenic cells due to the lack of antioxidant enzymes undergo oxidative and nitrosative stress-mediated cytotoxic and genotoxic events, which contribute to infertility by reduction in healthy sperm cells pool. In conclusion, electromagnetic field present in surrounding environment impairs male fertility by inducing p53/p21-mediated cell cycle arrest and apoptosis.

https://www.ncbi.nlm.nih.gov/pubmed/28323003

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Exposing the G-quadruplex to electric fields: the role played by telomeres in the propagation of DNA errors

Cerón-Carrasco JP, Jacquemin D. Exposing the G-quadruplex to electric fields: the role played by telomeres in the propagation of DNA errors. Phys Chem Chem Phys. 2017 Mar 20. doi: 10.1039/c7cp01034f. [Epub ahead of print]

Abstract

To protect their core machinery from the attack of exogenous agents, cells locate DNA in their nucleus. Nevertheless, some reactive chemical species and physical agents might reach DNA and alter its natural double helix structure. For instance, pulsed electric fields can be used to selectively rewrite the stored genetic information. However, for such modification to be effective, one needs, as a prerequisite, that the replication mechanism is not stopped by the field, so that the changes propagate over the following generations. Here, we use theoretical calculations to demonstrate that while such fields lead to permanent noncanonical Watson-Crick guanine-cytosine (GC) base pairs, the G-quadruplex motifs present in telomeres can more effectively preserve their native forms. Indeed, G-quadruplexes "resist" the perturbations induced by field strengths going up to 60 × 10-4 a.u., a figure constituting the upper limit before the complete destruction of the double helix architecture. Since the induced errors in the DNA base pairs are not transcribed into the telomeres, electric fields can indeed be used as a source of selective mutations in the genetic code.

https://www.ncbi.nlm.nih.gov/pubmed/28317975

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Effect of 1.8 GHz RF EMR on novel object associative recognition memory in mice

Wang K, Lu JM, Xing ZH, Zhao QR, Hu LQ, Xue L, Zhang J, Mei YA. Effect of 1.8 GHz radiofrequency electromagnetic radiation on novel object associative recognition memory in mice. Sci Rep. 2017 Mar 17;7:44521. doi: 10.1038/srep44521.

Abstract

Mounting evidence suggests that exposure to radiofrequency electromagnetic radiation (RF-EMR) can influence learning and memory in rodents. In this study, we examined the effects of single exposure to 1.8 GHz RF-EMR for 30 min on subsequent recognition memory in mice, using the novel object recognition task (NORT). RF-EMR exposure at an intensity of >2.2 W/kg specific absorption rate (SAR) power density induced a significant density-dependent increase in NORT index with no corresponding changes in spontaneous locomotor activity. RF-EMR exposure increased dendritic-spine density and length in hippocampal and prefrontal cortical neurons, as shown by Golgi staining. Whole-cell recordings in acute hippocampal and medial prefrontal cortical slices showed that RF-EMR exposure significantly altered the resting membrane potential and action potential frequency, and reduced the action potential half-width, threshold, and onset delay in pyramidal neurons. These results demonstrate that exposure to 1.8 GHz RF-EMR for 30 min can significantly increase recognition memory in mice, and can change dendritic-spine morphology and neuronal excitability in the hippocampus and prefrontal cortex. The SAR in this study (3.3 W/kg) was outside the range encountered in normal daily life, and its relevance as a potential therapeutic approach for disorders associated with recognition memory deficits remains to be clarified.

https://www.ncbi.nlm.nih.gov/pubmed/28303965

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Mitochondrial DNA damage and oxidative damage in HL-60 cells exposed to 900MHz RF

Sun Y, Zong L, Gao Z, Zhu S, Tong J, Cao Y. Mitochondrial DNA damage and oxidative damage in HL-60 cells exposed to 900MHz radiofrequency fields. Mutat Res. 2017 Mar 7;797-799:7-14. doi: 10.1016/j.mrfmmm.2017.03.001.

Abstract

HL-60 cells, derived from human promyelocytic leukemia, were exposed to continuous wave 900MHz radiofrequency fields (RF) at 120μW/cm2 power intensity for 4h/day for 5 consecutive days to examine whether such exposure is capable damaging the mitochondrial DNA (mtDNA) mediated through the production of reactive oxygen species (ROS). In addition, the effect of RF exposure was examined on 8-hydroxy-2'-dexoyguanosine (8-OHdG) which is a biomarker for oxidative damage and on the mitochondrial synthesis of adenosine triphosphate (ATP) which is the energy required for cellular functions. The results indicated a significant increase in ROS and significant decreases in mitochondrial transcription factor A, mtDNA polymerase gamma, mtDNA transcripts and mtDNA copy number in RF-exposed cells compared with those in sham-exposed control cells. In addition, there was a significant increase in 8-OHdG and a significant decrease in ATP in RF-exposed cells. The response in positive control cells exposed to gamma radiation (GR, which is also known to induce ROS) was similar to those in RF-exposed cells. Thus, the overall data indicated that RF exposure was capable of inducing mtDNA damage mediated through ROS pathway which also induced oxidative damage. Prior-treatment of RF- and GR-exposed the cells with melatonin, a well-known free radical scavenger, reversed the effects observed in RF-exposed cells.

https://www.ncbi.nlm.nih.gov/pubmed/28340409

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Personal medical electronic devices and walk-through metal detector security systems: assessing EMI effects

Guag J, Addissie B, Witters D. Personal medical electronic devices and walk-through metal detector security systems: assessing electromagnetic interference effects. Biomed Eng Online. 2017 Mar 20;16(1):33. doi: 10.1186/s12938-017-0328-9.

Abstract

BACKGROUND: There have been concerns that Electromagnetic security systems such as walk-through metal detectors (WTMDs) can potentially cause electromagnetic interference (EMI) in certain active medical devices including implantable cardiac pacemakers and implantable neurostimulators. Incidents of EMI between WTMDs and active medical devices also known as personal medical electronic devices (PMED) continue to be reported. This paper reports on emission measurements of sample WTMDs and testing of 20 PMEDs in a WTMD simulation system.

METHODS: Magnetic fields from sample WTMD systems were characterized for emissions and exposure of certain PMEDs. A WTMD simulator system designed and evaluated by FDA in previous studies was used to mimic the PMED exposures to the waveform from sample WTMDs. The simulation system allows for controlled PMED exposure enabling careful study with adjustable magnetic field strengths and exposure duration, and provides flexibility for PMED exposure at elevated levels in order to study EMI effects on the PMED. The PMED samples consisted of six implantable cardiac pacemakers, six implantable cardioverter defibrillators (ICD), five implantable neurostimulators, and three insulin pumps. Each PMED was exposed in the simulator to the sample WTMD waveforms using methods based on appropriate consensus test standards for each of the device type.

RESULTS: Testing the sample PMEDs using the WTMD simulator revealed EMI effects on two implantable pacemakers and one implantable neurostimulator for exposure field strength comparable to actual WTMD field strength. The observed effects were transient and the PMEDs returned to pre-exposure operation within a few seconds after removal from the simulated WTMD exposure fields. No EMI was observed for the sample ICDs or insulin pumps.

CONCLUSION: The findings are consistent with earlier studies where certain sample PMEDs exhibited EMI effects. Clinical implications were not addressed in this study. Additional studies are needed to evaluate potential PMED EMI susceptibilities over a broader range of security systems.

https://www.ncbi.nlm.nih.gov/pubmed/28320451

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Exposure to EMF from smart utility meters in Great Britain; part I) laboratory measurements

Peyman A, Addison D, Mee T, Goiceanu C, Maslanyj M, Mann S. Exposure to electromagnetic fields from smart utility meters in GB; part I) laboratory measurements. Bioelectromagnetics. 2017 Mar 21. doi: 10.1002/bem.22044. [Epub ahead of print]

Abstract

Laboratory measurements of electric fields have been carried out around examples of smart meter devices used in Great Britain. The aim was to quantify exposure of people to radiofrequency signals emitted from smart meter devices operating at 2.4 GHz, and then to compare this with international (ICNIRP) health-related guidelines and with exposures from other telecommunication sources such as mobile phones and Wi-Fi devices. The angular distribution of the electric fields from a sample of 39 smart meter devices was measured in a controlled laboratory environment. The angular direction where the power density was greatest was

identified and the equivalent isotropically radiated power was determined in the same direction. Finally, measurements were carried out as a function of distance at the angles where maximum field strengths were recorded around each device. The maximum equivalent power density measured during transmission around smart meter devices at 0.5 m and beyond was 15 mWm^{-2} , with an estimation of maximum duty factor of only 1%. One outlier device had a maximum power density of 91 mWm^{-2} . All power density measurements reported in this study were well below the 10 W m^{-2}

https://www.ncbi.nlm.nih.gov/pubmed/28324620

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The effect of Wi-Fi EMF on object recognition tasks in male rats

Hassanshahi A, Shafeie SA, Fatemi I, Hassanshahi E, Allahtavakoli M, Shabani M, Roohbakhsh A, Shamsizadeh A. The effect of Wi-Fi electromagnetic waves in unimodal and multimodal object recognition tasks in male rats.Neurol Sci. 2017 Mar 22. doi: 10.1007/s10072-017-2920-y. [Epub ahead of print]

Abstract

Wireless internet (Wi-Fi) electromagnetic waves (2.45 GHz) have widespread usage almost everywhere, especially in our homes. Considering the recent reports about some hazardous effects of Wi-Fi signals on the nervous system, this study aimed to investigate the effect of 2.4 GHz Wi-Fi radiation on multisensory integration in rats. This experimental study was done on 80 male Wistar rats that were allocated into exposure and sham groups. Wi-Fi exposure to 2.4 GHz microwaves [in Service Set Identifier mode (23.6 dBm and 3% for power and duty cycle, respectively)] was done for 30 days (12 h/day). Cross-modal visual-tactile object recognition (CMOR) task was performed by four variations of spontaneous object recognition (SOR) test including standard SOR, tactile SOR, visual SOR, and CMOR tests. A discrimination ratio was calculated to assess the preference of animal to the novel object. The expression levels of M1 and GAT1 mRNA in the hippocampus were assessed by quantitative real-time RT-PCR. Results demonstrated that rats in Wi-Fi exposure groups could not discriminate significantly between the novel and familiar objects in any of the standard SOR, tactile SOR, visual SOR, and CMOR tests. The expression of M1 receptors increased following Wi-Fi exposure. In conclusion, results of this study showed that chronic exposure to Wi-Fi electromagnetic waves might impair both unimodal and cross-modal encoding of information.

https://www.ncbi.nlm.nih.gov/pubmed/28332042

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Assessment of Public Exposure From WLANs in the West Bank-Palestine

Lahham A, Sharabati A, ALMasri H. Assessment of Public Exposure From WLANs in the West Bank-Palestine. Radiat Prot Dosimetry. 2017 Mar 3:1-5. doi: 10.1093/rpd/ncx028.

Abstract

A total of 271 measurements were conducted at 69 different sites including homes, hospitals, educational institutions and other public places to assess the exposure to radiofrequency emission from wireless local area networks (WLANs). Measurements were conducted at different distances from 40 to 10 m from the access points (APs) in real life conditions using Narda SRM-3000 selective radiation meter. Three measurements modes were considered at 1 m distance from the AP which are transmit mode, idle mode, and from the client card (laptop computer). All measurements were conducted indoor in the West Bank environment. Power density levels from WLAN systems were found to vary from 0.001 to ~1.9 μW cm-2 with an average of 0.12 μW cm-2. Maximum value found was in university environment, while the minimum was found in schools. For one measurement case where the AP was 20 cm far while transmitting large files, the measured power density

reached a value of ~4.5 μW cm-2. This value is however 221 times below the general public exposure limit recommended by the International Commission on Non-Ionizing Radiation Protection, which was not exceeded in any case. Measurements of power density at 1 m around the laptop resulted in less exposure than the AP in both transmit and idle modes as well. Specific absorption rate for the head of the laptop user was estimated and found to vary from 0.1 to 2 mW/kg. The frequency distribution of measured power densities follows a log-normal distribution which is generally typical in the assessment of exposure resulting from sources of radiofrequency emissions.

https://www.ncbi.nlm.nih.gov/pubmed/28338865

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Effect of acute millimeter wave exposure on dopamine metabolism of NGF-treated PC12 cells

Haas AJ, Le Page Y, Zhadobov M, Sauleau R, Dréan YL, Saligaut C. Effect of acute millimeter wave exposure on dopamine metabolism of NGF-treated PC12 cells. J Radiat Res. 2017 Feb 24:1-7. doi: 10.1093/jrr/rrx004.

Abstract

Several forthcoming wireless telecommunication systems will use electromagnetic frequencies at millimeter waves (MMWs), and technologies developed around the 60-GHz band will soon know a widespread distribution. Free nerve endings within the skin have been suggested to be the targets of MMW therapy which has been used in the former Soviet Union. So far, no studies have assessed the impact of MMW exposure on neuronal metabolism. Here, we investigated the effects of a 24-h MMW exposure at 60.4 GHz, with an incident power density (IPD) of 5 mW/cm², on the dopaminergic turnover of NGF-treated PC12 cells. After MMW exposure, both intracellular and extracellular contents of dopamine (DA) and 3,4-dihydroxyphenylacetic acid (DOPAC) were studied using high performance liquid chromatography. Impact of exposure on the dopamine transporter (DAT) expression was also assessed by immunocytochemistry. We analyzed the dopamine turnover by assessing the ratio of DOPAC to DA, and measuring DOPAC accumulation in the medium. Neither dopamine turnover nor DAT protein expression level were impacted by MMW exposure. However, extracellular accumulation of DOPAC was found to be slightly increased, but not significantly. This result was related to the thermal effect, and overall, no evidence of non-thermal effects of MMW exposure were observed on dopamine metabolism.

https://www.ncbi.nlm.nih.gov/pubmed/28339776

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SAR Simulations & Safety

Fiedler TM, Ladd ME, Bitz AK. SAR Simulations & Safety. Neuroimage. 2017 Mar 20. pii: S1053-8119(17)30243-4. doi: 10.1016/j.neuroimage.2017.03.035.

Abstract

At ultra-high fields, the assessment of radiofrequency (RF) safety presents several new challenges compared to low-field systems. Multi-channel RF transmit coils in combination with parallel transmit techniques produce time-dependent and spatially varying power loss densities in the tissue. Further, in ultra-high-field systems, localized field effects can be more pronounced due to a transition from the quasistationary to the electromagnetic field regime. Consequently, local information on the RF field is required for reliable RF safety assessment as well as for monitoring of RF exposure during MR examinations. Numerical RF and thermal simulations for realistic exposure scenarios with anatomical body models are currently the only practical way to obtain the requisite local information on magnetic and electric field distributions as well as tissue temperature. In this article, safety regulations and the fundamental characteristics of RF field distributions in ultra-high-field

systems are reviewed. Numerical methods for computation of RF fields as well as typical requirements for the analysis of realistic multi-channel RF exposure scenarios including anatomical body models are highlighted. In recent years, computation of the local tissue temperature has become of increasing interest, since a more accurate safety assessment is expected because temperature is directly related to tissue damage. Regarding thermal simulation, bio-heat transfer models and approaches for taking into account the physiological response of the human body to RF exposure are discussed. In addition, suitable methods are presented to validate calculated RF and thermal results with measurements. Finally, the concept of generalized simulation-based specific absorption rate (SAR) matrix models is discussed. These models can be incorporated into local SAR monitoring in multi-channel MR systems and allow the design of RF pulses under constraints for local SAR.

https://www.ncbi.nlm.nih.gov/pubmed/28336426

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Effect of adverse environmental conditions & protective clothing on temperature rise in a human exposed to RF EMF

Moore SM, McIntosh RL, Iskra S, Lajevardipour A, Wood AW. Effect of adverse environmental conditions and protective clothing on temperature rise in a human body exposed to radiofrequency electromagnetic fields. Bioelectromagnetics. 2017 Mar 24. doi: 10.1002/bem.22048.

Abstract

This study considers the computationally determined thermal profile of a finely discretized, heterogeneous human body model, simulating a radiofrequency electromagnetic field (RF-EMF) worker wearing protective clothing subject to RF-EMF exposure, and subject to various environmental conditions including high ambient temperature and high humidity, with full thermoregulatory mechanisms in place. How the human body responds in various scenarios was investigated, and the information was used to consider safety limits in current international RF-EMF safety guidelines and standards. It was found that different environmental conditions had minimal impact on the magnitude of the thermal response due to RF-EMF exposure, and that the current safety factor of 10 applied in international RF-EMF safety guidelines and standards for RF-EMF workers is generally conservative, though it is only narrowly so when workers are subjected to the most adverse environmental conditions.

https://www.ncbi.nlm.nih.gov/pubmed/28342187

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"These Power Lines Make Me Ill": A Typology of Residents' Health Responses to a New High-Voltage Power Line

Porsius JT, Claassen L, Woudenberg F, Smid T, Timmermans DR."These Power Lines Make Me Ill": A Typology of Residents' Health Responses to a New High-Voltage Power Line. Risk Anal. 2017 Mar 17. doi: 10.1111/risa.12786. [Epub ahead of print]

Abstract

Little attention has been devoted to the potential diversity in residents' health responses when exposed to an uncertain environmental health risk. The present study explores whether subgroups of residents respond differently to a new high-voltage power line (HVPL) being put into operation. We used a quasi-experimental prospective field study design with two pretests during the construction of a new HVPL, and two posttests after it was put into operation. Residents living nearby (0-300 m, n = 229) filled out questionnaires about their health and their perception of the environment. We applied latent class growth models to investigate heterogeneity in the belief that health complaints were caused by a power line. Classes were compared on a wide range of variables relating to negative-oriented personality traits, perceived physical and mental health, and perceptions of the environment. We identified five distinct classes of residents, of which the largest (49%) could be described as emotionally stable and healthy with weak responses to the introduction of a new power line. A considerable minority (9%) responded more strongly to the new line being activated. Residents in this class had heard more about the health effects of power lines beforehand, were more aware of the activation of the new line, and reported a decrease in perceived health afterwards. Based on our findings we can conclude that there is a considerable heterogeneity in health responses to a new HVPL. Health risk perceptions appear to play an important role in this typology, which has implications for risk management.

https://www.ncbi.nlm.nih.gov/pubmed/28314060

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Measuring Occupational Exposure to Extremely Low-Frequency Electric Fields at 220 kV Substations

Pirkkalainen H, Heiskanen T, Tonteri J, Elovaara J, Mika P, Korpinen L.Measuring Occupational Exposure to Extremely Low-Frequency Electric Fields at 220 kV Substations. Radiat Prot Dosimetry. 2017 Mar 3:1-4. doi: 10.1093/rpd/ncx023.

Abstract

Earlier studies conducted at 400 and 110 kV substations in Finland have shown that the occupational exposure to electric fields can exceed the action levels (ALs) set by Directive 2013/35/EU. This is a case study investigating the level of occupational exposure experienced by workers at 220 kV substations in order to determine if the actions levels are being exceeded. The measurements were conducted at two old 220 kV substations in Finland. The higher AL of 20 kV m-1 was exceeded at both substations.

https://www.ncbi.nlm.nih.gov/pubmed/28338889

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Effects of power-frequency MF on cardiomyocytes differentiated from human induced pluripotent stem cells

Takahashi M1, Saito A, Jimbo Y, Nakasono S. Evaluation of the effects of power-frequency magnetic fields on the electrical activity of cardiomyocytes differentiated from human induced pluripotent stem cells. J Toxicol Sci. 2017;42(2):223-231. doi: 10.2131/jts.42.223.

Abstract

Although cardiac activity is known to differ between species in many respects, most evaluations of the cardiac effects of low-frequency electric and magnetic fields, which have a stimulant effect on electrically activated cells, have been performed in non-human experimental animals and cells, and the effects in humans have been assessed using theoretical models. In recent years, it has been verified that human cardiomyocytes differentiated from human induced pluripotent stem cells (hiPS-CM) are useful for evaluating human responses to various cardioactive compounds. In this study, we applied hiPSCMs for the first time to evaluate the human cardiac effects of power-frequency magnetic fields (MFs). After preparation of hiPS-CMs, we subjected a hiPS-CM monolayer formed on a multi-electrode array to short-term exposure to a 50 Hz MF at 400 mT with recording of the extracellular field potentials. The field potential duration of the hiPS-CMs did not differ significantly pre- and post-exposure, indicating that under these conditions, exposure to a 50 Hz MF at 400 mT does not affect the electrical activity of hiPSCMs.

https://www.ncbi.nlm.nih.gov/pubmed/28321048

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EMF Seems to Not Influence Transcription via CTCT Motif in Three Plant Promoters

Sztafrowski D, Aksamit-Stachurska A, Kostyn K, Mackiewicz P, Łukaszewicz M. Electromagnetic Field Seems to Not Influence Transcription via CTCT Motif in Three Plant Promoters. Front Plant Sci. 2017 Mar 7;8:178. doi: 10.3389/fpls.2017.00178.

Abstract

It was proposed that magnetic fields (MFs) can influence gene transcription via CTCT motif located in human HSP70 promoter. To check the universality of this mechanism, we estimated the potential role of this motif on plant gene transcription in response to MFs using both bioinformatics and experimental studies. We searched potential promoter sequences (1000 bp upstream) in the potato Solanum tuberosum and thale cress Arabidopsis thaliana genomes for the CTCT sequence. The motif was found, on average, 3.6 and 4.3 times per promoter (148,487 and 134,361 motifs in total) in these two species, respectively; however, the CTCT sequences were not randomly distributed in the promoter regions but were preferentially located near the transcription initiation site and were closely packed. The closer these CTCT sequences to the transcription initiation site, the smaller distance between them in both plants. One can assume that genes with many CTCT motifs in their promoter regions can be potentially regulated by MFs. To check this assumption, we tested the influence of MFs on gene expression in a transgenic potato with three promoters (16R, 20R, and 5UGT) containing from 3 to 12 CTCT sequences and starting expression of β-glucuronidase as a reported gene. The potatoes were exposed to a 50 Hz 60-70 A/m MF for 30 min and the reporter gene activity was measured for up to 24 h. Although other factors induced the reporter gene activity, the MF did not. It implies the CTCT motif does not mediate in response to MF in the tested plant promoters.

Open Access Paper: https://www.ncbi.nlm.nih.gov/pubmed/28326086

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ELF exposure from mobile and cordless phones for the epidemiological MOBI-Kids study

Calderón C, Ichikawa H, Taki M, Wake K, Addison D, Mee T, Maslanyj M, Kromhout H, Lee AK, Sim MR, Wiart J, Cardis E.
ELF exposure from mobile and cordless phones for the epidemiological MOBI-Kids study. Environ Int. 2017 Jan 23. pii: S0160-4120(17)30047-8. doi: 10.1016/j.envint.2017.01.005. [Epub ahead of print]

Abstract

This paper describes measurements and computational modelling carried out in the MOBI-Kids case-control study to assess the extremely low frequency (ELF) exposure of the brain from use of mobile and cordless phones. Four different communication systems were investigated: Global System for Mobile (GSM), Universal Mobile Telecommunications System (UMTS), Digital Enhanced Cordless Telecommunications (DECT) and Wi-Fi Voice over Internet Protocol (VoIP). The magnetic fields produced by the phones during transmission were measured under controlled laboratory conditions, and an equivalent loop was fitted to the data to produce three-dimensional extrapolations of the field. Computational modelling was then used to calculate the induced current density and electric field strength in the brain resulting from exposure to these magnetic fields. Human voxel phantoms of four different ages were used: 8, 11, 14 and adult. The results indicate that the current densities induced in the brain during DECT calls are likely to be an order of magnitude lower than those generated during GSM calls but over twice that during UMTS calls. The average current density during Wi-Fi VoIP calls was found to be lower than for UMTS by 30%, but the variability across the samples investigated was high. Spectral contributions were important to consider in relation to current density, particularly for DECT phones. This study suggests that the spatial distribution of the ELF induced current densities in brain tissues is determined by the physical characteristics of the phone (in particular battery position) while the amplitude is

mainly dependent on communication system, thus providing a feasible basis for assessing ELF exposure in the epidemiological study. The number of phantoms was not large enough to provide definitive evidence of an increase of induced current density with age, but the data that are available suggest that, if present, the effect is likely to be very small.

https://www.ncbi.nlm.nih.gov/pubmed/28126406

Also see: http://www.saferemr.com/2013/05/mobi-kids-childhood-brain-tumor-risk.html

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Corrigendum to "Inferring the 1985-2014 impact of mobile phone use on selected brain cancer subtypes using Bayesian structural time series and synthetic controls"

de Vocht F. Corrigendum to "Inferring the 1985-2014 impact of mobile phone use on selected brain cancer subtypes using Bayesian structural time series and synthetic controls" [Environ. Int. (2016), 97, 100-107]. Environ Int. 2017 Jan 25. pii: S0160-4120(17)30124-1. doi: 10.1016/j.envint.2017.01.015. [Epub ahead of print]

https://www.ncbi.nlm.nih.gov/pubmed/28131518

Also see: Changing Mix of Brain Tumors in U.K. http://microwavenews.com/short-takes-archive/changing-mix-uk-bts

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Effects of RF-EMF Exposure from GSM Mobile Phones on Proliferation Rate of Human Adipose-derived Stem Cells: An In-vitro Study

Shahbazi-Gahrouei D, Hashemi-Beni B, Ahmadi Z. Effects of RF-EMF Exposure from GSM Mobile Phones on Proliferation Rate of Human Adipose-derived Stem Cells: An In-vitro Study. J Biomed Phys Eng. 2016 Dec 1;6(4):243-252. eCollection 2016.

Abstract

BACKGROUND: As the use of mobile phones is increasing, public concern about the harmful effects of radiation emitted by these devices is also growing. In addition, protection questions and biological effects are among growing concerns which have remained largely unanswered. Stem cells are useful models to assess the effects of radiofrequency electromagnetic fields (RF-EMF) on other cell lines. Stem cells are undifferentiated biological cells that can differentiate into specialized cells. Adipose tissue represents an abundant and accessible source of adult stem cells. The aim of this study is to investigate the effects of GSM 900 MHz on growth and proliferation of mesenchymal stem cells derived from adipose tissue within the specific distance and intensity.

MATERIALS AND METHODS: ADSCs were exposed to GSM mobile phones 900 MHz with intensity of 354.6 µW/cm2 square waves (217 Hz pulse frequency, 50% duty cycle), during different exposure times ranging from 6 to 21 min/day for 5 days at 20 cm distance from the antenna. MTT assay was used to determine the growth and metabolism of cells and trypan blue test was also done for cell viability. Statistical analyses were carried out using analysis of one way ANOVA. $P<0.05$ was considered to be statistically significant.

RESULTS: The proliferation rates of human ADSCs in all exposure groups were significantly lower than control groups ($P<0.05$) except in the group of 6 minutes/day which did not show any significant difference with control groups.

CONCLUSION: The results show that 900 MHz RF signal radiation from antenna can reduce cell viability and

proliferation rates of human ADSCs regarding the duration of exposure.

https://www.ncbi.nlm.nih.gov/pubmed/28144594

Excerpts

Electromagnetic radiation sources such as cordless phones, telecommunications stations, high-voltage lines, Wi-Fi, wireless, radio and television antenna could be one of the main reasons for human abnormalities if protection protocol recommendations for safety are not used [4]. Since mobile phone cannot be removed from human lives, to protect from the probable effects of radiations, all mobile operators according to CRA (Community Reinvestment Act) agreements with radio communication, must obtain a license to work with radio-waves and microwaves from the radiation protection for installation and the operation of mobile phone equipment. The most of literature and findings of researchers [3-7, 25- 27] agree on the protection methods against irradiation of EMFs. They believe that using some protection methods are recommended like reducing the length of calls, talking to phone in case of emergency, keeping the phone away from vital organs, using special anti-radiation coatings for mobile phones and banning the use of cell phones during pregnancy and childhood, the least presence in environments with high levels of microwave in main stations, consumption of antioxidants such as vitamins A, C, E and green tea in daily diet. Of course, more studies are needed to cover all biological effects of EMFs on living systems.

Conclusion Based on the findings of the present study, it is believed that GSM mobile phone 900 MHz with intensity of 354.6 µW/cm2 five times exposure at 20cm distance may inhibit the proliferation rates of human ADSCs, but no mechanism has been proposed to explain the effects of this radiation. However, further studies for assessing RF-EMF with other intensities, frequencies and different exposure times on stem cells are suggested.

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The Fundamental Reasons Why Laptop Computers should not be Used on Your Lap

S A R Mortazavi, S Taeb, S M J Mortazavi, S Zarei, M Haghani, P Habibzadeh, M B Shojaei-fard. The Fundamental Reasons Why Laptop Computers should not be Used on Your Lap. J Biomed Phys Eng. 2016 Dec 1;6(4):279-284. eCollection 2016.

Abstract

As a tendency to use new technologies, gadgets such as laptop computers are becoming more popular among students, teachers, businessmen and office workers. Today laptops are a great tool for education and learning, work and personal multimedia. Millions of men, especially those in the reproductive age, are frequently using their laptop computers on the lap (thigh). Over the past several years, our lab has focused on the health effects of exposure to different sources of electromagnetic fields such as cellular phones, mobile base stations, mobile phone jammers, laptop computers, radars, dentistry cavitrons and Magnetic Resonance Imaging (MRI). Our own studies as well as the studies performed by other researchers indicate that using laptop computers on the lap adversely affects the male reproductive health. When it is placed on the lap, not only the heat from a laptop computer can warm men's scrotums, the electromagnetic fields generated by laptop's internal electronic circuits as well as the Wi-Fi Radiofrequency radiation hazards (in a Wi-Fi connected laptop) may decrease sperm quality. Furthermore, due to poor working posture, laptops should not be used on the lap for long hours.

https://www.ncbi.nlm.nih.gov/pubmed/28144597

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Characterizing and Mapping of Exposure to Radiofrequency Electromagnetic Fields (20-3,000 Mhz) in Chengdu, China

Zhu G, Gong X, Luo R. Characterizing and Mapping of Exposure to Radiofrequency Electromagnetic Fields (20-3,000 Mhz) in Chengdu, China. Health Phys. 2017 Mar;112(3):266-275. doi: 10.1097/HP.0000000000000599.

Abstract

With radiofrequency exposure caused by electronic applications increasing, some members of the public are worrying about potential health risks. In this paper, methods of performing large-scale radiofrequency exposure evaluation are described. All studied sites were divided into three categories: commercial-area, residential-urban, and residential-rural. Then a series of site investigations were conducted on a car-mounted system in the years 2014 and 2015, aiming to characterize electric field exposure from 12 different radiofrequency sources. The results indicate that the studied environment is safe as indicated by exposure below guidelines and standards. The highest exposure measured in the 2 y of monitoring was from an FM source, 316.23 mV m. Telecommunication sources dominate exposure, contributing the most power density (65-90%). Meanwhile, intergroup differences are discussed and summarized. The spatial distributions of FM and GSM1800 exposure are demonstrated on a map. This study describes an approach for the assessment of the spatiotemporal pattern of radiofrequency exposures in Chengdu and facilitates the identification of any sources causing exposure above relevant guidelines and standards.

https://www.ncbi.nlm.nih.gov/pubmed/28121727

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The effects of human height and mass on the calculated induced electric fields at 50 Hz for comparison with the EMF Directive 2013/35/EU

Findlay RP. The effects of human height and mass on the calculated induced electric fields at 50 Hz for comparison with the EMF Directive 2013/35/EU.J Radiol Prot. 2017 Jan 24;37(1):201-213. doi: 10.1088/1361-6498/37/1/201. [Epub ahead of print]

Abstract

A worker's height and mass can significantly affect the way in which incident low frequency electric and magnetic fields are absorbed in the body. To investigate this, several anatomically realistic human models were produced for heights between 1.56 and 1.96 m and masses between 33 and 113 kg. The human models were derived from the MAXWEL surface-based phantom, the model previously used in the EMF Directive 2013/35/EU Practical Guide to demonstrate how induced electric fields in the body are calculated. Computer simulations were carried out to calculate the low frequency EMF directive exposure limit value (ELV) quantities, i.e. the induced electric fields, in these human model variations from exposure to external 50 Hz magnetic and electric fields. The computational work showed that simple relationships relating the human model's height/weight with the induced electric fields in tissue types such as bone, fat, muscle, brain, spinal cord and retina could be developed. Calculations of parameters that affected absorption and fields required to produce the EMF Directive ELVs were carried out and compared with the action levels (ALs). It was found that the ALs generally provided a conservative estimate of the ELVs for the various human models and exposure situations studied.

https://www.ncbi.nlm.nih.gov/pubmed/28118155

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Risk agents related to work and amyotrophic lateral sclerosis: An occupational medicine focus

Garzillo EM, Miraglia N, Pedata P, Feola D, Lamberti M. Risk agents related to work and amyotrophic lateral sclerosis: An occupational medicine focus. Int J Occup Med Environ Health. 2016;29(3):355-67. doi: 10.13075/ijomeh.1896.00368.

Abstract

Amyotrophic lateral sclerosis (ALS) is a neurodegenerative disease characterized by progressive muscular paralysis reflecting degeneration of motor neurons. In recent years, in addition to several studies about genetic mechanisms leading to motor neurons damage, various epigenetic theories have been developed, involving the study of the patients' work and lifestyle. The work aims at focusing the role of occupational exposure related to ALS by literature data analysis. Articles, selected on the basis of keywords, year of publication and topics, are related to occupational exposure, suggesting an impact on ALS onset. The literature review shows that there are still a lot of biases in the studies design, which actually do not allow to draw unequivocal conclusions.

https://www.ncbi.nlm.nih.gov/pubmed/26988875

Excerpt

Exposure to electromagnetic fields has been studied in epidemiological [62–66], observational [67] and laboratory works [68]. A recent meta-analysis suggests a slightly but significantly increased risk of ALS among workers exposed to an extremely low frequency electromagnetic field (ELF-EMF), but does not deny the possibility of bias in the data analysis [69]. However, in the case of electromagnetic fields, there are many problems: at present, no apparent correlation between the exposure assessment and the observed associations is possible. In order to better assess exogenous risk factors of ALS, a job exposure matrix (JEM) may have to be used, with a detailed exposure index to electric fields and magnetic fields [70].

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Rapid and Delayed Effects of Pulsed Radiofrequency on Neuropathic Pain: Electrophysiological, Molecular, and Behavioral Evidence Supporting Long-Term Depression

Huang RY, Liao CC, Tsai SY, Yen CT, Lin CW, Chen TC, Lin WT, Chang CH, Wen YR.Rapid and Delayed Effects of Pulsed Radiofrequency on Neuropathic Pain: Electrophysiological, Molecular, and Behavioral Evidence Supporting Long-Term Depression. Pain Physician. 2017 Feb;20(2):E269-E283.

Abstract

BACKGROUND: Pulsed radiofrequency (PRF) has been widely employed for ameliorating clinical neuropathic pain. How PRF alters electrophysiological transmission and modulates biomolecular functions in neural tissues has yet to be clarified. We previously demonstrated that an early application of low-voltage bipolar PRF adjacent to the dorsal root ganglion (DRG) reduced acute neuropathic pain in animals. By contrast, the present study investigated how PRF alters postsynaptic sensitization to produce early and delayed effects on neuropathic pain.

OBJECTIVES: Our objective was to test the hypothesis that a 5-minute session of PRF could rapidly produce selective long-term depression (LTD) on C-fiber-mediated spinal sensitization and sustain the effect through the long-lasting inhibition of injury-induced ERK-MAPK activation. This may explain the prolonged analgesic effect of PRF on chronic neuropathic pain.

STUDY DESIGN: Experiments were conducted on both normal rats and neuropathic pain rats that received spinal nerve ligation (SNL) 8 days prior.

SETTING: An animal laboratory in a medical center of a university in Taiwan.

METHODS: We first compared changes in field potentials in the L5 superficial spinal dorsal horn (SDH) that were evoked by conditioning electrical stimuli in the sciatic nerve in male adult rats before (as the baseline) and after PRF stimulation for at least 2 hours. Bipolar PRF was applied adjacent to the L5 DRG at an intensity of 5 V for 5 minutes, whereas the control rats were treated with sham applications. The electrophysiological findings were tested for any correlation with induction of spinal phospho-ERK (p-ERK) in normal and neuropathic pain rats. We then investigated the delayed effect of PRF on SNL-maintained pain behaviors for 2 weeks as well as p-ERK in SDH among the control, SNL, and PRF groups. Finally, potential injury in the DRGs after PRF stimulation was evaluated through behavioral observations and ATF-3, a neuronal stress marker.

RESULTS: In the evoked field-potential study, the recordings mediated through A- and C-afferent fibers were identified as A-component and C-component, respectively. PRF significantly reduced the C-components over 2 hours in both the normal and SNL rats, but it did not affect the A-components. In the SNL rats, the C-component was significantly depressed in the PRF group compared with the sham group. PRF also inhibited acute p-ERK induced by mechanical nociception in both the control and SNL rats. For a longer period, PRF ameliorated SNL-maintained mechanical allodynia for 10 days and thermal analgesia for 14 days, and it significantly reduced late ERK activation within spinal neurons and astrocytes 14 days afterward. Moreover, PRF in the normal rats did not alter basal withdrawal thresholds or increase the expression and distribution of ATF-3 in the DRGs.

LIMITATIONS: Several issues should be considered before translating the animal results to clinical applications.

CONCLUSIONS: Low-voltage bipolar PRF produces LTD through selective suppression on the C-component, but not on the A-component. It also inhibits ERK activation within neurons and astrocytes in SDHs. The findings suggest that PRF alleviates long-lasting neuropathic pain by selectively and persistently modulating C-fiber-mediated spinal nociceptive hypersensitivity.Key words: Pulsed radiofrequency (PRF), dorsal root ganglion (DRG), neuropathic pain, ERK activation, evoked field potential, ATF-3, long-term depression (LTD), spinal nerve ligation (SNL).
https://www.ncbi.nlm.nih.gov/pubmed/28158164

Excerpt
The specially designed bipolar system has been described previously (27,29). The stimulation electrode was inserted into the left L5 foraminal canal, whereas the reference electrode was placed in contact with the surrounding non-neural tissues. The electrodes were connected to a PXI-5402 Function Generator (National Instruments, Austin, TX) to generate RF pulses with the following parameter settings based on clinical settings: 2-Hz biphasic trains with 500-kHz RF waves, 25-ms train width, and oscillating amplitudes at an intensity of ± 2.5 V. The PRF duration was 300 seconds. The control group received an electrode placement without electricity as a sham stimulation.

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Evaluation of the potential of mobile phone specific electromagnetic fields (UMTS) to produce micronuclei in human glioblastoma cell lines

Halh Al-Serori, Michael Kundi, Franziska Ferk, Miroslav Mišík,Armen Nersesyan, Manuel Murbach, Tamara T. Lah, Siegfried Knasmüller. Evaluation of the potential of mobile phone specific electromagnetic fields (UMTS) to produce micronuclei in human glioblastoma cell lines. Toxicology in Vitro. 40:264-271. April 2017.
http://dx.doi.org/10.1016/j.tiv.2017.01.012

Highlights

- Aim was to find out if mobile phone specific radiation causes chromosomal damage.
- The effect of the UMTS signal was tested in two human glioblastoma cell lines.
- No induction of micronuclei and several other nuclear anomalies were found.
- Induction of programmed cell death was observed in a p53 mutated cell line (U251).
- In p53 proficient cells (U87) the apoptosis rate was not increased.

Abstract

Some epidemiological studies indicate that mobile phones cause glioblastomas in humans. Since it is known that genomic instability plays a key role in the etiology of cancer, we investigated the effects of the universal mobile telecommunications system radiofrequency (UMTS-RF) signal, which is used in "smart" phones, on micronucleus (MN) formation and other anomalies such as nuclear buds (NBUDs) and nucleoplasmatic bridges (NPBs). MN are formed by structural and numerical aberrations, NBs reflect gene amplification and NPBs are formed from dicentric chromosomes. The experiments were conducted with human glioblastoma cell lines, which differ in regard to their p53 status, namely U87 (wild-type) and U251 (mutated). The cells were cultivated for 16 h in presence and absence of fetal calf serum and exposed to different SAR doses (0.25, 0.50 and 1.00 W/kg), which reflect the exposure of humans, in presence and absence of mitomycin C as former studies indicate that RF may cause synergistic effects in combination with this drug. We found no evidence for induction of MN and other anomalies. However, with the highest dose, induction of apoptosis was observed in U251 cells on the basis of the morphological features of the cells. Our findings indicate that the UMTS-RF signal does not cause chromosomal damage in glioblastoma cells; the mechanisms which lead to induction of programmed cell death will be investigated in further studies.

Excerpts

1950 MHz UMTS

In conclusion, the results of the present study indicate that exposure of cultured human glioblastoma cells to mobile phone specific RF does not cause MN formation. These findings can be taken as an indication that mechanisms other than chromosomal damage lead to induction of glioblastomas, which was observed in a number of epidemiological studies (for review see IARC (2013) Volume 102). However, as described above we found clear evidence for induction of apoptosis in one of the cell lines with defective *p53*. The observation of induction of programmed cell death in a glioma derived cell line indicates that the UMTS signal causes physiological effects (such as primary DNA damage or other processes), which finally leads to the elimination of the cells. Future investigations will be conducted to understand the biological consequences and the molecular mechanisms which cause this phenomenon.

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Numerical Exposure Assessment Method for Low Frequency Range and Application to Wireless Power Transfer

Park S, Kim M. Numerical Exposure Assessment Method for Low Frequency Range and Application to Wireless Power Transfer. PLoS One. 2016 Nov 29;11(11):e0166720. doi: 10.1371/journal.pone.0166720. eCollection 2016.

Abstract

In this paper, a numerical exposure assessment method is presented for a quasi-static analysis by the use of finite-difference time-domain (FDTD) algorithm. The proposed method is composed of scattered field FDTD method and quasi-static approximation for analyzing of the low frequency band electromagnetic problems. The

proposed method provides an effective tool to compute induced electric fields in an anatomically realistic human voxel model exposed to an arbitrary non-uniform field source in the low frequency ranges. The method is verified, and excellent agreement with theoretical solutions is found for a dielectric sphere model exposed to a magnetic dipole source. The assessment method serves a practical example of the electric fields, current densities, and specific absorption rates induced in a human head and body in close proximity to a 150-kHz wireless power transfer system for cell phone charging. The results are compared to the limits recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the IEEE standard guidelines.

Open access: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0166720

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Quantitative changes in testicular structure and function in rat exposed to mobile phone radiation

Çetkin M, Kızılkan N, Demirel C, Bozdağ Z, Erkılıç S, Erbağcı H. Quantitative changes in testicular structure and function in rat exposed to mobile phone radiation. Andrologia. 2017 Jan 26. doi: 10.1111/and.12761. [Epub ahead of print]

Abstract

The possible effects of the electromagnetic fields (EMF) generated by mobile phones on reproductive functions have been discussed in recent years. The aim of this study was to evaluate the effects of EMF emitted from mobile phones on the rat testis morphology and histopathology using stereological techniques. We also investigated cortisol, testosterone, FSH and LH levels. A total of thirty-two (n = 32) male Wistar albino rats were used in this study. Animals were randomly divided into four groups as control (C, n = 8), sham (Sh, n = 8), mobile phone speech (Sp, n = 8) and mobile phone standby (ST by). Morphometric measurements were made with the help of a computer-assisted stereological analysis system. The testis weight and volume were significantly lower in the EMF exposed groups. The mean volume fraction of interstitial tissue was higher, but the volume fraction of tubular tissue was lower in the EMF-exposed groups. The mean tubular and germinal tissue volume, seminiferous tubule diameter and germinal epithelium height were also lower in EMF exposed groups. The cortisol levels in the EMF-exposed groups were significantly higher. In conclusion, the EMF created by mobile phones caused morphologic and histological changes by the affecting germinal epithelium tissue negatively.

https://www.ncbi.nlm.nih.gov/pubmed/28124386

Excerpts

In order to generate EMF, mobile phones using GSM mobile phone systems were employed. The highest SAR (specific absorption rate) of the mobile phones was 0.96 W/kg and each of these phones had a 890-915 MHz carrier frequency band, 217 Hz modulation frequency, 250 mW maximum average power and 2 W maximum peak power (Dasdag et al., 1999).

Speech mode was obtained by keeping the mobile phone in the experiment box on speech mode for 2 hr/day. For the standby mode, the mobile phone was put on standby for 12 hr/day.

It was seen at the end of the study that exposure to mobile phones caused degeneration in germinal epithelium tissue and as a result, such parameters as testis volume, tubular tissue volume fraction and volume, germinal epithelium volume, STD, GEH and Johnsen biopsy score were affected adversely. Moreover, exposure to mobile phones was found to increase cortisol levels as well.

Inconclusion, it has been found in our study that EMF generated by mobile phones causes degeneration in the germinal epithelium. As a result of this degeneration, significant decreases were observed in the testis volumes, tubular tissue volumes, STD and GEH of the experimental groups. While EMF increased serum cortisol levels in the experimental group, it caused no change in gonadal hormones. All these findings are considered to be useful for studies examining the effects of EMF on reproductive functions.

Also see: http://www.saferemr.com/2015/09/effect-of-mobile-phones-on-sperm.html

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GSM-like radiofrequency exposure induces apoptosis via caspase-dependent pathway in infant rabbits

Meral O, Ozgur E, Kismali G, Guler G, Alpay M, Sel T, Seyhan N. GSM-like radiofrequency exposure induces apoptosis via caspase-dependent pathway in infant rabbits. Bratisl Lek Listy. 2016;117(11):672-676. doi: 10.4149/BLL_2016_129.

Abstract

BACKGROUND: There have been several Radio Frequency (RF) field researches on various populations and groups of different ages in recent years. However, the most important group for research has been declared as the pregnant women and their babies.

OBJECTIVE: The aim of the study was to analyse the effect on apoptotic factors of RF fields on newborn rabbit liver tissues.

MATERIALS AND METHODS: Cytochrome c and AIF (Apoptosis Inducing Factor) levels were measured by western blot and caspase 1, 3 and 9 activities were measured by colorimetric method.

RESULTS: Cytochrome c and AIF levels were not altered, but all caspase activities were increased in female infant rabbits that exposed to 1800 MHz GSM-like RF signals when they reached 1 month of age and caspase 1 and caspase 3 levels were decreased in male infant rabbits that exposed to 1800 MHz GSM-like RF signals between 15th and 22nd days of the gestational period. Results showed that 1800 MHz GSM-like RF exposure might lead to apoptosis in infant rabbit's liver tissues.

CONCLUSION: According to the results, we suggest that postnatal RF exposure causes caspase dependent apoptosis in female infant rabbits liver tissues (Tab. 1, Fig. 2, Ref. 27).

https://www.ncbi.nlm.nih.gov/pubmed/28125894

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GSM 900 MHz Microwave Radiation-Induced Alterations of Insulin Level and Histopathological Changes of Liver and Pancreas in Rat

Mortazavi SMJ, Owji SM, Shojaie-fard MB, Ghader-Panah M, Mortazavi SAR, Tavakoli-Golpayegani A, Haghani M, Taeb S, Shokrpour N, Koohi O. GSM 900 MHz Microwave Radiation-Induced Alterations of Insulin Level and Histopathological Changes of Liver and Pancreas in Rat. J Biomed Phys Eng. 2016 Dec 1;6(4):235-242. eCollection 2016.

Abstract

Background: The rapidly increasing use of mobile phones has led to public concerns about possible health effects of these popular communication devices. This study is an attempt to investigate the effects of radiofrequency (RF) radiation produced by GSM mobile phones on the insulin release in rats.

Methods: Forty two female adult Sprague Dawley rats were randomly divided into 4 groups. Group1 were exposed to RF radiation 6 hours per day for 7 days. Group 2 received sham exposure (6 hours per day for 7 days). Groups 3 and 4 received RF radiation 3 hours per day for 7 days and sham exposure (3 hours per day), respectively. The specific absorption rate (SAR) of RF was 2.0 W/kg.

Results: Our results showed that RF radiations emitted from mobile phone could not alter insulin release in rats. However, mild to severe inflammatory changes in the portal spaces of the liver of rats as well as damage in the cells of islet of Langerhans were observed. These changes were linked with the duration of the exposures.

Conclusion: RF exposure can induce inflammatory changes in the liver as well causing damage in the cells of islet of Langerhans.

http://www.jbpe.org/Journal_OJS/JBPE/index.php/jbpe/article/view/447/224

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The effect of the non ionizing radiation on exposed, laboratory cultivated upland cotton plants

Aikaterina L. Stefi, Lukas H. Margaritis, Nikolaos S. Christodoulakis.The effect of the non ionizing radiation on exposed, laboratory cultivated upland cotton (Gossypium hirsutum L.) plants. Flora - Morphology, Distribution, Functional Ecology of Plants. Volume 226:55-64. January 2017. http://dx.doi.org/10.1016/j.flora.2016.11.009.

Highlights

• Upland cotton plants grow under long term microwave radiation.
• They suffer significant biomass reduction of exposed plants.
• Chloroplast structure is severely affected.
• Photosynthetic pigment content reduces.
• Roots do respond to radiation stress.

Abstract

A series of experiments was carried out to investigate possible structural or biochemical alterations in Gossypium hirsutum plants after a long term (21 days) exposure to non ionizing radiation (1882 MHz) emitted from the base unit of a cordless DECT system. Exposed plants, compared to the negative (matched) controls, seem to be seriously affected. Notably lower biomass production for the above ground part and the root was recorded. Reduction of the photosynthetic pigments and severe damage of the chloroplast structure were also observed. It seems that non ionizing radiation can be noxious for plant life functions.

Excerpts

In the middle of one of the two cages, the base unit of a DECT telephone apparatus (General, Model 123) was appropriately positioned. The DECT base was in a 24 h a day, 7 days a week, pulsed transmission mode, at 1882 MHz, as described elsewhere (Margaritis et al., 2014)....

Supplementary, low precision measurements were made in the control cage; with a broadband field meter (TES-92, 50 MHz–3.5 GHz, Electromagnetic radiation detector – TES Electrical Electronic Corp. Taipei, Taiwan, R.O.C.) at the value of 490.1 mV/m. In the nearby cage (exposed), radiation reached the value of 27.46 V/m (27.460 mV/m, at 1882 MHz) (55 fold higher).

Conclusion

The effect of the non-ionizing radiation at the microwave band, on the *Gossypium hirsutum* young plants, after a long term exposure, can be considered as significant. The disastrous effect on chloroplast structure, the reduction of the photosynthetic pigments and the suppression of the photosynthetic potential, are the main causes for the significant reduction of the primary productivity. Moreover, a serious effect on the underground part of the plant was recorded but this cannot be evaluated yet.

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Sustainable perspectives on energy consumption, EMR, environment, health & accident risks associated with mobile phone use

Manivannan Senthil Velmurugan. Sustainable perspectives on energy consumption, EMRF, environment, health and accident risks associated with the use of mobile phones. Renewable and Sustainable Energy Reviews. 67:192-206. January 2017. http://dx.doi.org/10.1016/j.rser.2016.09.011

Abstract

Mobile phones have grown rapidly using today's wireless technology thereby providing a new dimension to simplify daily routine jobs by users. Mobile phone's applications have a great impact on the way of faster and more effective to convey information. In contrast, mobile phones could harm its users. This paper explored detrimental effects of mobile phones on energy consumption, electromagnetic radiofrequency radiation, environment, health and accidents. The effect of mobile phone's energy consumption can be considered during energy spend for its production and use. The electromagnetic radiofrequency radiation (EMRF) may cause adverse health effects on human. The raw materials which are used to manufacture for mobile phones may cause the severe environmental impacts due to their levels of toxicity. The health hazards are correlated with high-toxic substances released from the mobile phones and its addiction through a prolonged use. Mobile phone usage while driving can cause road traffic collisions and motor vehicle crashes. Furthermore, sustainable perspectives have been suggested as a way to overcoming these detrimental effects of mobile phones.

http://www.sciencedirect.com/science/article/pii/S1364032116305056

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Major influences in households and business spaces — Wi-Fi, telecommunication masts outputs and electrical pollution

Francis Markho, Ioan Tuleasca. Major influences in households and business spaces — Wi-Fi, telecommunication masts outputs and electrical pollution. Electrical and Power Engineering (EPE), 2016 International Conference and Exposition on Electrical and Power Engineering. Oct 20-22, 2016. Iasi, Romania.

Abstract

The paper offers a non-exhaustive perspective, as well as a spectrum of performed measurements, in the field of non-ionizing electromagnetic radiation. Shielding Wi-Fi is shown to be an effective means of counteracting its health risks. The effects of cell phone towers positioning next to living and working spaces is presented and analyzed. Electrical pollution mitigation is described, as well as the problem of earth bound stray electrical currents. Effective actions and measures to be taken for the benefit of future generations are suggested and justified.

Conclusions

The adverse health effects due to Wi-Fi and cell phone towers are well known (Carpenter's testimony [29] and Dode's findings [19]) should be more than enough to put the matter to rest in this respect). However, it seems to be no willingness to change the status quo, even if Lloyd's took steps [30] to distance themselves from the possible EMF claims related issues. The careless use of this type of technology might cost us dearly in the future in both health sector national budgets blowouts and genetic degeneration.

Dirty electricity (electrical pollution) just completes the picture and adds to the effects of the above mentioned stressors. The seriousness of the problem is compounded by the availability and cheapness of various electrical devices and systems that are responsible for the creation of high frequency voltage transients in the electrical networks. Mitigating these transients can, fortunately, be performed using shielding and adequate design for electrical circuitry in addition to other appropriate means [31].

The way forward, however, may be linked to broad, thorough and mandatory institutional measures at national and international levels. The first step in this direction was taken by France [32], where the French National Assembly passed a Law that regulates the exposure to electromagnetic field EMF (Law on Sobriety, Transparency, Information and Consultation for Exposure to Electromagnetic Waves, 29 January 2015). The Law addresses a range of EMF-related aspects, from Wi-Fi usage in nurseries (banned) and schools (limited), to mobile phones Specific Absorption Rate SAR labelling and cell phone towers emissions compliance verification. The Electrohypersensitivity EHS issue was also addressed as part of this Law, where a Report on EHS must be presented to the French Parliament within one year.

At international level it may be that not only the Precautionary Principle has to have a role in organising adequate EMF exposure limits, but also specific internationally recognized legal instruments, like the Nuremberg Code of Ethics. According to this Code, one cannot submit human beings to actions causing them harm, where the said human beings are not able to "bring the experiment to an end" [33]. Since the human race is unwittingly submitted to a world-wide encompassing, society-directed, experiment, in the form of biologically adverse, profit driven, imposed EMF exposure, the Code is duly applicable.

Considering the way other crucial health-related issues (asbestos, tobacco, ionizing radiation) were dealt with over the years, it seems that there is a long way ahead in tackling EMF exposure risks. However, this time is different, since our own long term wellbeing as a species is at risk [34], due to the genotoxic effect of the presented stressors.

http://ieeexplore.ieee.org/document/7781450/

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Inaccurate official assessment of RF safety by the Advisory Group on Non-ionising Radiation (AGNIR)

Starkey SJ. Inaccurate official assessment of radiofrequency safety by the Advisory Group on Non-ionising Radiation. Rev Environ Health. 2016 Dec 1;31(4):493-503. doi: 10.1515/reveh-2016-0060.

Abstract

The Advisory Group on Non-ionising Radiation (AGNIR) 2012 report forms the basis of official advice on the safety of radiofrequency (RF) electromagnetic fields in the United Kingdom and has been relied upon by health protection agencies around the world. This review describes incorrect and misleading statements from within the report, omissions and conflict of interest, which make it unsuitable for health risk assessment. The executive summary and overall conclusions did not accurately reflect the scientific evidence available. Independence is needed from the International Commission on Non-Ionizing Radiation Protection (ICNIRP), the group that set the exposure guidelines being assessed. This conflict of interest critically needs to be addressed for the forthcoming World Health Organisation (WHO) Environmental Health Criteria Monograph on Radiofrequency Fields. Decision makers, organisations and individuals require accurate information about the safety of RF electromagnetic signals if they are to be able to fulfil their safeguarding responsibilities and protect

those for whom they have legal responsibility.

https://www.ncbi.nlm.nih.gov/pubmed/27902455

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Does cell phone use increase the chances of parotid gland tumor development? A systematic review and meta-analysis

de Siqueira EC, de Souza FT, Gomez RS, Gomes CC, de Souza RP. Does cell phone use increase the chances of parotid gland tumor development? A systematic review and meta-analysis. J Oral Pathol Med. 2016 Dec 9. doi: 10.1111/jop.12531. [Epub ahead of print]

Abstract

BACKGROUND: Prior epidemiological studies had examined the association between cell phone use and the development of tumors in the parotid glands. However there is no consensus about the question of whether cell phone use is associated with increased risk of tumors in the parotid glands. We performed a meta-analysis to evaluate the existing literature about the mean question and to determine their statistical significance.

METHODS: Primary association studies. Papers that associated cell phone use and parotid gland tumors development were included, with no restrictions regarding publication date, language and place of publication. Systematic literature search using PubMed, Scielo and Embase followed by meta-analysis.

RESULTS AND CONCLUSION: Initial screening included 37 articles and three were included in meta-analysis. Using three independent samples including 5087 subjects from retrospective case-control studies, cell phone use seems to be associated with greater odds (1.28, 95%- confidence interval 1.09 - 1.51) to develop salivary gland tumor. Results should be read with caution due to the limited number of studies available and their retrospective design.

http://bit.ly/2gFfUBh

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Cell phone use is associated with an inflammatory cytokine profile of parotid gland saliva

Siqueira EC, de Souza FT, Ferreira E, Souza RP, Macedo SC, Friedman E, Gomez MV, Gomes CC, Gomez RS. Cell phone use is associated with an inflammatory cytokine profile of parotid gland saliva.. J Oral. Pathol Med. 45(9):682-686. doi: 10.1111/jop.12434. 2016.

Abstract

BACKGROUND: There is controversy on the effects of the non-ionizing radiation emitted by cell phones on cellular processes and the impact of such radiation exposure on health. The purpose of this study was to investigate whether cell phone use alters cytokine expression in the saliva produced by the parotid glands.

METHODS: Cytokine expression profile was determined by enzyme linked immuno sorbent assay (ELISA) in the saliva produced by the parotid glands in healthy volunteers, and correlated with self-reported cell phone use and laterality.

RESULTS: The following parameters were determined, in 83 Brazilian individuals in saliva produced by the parotid glands comparing the saliva from the gland exposed to cell phone radiation (ipsilateral) to that from the contralateral parotid: salivary flow, total protein concentration, interleukin 1 β (IL-1 β), interleukin 6 (IL-6), interleukin 10 (IL-10), interferon γ (IFN-γ), and tumor necrosis factor α (TNF-α) salivary levels by ELISA. After multiple testing correction, decreased IL-10 and increased IL-1β salivary levels in the ipsilateral side compared with the contralateral side ($P < 0.05$) were detected. Subjects who used cell phones for more than 10 years presented higher differences between IL-10 levels in ipsilateral versus contralateral parotids ($P = 0.0012$). No difference was observed in any of the tested parameters in correlation with cell phone monthly usage in minutes.

CONCLUSION: The exposure of parotid glands to cell phones can alter salivary IL-10 and IL-1β levels, consistent with a pro-inflammatory microenvironment that may be related to heat production.

http://1.usa.gov/24cKkun

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Electromagnetic hypersensitivity: Nation-wide survey among general practitioners, occupational physicians & hygienists in the Netherlands

Slottje P, van Moorselaar I, van Strien R, Vermeulen R, Kromhout H, Huss A. Electromagnetic hypersensitivity (EHS) in occupational and primary health care: A nation-wide survey among general practitioners, occupational physicians and hygienists in the Netherlands. Int J Hyg Environ Health. 2016 Dec 2. pii: S1438-4639(16)30385-6. doi: 10.1016/j.ijheh.2016.11.013. [Epub ahead of print]

Abstract

Subjects who attribute health complaints to every day levels of non-ionizing electromagnetic fields (EMF) have been referred to as electrohypersensitive (EHS). Previous surveys in Europe showed that 68-75% of general practitioners had ever been consulted on EHS. Given the lack of data on EHS in the Netherlands in the general population and on EHS in occupational settings, we performed a national survey among three professional groups that are likely in the first line of being consulted by EHS individuals. Results show that about one third of occupational hygienists, occupational physicians and general practitioners had ever been consulted by one or more EHS subjects. Many of these professionals considered a causal relationship between EMF and health complaints to some degree plausible, and their approach often included exposure reduction advice. Given the lack of scientific evidence for EHS and how low level EMF exposure could cause reported health complaints and given the finding that the majority of these professionals felt insufficiently informed about EMF and health, targeted information campaigns might assist them in their evidence based dealing with subjects who attribute symptoms to EMF.

Conclusions

About a third of occupational hygienist, occupational physicians and general practitioners in the Netherlands are consulted by patients attributing symptoms to EMF exposure. Many of these professionals consider a causal relationship between EMF and health complaints to some degree plausible, and their approach often also includes exposure reduction advice. Given the lack of a scientific evidence basis for EMF to cause symptoms and the finding that the majority of these professionals feels insufficiently informed about EMF and health, targeted information campaigns might assist them in their evidence based dealing with patients who attribute symptoms to EMF.

http://www.sciencedirect.com/science/article/pii/S1438463916303856

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Extrapolation techniques evaluating 24 hours of average EMF emitted by radio base station installations: spectrum analyzer measurements of LTE and UMTS signals

Mossetti S, de Bartolo D, Veronese I, Cantone MC, Cosenza C, Nava E. Extrapolation techniques evaluating

24 hours of average electromagnetic field emitted by radio base station installations: spectrum analyzer measurements of LTE and UMTS signals.
Radiat Prot Dosimetry. 2016 Dec 1. [Epub ahead of print]

Abstract

International and national organizations have formulated guidelines establishing limits for occupational and residential electromagnetic field (EMF) exposure at high-frequency fields. Italian legislation fixed 20 V/m as a limit for public protection from exposure to EMFs in the frequency range 0.1 MHz-3 GHz and 6 V/m as a reference level. Recently, the law was changed and the reference level must now be evaluated as the 24-hour average value, instead of the previous highest 6 minutes in a day. The law refers to a technical guide (CEI 211-7/E published in 2013) for the extrapolation techniques that public authorities have to use when assessing exposure for compliance with limits. In this work, we present measurements carried out with a vectorial spectrum analyzer to identify technical critical aspects in these extrapolation techniques, when applied to UMTS and LTE signals. We focused also on finding a good balance between statistically significant values and logistic managements in control activity, as the signal trend in situ is not known. Measurements were repeated several times over several months and for different mobile companies. The outcome presented in this article allowed us to evaluate the reliability of the extrapolation results obtained and to have a starting point for defining operating procedures.

https://www.ncbi.nlm.nih.gov/pubmed/27909155

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Randomised, placebo-controlled trial of transcranial pulsed EMF in patients with multiple chemical sensitivity

Tran MT, Skovbjerg S, Arendt-Nielsen L, Christensen KB, Elberling J. A randomised, placebo-controlled trial of transcranial pulsed electromagnetic fields in patients with multiple chemical sensitivity. Acta Neuropsychiatr. 2016 Dec 6:1-11. [Epub ahead of print]

Abstract

OBJECTIVE: To evaluate the efficacy of transcranially applied pulsed electromagnetic fields (PEMF) on functional impairments and symptom severity in multiple chemical sensitivity (MCS) patients.

METHODS: The study was conducted as a nationwide trial in Denmark using a randomised, parallel-group, double-blind and placebo-controlled design. Sample size was estimated at 40 participants. Eligibility criteria were age 18-75 years and fulfilment of the MCS case criteria. Participants received either PEMF or placebo PEMF (no stimulation) applied transcranially for 6 weeks. The primary outcome was the Life Impact Scale (LIS) of the Quick Environmental Exposure and Sensitivity Inventory (QEESI). Secondary outcomes were the Symptom Severity Scale (SSS) and the Chemical Intolerance Scale of QEESI.

RESULTS: A total of 39 participants were randomised to PEMF or placebo treatment. No significant difference was observed on QEESI LIS between groups with a mean change score of -5.9 in the PEMF group compared with -1.5 in the placebo group (p=0.35, effect size=-0.31). However, a significant decrease was detected on QEESI SSS within and between groups with a mean change score of -11.3 in the PEMF group compared with -3.2 in the placebo group (p=0.03, effect size=-0.60).

CONCLUSION: PEMF treatment of 6 weeks showed no effect on functional impairments in MCS. However, a significant decrease in symptom severity was observed.

https://www.ncbi.nlm.nih.gov/pubmed/27919300

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Mobile-phone Radiation-induced Perturbation of Gene-expression Profiling, Redox Equilibrium & Sporadic-apoptosis Control in the Ovary of Drosophila melanogaster

Manta AK, Papadopoulou D, Polyzos AP, Fragopoulou AF, Skouroliakou AS, Thanos D, Stravopodis DJ, Margaritis LH. Mobile-phone Radiation-induced Perturbation of Gene-expression Profiling, Redox Equilibrium and Sporadic-apoptosis Control in the Ovary of Drosophila melanogaster.
Fly (Austin). 2016 Dec 14:0. [Epub ahead of print]

Abstract

BACKGROUND: The daily use by people of wireless communication devices has increased exponentially in the last decade, begetting concerns regarding its potential health hazards.

METHODS: Drosophila melanogaster four days-old adult female flies were exposed for 30 min to radiation emitted by a commercial mobile phone at a SAR of 0.15 W/kg and a SAE of 270 J/kg. ROS levels and apoptotic follicles were assayed in parallel with a genome-wide microarrays analysis.

RESULTS: ROS cellular contents were found to increase by 1.6 fold (x), immediately after the end of exposure, in follicles of pre-choriogenic stages (germarium - stage 10), while sporadically generated apoptotic follicles (germarium 2b and stages 7-9) presented with an averaged 2x upregulation in their sub-population mass, 4 h after fly's irradiation with mobile device. Microarray analysis revealed 168 genes being differentially expressed, 2 h post-exposure, in response to radiofrequency (RF) electromagnetic field-radiation exposure (≥1.25x, $P<0.05$) and associated with multiple and critical biological processes, such as basic metabolism and cellular subroutines related to stress response and apoptotic death.

CONCLUSION: Exposure of adult flies to mobile-phone radiation for 30 min has an immediate impact on ROS production in animal's ovary, which seems to cause a global, systemic and non-targeted transcriptional reprogramming of gene expression, 2 h post-exposure, being finally followed by induction of apoptosis 4 h after the end of exposure. Conclusively, this unique type of pulsed radiation, mainly being derived from daily used mobile phones, seems capable of mobilizing critical cytopathic mechanisms, and altering fundamental genetic programs and networks in D. melanogaster.

https://www.ncbi.nlm.nih.gov/pubmed/27960592

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Effect of electromagnetic waves from mobile phone on immune status of male rats: possible protective role of vitamin D

El-Gohary O, Said MA. Effect of electromagnetic waves from mobile phone on immune status of male rats: possible protective role of vitamin D. Can J Physiol Pharmacol. 2016 Sep 5:1-6. [Epub ahead of print]

Abstract

There are considerable public concerns about the relationship between mobile phone radiation and human health. The present study assesses the effect of electromagnetic field (EMF) emitted from a mobile phone on the immune system in rats and the possible protective role of vitamin D. Rats were randomly divided into six groups: Group I: control group; Group II: received vitamin D (1000 IU/kg/day) orally; Group III: exposed to EMF 1 h/day; Group IV: exposed to EMF 2 h/day; Group V: exposed to EMF 1 h/day and received vitamin D (1000 IU/kg/day); Group VI: exposed to EMF 2 h/day and received vitamin D (1000 IU/kg/day). After 30 days of exposure time, 1 h/day EMF exposure resulted in significant decrease in immunoglobulin levels (IgA, IgE, IgM, and IgG); total leukocyte, lymphocyte, eosinophil and basophil counts; and a significant increase in neutrophil and monocyte counts. These changes were more increased in the group exposed to 2 h/day EMF. Vitamin D supplementation in EMF-exposed rats reversed these results when compared with EMF-exposed groups. In contrast, 7, 14, and 21 days of EMF exposure produced nonsignificant differences in these parameters among all experimental groups. We concluded that exposure to mobile phone radiation compromises the immune system of rats, and vitamin D appears to have a protective effect.

https://www.ncbi.nlm.nih.gov/pubmed/27901344

Excerpts

In the EMF exposure room, there were no other metals, and the use of any other EMF-emitting device except the mobile phone used in the study was not allowed. There was no WiFi or cellular signal in the room. The rats were exposed to EMF (900 MHz at a specific absorption rate of approximately 0.9 W/kg) emitted by Nokia N70 mobile phone (Nokia Corporation, Finland) for 1 h daily (from 0800 to 0900) for groups III and V or 2 h daily (from 0800 to 1000) for groups IV and VI for 30 days. For the used mobile phone (Nokia N70), the highest SAR value under the International Commission on Non-Ionizing Radiation Protection guidelines for use of the device and the European Union SAR value stated by the manufacturer was 0.95 W/kg of body mass (Chan et al. 1997; Sieroń-Stołtny et al. 2015). The mobile phone was placed directly under the cage in which the animals stayed during the exposure. It was kept in the silent mode during the time of exposure; this means that both sound of a bell and sound in the receiver were switched off, so the animals were exposed solely to EMF generated by the mobile phone (Al-Damegh 2012; Hammodi 2011).

Several mechanisms have been proposed to explain the effects of EMF on the immune system. Cell phone radiation results in activation of the hypothalamo-pituitary adrenal system, leading to elevated serum level of corticosteroid, indicating the existence of stress response in rats exposed to cell phone radiation. The elevated corticosteroid level may be the reason for the decreased lymphocytes (Ahmadi et al. 2014; Barnes and Greenebaum 2006). The percentage of lymphocytes and neutrophils are inversely related to each other both in basal and stressed conditions. Thus, the increase in the neutrophil count could be secondary to the decrease in the lymphocyte count (Keller et al. 1983).

Among the putative mechanisms by which EMF from mobile phones may affect biological systems is the interference of EMF with Ca2+ regulatory processes in lymphoid cells (Walleczek 1992) or increasing free radicals' life span and cellular concentration of reactive oxygen species (Balci et al. 2007). This leads to oxidative damage in major cell macromolecules such as lipids and nucleic acids (Lee et al. 2004). Lantow et al. (2006) reported a significant increase in reactive oxygen species production in human monocytes and lymphocytes after exposure to 1800 MHz RF–EMFs. Increased free radicals and interference with Ca2+ regulatory processes can both cause cell growth inhibition, protein misfolding, and DNA breaks (Gye and Park 2012).--

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Different responses of Drosophila to ELF magnetic field: fitness components & locomotor activity

Zmejkoski D, Petković B, Pavković-Lučić S, Prolić Z, Anđelković M, Savić T. Different responses of Drosophila subobscura isofemale lines to extremely low frequency magnetic field (50 Hz, 0.5 mT): fitness components and locomotor activity. Int J Radiat Biol. 2016 Dec 6:1-29. [Epub ahead of print]

Abstract

PURPOSE: Extremely low frequency (ELF) magnetic fields as essential ecological factor may induce specific responses in genetically different lines. The subject of this study was to investigate the impact of ELF magnetic field on fitness components and locomotor activity of five Drosophila subobscura isofemale (IF) lines.

MATERIALS AND METHODS: Each D. subobscura IF line, arbitrarily named: B16/1, B24/4, B39/1, B57/2 and

B69/5, was maintained in five full-sib inbreeding generations. Their genetic structures were defined based on the mitochondrial DNA variability. Egg-first instar larvae and one-day-old flies were exposed to ELF magnetic field (50 Hz, 0.5 mT, 48 h) and thereafter, fitness components and locomotor activity of males and females in an open field test were observed for each selected IF line, respectively.

RESULTS: Exposure of egg-first instar larvae to ELF magnetic field shortened developmental time, and did not affect viability and sex ratio of D. subobscura IF lines. Exposure of one-day-old males and females IF lines B16/1 and B24/4 to ELF magnetic field significantly decreased their locomotor activity and this effect lasted longer in females than males.

CONCLUSIONS: These results indicate various responses of D. subobscura IF lines to the applied ELF magnetic field depending on their genetic background.

http://www.tandfonline.com/doi/abs/10.1080/09553002.2017.1268281

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15 Hz square wave magnetic fields affects voltage-gated sodium & potassium channels in neurons

Zheng Y, Dou JR, Gao Y, Dong L, Li G. Effects of 15 Hz square wave magnetic fields on the voltage-gated sodium and potassium channels in prefrontal cortex pyramidal neurons. Int J Radiat Biol. 2016 Dec 7:1-7. [Epub ahead of print]

Abstract

PURPOSE: Although magnetic fields have significant effects on neurons, little is known about the mechanisms behind their effects. The present study aimed to measure the effects of magnetic fields on ion channels in cortical pyramidal neurons.

MATERIALS AND METHODS: Cortical pyramidal neurons of Kunming mice were isolated and then subjected to 15 Hz, 1 mT square wave (duty ratio 50%) magnetic fields stimulation. Sodium currents (INa), transient potassium currents (IA) and delayed rectifier potassium currents (IK) were recorded by whole-cell patch clamp method.

RESULTS: We found that magnetic field exposure depressed channel current densities, and altered the activation kinetics of sodium and potassium channels. The inactivation properties of INa and IA were also altered.

CONCLUSION: Magnetic field exposure alters ion channel function in neurons. It is likely that the structures of sodium and potassium channels were influenced by the applied field. Sialic acid, which is an important component of the channels, could be the molecule responsible for the reported results.

https://www.ncbi.nlm.nih.gov/pubmed/27924669

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A follow-up study of the association between mobile phone use and symptoms of ill health

Cho YM, Lim HJ, Jang H, Kim K, Choi JW, Shin C, Lee SK, Kwon JH, Kim N. A follow-up study of the association between mobile phone use and symptoms of ill health. Environ Health Toxicol. 2016 Dec 29. doi: 10.5620/eht.e2017001. [Epub ahead of print]

Abstract

Objectives: The duration and frequency of mobile phone calls, and their relationship with various health effects, have been investigated in our previous cross-sectional study. This two-year period follow-up study after aimed to assess the changes in these variables of same subjects.

Methods: The study population comprised 532 non-patient adult subjects sampled from the Korean Genome Epidemiology Study. The subjects underwent a medical examination at a hospital in 2012/2013 and revisited the same hospital in 2014/2015 to have the same examination for the characteristics of mobile phone use performed. In addition, to evaluate the effects on health, the Headache Impact Test-6 (HIT-6), Psychosocial Well-being Index-Short Form (PWI-SF), Beck Depression Inventory (BDI), Korean-Instrumental Activities of Daily Living (K-IADL), Perceived Stress Scale (PSS), Pittsburgh Sleep Quality Index (PSQI), and 12-Item Short Form Health Survey (SF-12) were analyzed. For all these tests, the higher the score, the greater the effect on health. Variances between scores in all the indices in the baseline and follow-up surveys were calculated, and correlations of each index were analyzed.

Results: The average duration per call and HIT-6 score of the subjects decreased significantly compared with those recorded two years ago. The results showed a slight but significant correlation between call duration changes and HIT-6 score changes for female subjects, but not for males. HIT-6 scores in the follow-up survey significantly decreased compared to those in the baseline survey, but long-time call users (subjects whose call duration was ≥5 min in both the baseline and follow-up surveys) had no statistically significant reduction in HIT-6 scores.

Conclusion: This study suggests that increased call duration is a greater risk factor for increases in headache than any other type of adverse health effect, and that this effect can be chronic.

https://www.ncbi.nlm.nih.gov/pubmed/28111420

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Symptoms and the use of wireless communication devices: A prospective cohort study in Swiss adolescents

Schoeni A, Roser K, Röösli M. Symptoms and the use of wireless communication devices: A prospective cohort study in Swiss adolescents.Environ Res. 2017 Jan 20;154:275-283. doi: 10.1016/j.envres.2017.01.004. [Epub ahead of print]

Abstract

BACKGROUND: We investigated whether radiofrequency electromagnetic fields (RF-EMF) from mobile phones and other wireless devices or by the wireless device use itself due to non-radiation related factors in that context are associated with an increase in health symptom reports of adolescents in Central Switzerland.

METHODS: In a prospective cohort study, 439 study participants (participation rate: 36.8%) aged 12-17 years, completed questionnaires about their mobile and cordless phone use, their self-reported symptoms and possible confounding factors at baseline (2012/2013) and one year later (2013/2014). Operator recorded mobile phone data was obtained for a subgroup of 234 adolescents. RF-EMF dose measures considering various factors affecting RF-EMF exposure were computed for the brain and the whole body. Data were analysed using a mixed-logistic cross-sectional model and a cohort approach, where we investigated whether cumulative dose over one year was related to a new onset of a symptom between baseline and follow-up. All analyses were adjusted for relevant confounders.

RESULTS: Participation rate in the follow-up was 97% (425 participants). In both analyses, cross-sectional and cohort, various symptoms tended to be mostly associated with usage measures that are only marginally related to RF-EMF exposure such as the number of text messages sent per day (e.g. tiredness: OR:1.81;

95%CI:1.20-2.74 for cross-sectional analyses and OR:1.87; 95%CI:1.04-3.38 for cohort analyses). Outcomes were generally less strongly or not associated with mobile phone call duration and RF-EMF dose measures.

CONCLUSIONS: Stronger associations between symptoms of ill health and wireless communication device use than for RF-EMF dose measures were observed. Such a result pattern does not support a causal association between RF-EMF exposure and health symptoms of adolescents but rather suggests that other aspects of extensive media use are related to symptoms.

https://www.ncbi.nlm.nih.gov/pubmed/28113068

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Exposure to Radiofrequency Electromagnetic Fields From Wi-Fi in Australian Schools

Karipidis K, Henderson S, Wijayasinghe D, Tjong L, Tinker R.Exposure to Radiofrequency Electromagnetic Fields From Wi-Fi in Australian Schools.Radiat Prot Dosimetry. 2017 Jan 10. doi: 10.1093/rpd/ncw370. [Epub ahead of print]

Note: Typical and peak RF levels were found to be lower than ICNIRP guidelines. However, many researchers believe that the guidelines are inadequate to ensure safety. Furthermore,peak RF levels were averaged over 1 minute which is much too long as very short-term intense pulses may have biologic effects.

Abstract

The increasing use of Wi-Fi in schools and other places has given rise to public concern that the radiofrequency (RF) electromagnetic fields from Wi-Fi have the potential to adversely affect children. The current study measured typical and peak RF levels from Wi-Fi and other sources in 23 schools in Australia. All of the RF measurements were much lower than the reference levels recommended by international guidelines for protection against established health effects. The typical and peak RF levels from Wi-Fi in locations occupied by children in the classroom were of the order of 10-4 and 10-2% of the exposure guidelines, respectively. Typical RF levels in the classroom were similar between Wi-Fi and radio but higher than other sources. In the schoolyard typical RF levels were higher for radio, TV and mobile phone base stations compared to Wi-Fi. The results of this study showed that the typical RF exposure of children from Wi-Fi at school is very low and comparable or lower to other sources in the environment.

Excerpts

Wi-Fi transmissions consist of sequences of RF burst signals or pulses ranging in duration depending on the amount of data being carried by a pulse(15). The proportion of time that Wi-Fi transmits RF signals is called the duty cycle. Joseph et al.(14) in measuring Wi-Fi in 176 different urban locations (outdoors, homes, offices) found a median duty cycle of 1.4% over all the measurements. Particularly in schools, Khalid et al.(10) in measuring Wi-Fi in six schools found a mean duty cycle from the access points of 4.8%. In our study duty cycle was measured separately for the 2.45 and 5 GHz transmissions when performing the stationary Wi-Fi measurements in the centre of the classroom. The median duty cycle for 23 schools that were measured in the current study was 6.3 and 2.4% for 2.45 and 5 GHz transmissions, respectively.

Members of the public often ask about the cumulative exposure that a child receives when using a Wi-Fi device in a classroom in which a number of children are simultaneously using Wi-Fi. When downloading files, most of the transmissions will be from the access point, not the students' device. When downloading and uploading only a portion of the maximum capacity of a network would be used even in a classroom filled with children using Wi-Fi. The Wi-Fi network divides RF transmissions among the access points and client devices therefore the individual RF exposure to a child in a classroom that is using a device consists of sequential exposures from all active devices, the majority of which are located at some distance away(15). For the majority of schools (20) the measurements in the current study were conducted in an empty classroom (to avoid lesson disruption) with an access point and one laptop. In three schools, measurements were conducted with students or teachers present and using Wi-Fi devices. A comparison between measurements conducted in empty classrooms and classrooms with multiple students/teachers using Wi-Fi showed no significant difference in the RF levels ($p > 0.1$ for all); although this may have been due to low numbers (only three schools measured with multiple users in the classroom).

Open Access Paper: http://rpd.oxfordjournals.org/content/early/2017/01/10/rpd.ncw370.long

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Monitoring of RF/Microwave field strength at schools in a pilot district in Samsun/Turkey

Çetin Kurnaz, Begüm Korunur Engiz, Murat Cem Bozkurt. Monitoring of RF/Microwave field strength at schools in a pilot district in Samsun/Turkey. Microwave Symposium (MMS), 2016 16th Mediterranean. 14-16 Nov 2016.

Abstract

As a result of the growing usage of wireless devices and a large number of WLANs installations at schools; determining the exposure levels to students and staff from these systems has become more crucial than before. Since microwave radio links are used to provide connection between wireless devices, proper assessment of exposure to microwave emissions must be carried out. For this reason, in this study electromagnetic radiation (EMR) measurements were conducted at 92 different schools in Ilkadim district twice in 2016 using PMM 8053 EMR meter. The changes in and statistical properties of electric field strengths (E) are determined on the basis of these measurements. The maximum Es (Emax) are 5.39 V/m and 3.04 V/m for each measurement while the maximum average Es (Eavg) are 2.22 and 2.25 V/m. Even though the measured E levels are below the limits that are determined by the International Commission on Non-Ionizing Radiation Protection (ICNIRP); for providing a wide margin of protection and evaluating the health risks they may cause, regular control/measurement of exposed EMR levels is recommended.

Excerpt

The pie chart showing the distributions of all EMR sources is given in Fig.5. As seen from the figure, 99.16% of total EMR in the medium is emitted by base stations which use 800MHz (LTE800), 900MHz (GSM900), 1800MHz (GSM1800) and 2100MHz (UMTS2100) frequency bands. Among the four of them, GSM900 has the most contribution
with 36.49%**.**

[Note: The paper did not discuss the extent Wi-Fi was used in these schools. WLAN was found to emit 0.024 V/m on average.]

http://ieeexplore.ieee.org/document/7803786/

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RF exposure survey of children and adults: First results from Slovenia

Gajšek P, Struchen B, Valič B. RF exposure survey of children and adults: First results from Slovenia. IEEE Radio and Antenna Days of the Indian Ocean (RADIO). 10-13 Oct. 2016. 10.1109/RADIO.2016.7772027

Abstract

Although RF exposure surveys have been carried out in the general environment using recently developed personal measurement devices (exposure meters), comprehensive measurement of exposure with a true population based sampling frame and a common protocol across countries has never been conducted. Within the FP-7 funded project Geronimo a personal RF exposure measurements in 5 European countries are

conducted following a common measurement protocol. First measurements from 49 children and 49 parents in Slovenia yielded an average personal RF-EMF exposure of 0.26 V/m. Average personal RF-EMF exposure by technology was 0.11 V/m from uplink, 0.18 V/m from downlink, 0.15 V/m from broadcasting, 0.07 V/m from DECT and 0.08 V/m from WLAN.

http://ieeexplore.ieee.org/document/7772027/

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Can body-worn devices be used for measuring personal exposure to mm waves?

Thielens A, Martens L, Joseph W. Can body-worn devices be used for measuring personal exposure to mm waves? Bioelectromagnetics. 2017 Jan 20. doi: 10.1002/bem.22036. [Epub ahead of print]

Abstract

Fifth generation (5G) telecommunication networks will require more bandwidth and will use mm waves (30-300 GHz). Consequently, the aperture of antennas that are used for electromagnetic field measurements will be reduced in comparison to the ones currently used for lower frequencies (0.1-6 GHz). In combination with existing limits on incident power density prescribed by exposure guidelines, this provides an upper limit to received powers during exposure measurements. Simultaneously, an increase in the noise floor of transmitted signals will occur. These effects limit the dynamic range of measurements to 53 dB (2×10^5) at 300 GHz and 73 dB (2×10^7) at 30 GHz, which are determined using a simplified model. Additional propagation losses that exceed this dynamic range can occur during on-body measurements. Therefore, in future wireless networks, an on-body measurement of the incident power density cannot be guaranteed using a single antenna. This effect is problematic for both occupational measurements and epidemiological studies. We propose to use multiple, dynamic antennas on the body instead.

https://www.ncbi.nlm.nih.gov/pubmed/28106915

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Measurements of intermediate-frequency electric and magnetic fields in households

Aerts S, Calderon C, Valič B, Maslanyj M, Addison D, Mee T, Goiceanu C, Verloock L, Van den Bossche M, Gajšek P Vermeulen 5, Röösli M, Cardis E, Martens L, Joseph W.Measurements of intermediate-frequency electric and magnetic fields in households. Environ Res. 2017 Jan 10;154:160-170. doi: 10.1016/j.envres.2017.01.001. [Epub ahead of print]

Highlights

• Survey of residential electric and magnetic fields at intermediate frequencies (IF).
• IF-EF and -MF emitted by 280 household appliances were characterised.
• Strongest emitters were induction cookers, CFLs, LCD-TVs, and microwave ovens.
• No emissions exceeded ICNIRP limits (highest exposure quotient was 1.00).

Abstract

Historically, assessment of human exposure to electric and magnetic fields has focused on the extremely-low-frequency (ELF) and radiofrequency (RF) ranges. However, research on the typically emitted fields in the intermediate-frequency (IF) range (300Hz to 1MHz) as well as potential effects of IF fields on the human body remains limited, although the range of household appliances with electrical components working in the IF range has grown significantly (e.g., induction cookers and compact fluorescent lighting). In this study, an extensive measurement survey was performed on the levels of electric and magnetic fields in the IF range

typically present in residences as well as emitted by a wide range of household appliances under real-life circumstances. Using spot measurements, residential IF field levels were found to be generally low, while the use of certain appliances at close distance (20cm) may result in a relatively high exposure. Overall, appliance emissions contained either harmonic signals, with fundamental frequencies between 6kHz and 300kHz, which were sometimes accompanied by regions in the IF spectrum of rather noisy, elevated field strengths, or much more capricious spectra, dominated by 50Hz harmonics emanating far in the IF domain. The maximum peak field strengths recorded at 20cm were 41.5V/m and 2.7A/m, both from induction cookers. Finally, none of the appliance emissions in the IF range exceeded the exposure summation rules recommended by the International Commission on Non-Ionizing Radiation Protection guidelines and the International Electrotechnical Commission (IEC 62233) standard at 20cm and beyond (maximum exposure quotients EQE 1.0 and EQH 0.13).

https://www.ncbi.nlm.nih.gov/pubmed/28086101

Conclusions

Measurements of electric and magnetic fields at intermediate frequencies (IF) were performed in residences in three countries by way of a common protocol. Typical IF fields in the most frequented rooms were assessed as well as emissions from a wide range of household appliances. At distances of 1 m or more from the IF sources, field levels were found to be generally low. However, use of certain appliances at close distances (20–50cm), including induction cookers, LCD screens, microwave ovens and refrigerators with inverter technology, and (compact) fluorescent lighting, may result in exposures above 5% of public ICNIRP (2010) reference levels. In general, EF and MF emissions of household appliances in the IF range contained either harmonic signals, with fundamental frequencies between 6 and 293 kHz, which were sometimes accompanied by regions in the IF spectrum of rather noisy, elevated field strengths, or much more capricious spectra, seemingly dominated by 50 Hz harmonics emanating far in the IF domain. The maximum peak field strengths recorded in this study were 41.5 V/m and 2.7 A/m (both resulting from induction cookers) and at 20 cm and beyond none of the appliances exceeded the ICNIRP and IEC exposure summation rules (maximum observed electric- and magnetic-field exposure quotients were 1.00 and 0.13, respectively). The results reported here may provide a useful resource for epidemiological studies investigating the potential link between (adverse) health effects and exposure to IF fields.

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Effect of Low Level Subchronic Microwave Radiation on Rat Brain

Deshmukh PS, Megha K, Nasare N, Banerjee BD, Ahmed RS, Abegaonkar MP, Tripathi AK, Mediratta PK. Effect of Low Level Subchronic Microwave Radiation on Rat Brain. Biomed Environ Sci. 2016 Dec;29(12):858-867. doi: 10.3967/bes2016.115.

Abstract

OBJECTIVE: The present study was designed to investigate the effects of subchronic low level microwave radiation (MWR) on cognitive function, heat shock protein 70 (HSP70) level and DNA damage in brain of Fischer rats.

METHODS: Experiments were performed on male Fischer rats exposed to microwave radiation for 90 days at three different frequencies: 900, 1800, and 2450 MHz. Animals were divided into 4 groups: Group I: Sham exposed, Group II: animals exposed to microwave radiation at 900 MHz and specific absorption rate (SAR) 5.953 × 10-4 W/kg, Group III: animals exposed to 1800 MHz at SAR 5.835 × 10-4 W/kg and Group IV: animals exposed to 2450 MHz at SAR 6.672 × 10-4 W/kg. All the animals were tested for cognitive function using elevated plus maze and Morris water maze at the end of the exposure period and subsequently sacrificed to collect brain tissues. HSP70 levels were estimated by ELISA and DNA damage was assessed using alkaline comet assay.

RESULTS: Microwave exposure at 900-2450 MHz with SAR values as mentioned above lead to decline in cognitive function, increase in HSP70 level and DNA damage in brain.

CONCLUSION: The results of the present study suggest that low level microwave exposure at frequencies 900, 1800, and 2450 MHz may lead to hazardous effects on brain.

Open source paper: http://bit.ly/2jhXm84

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Long-term exposure to 835 MHz RF-EMF induces hyperactivity, autophagy and demyelination in the cortical neurons of mice

Kim JH, Yu DH, Huh YH, Lee EH, Kim HG, Kim HR.Long-term exposure to 835 MHz RF-EMF induces hyperactivity, autophagy and demyelination in the cortical neurons of mice. Sci Rep. 2017 Jan 20;7:41129. doi: 10.1038/srep41129.

Abstract

Radiofrequency electromagnetic field (RF-EMF) is used globally in conjunction with mobile communications. There are public concerns of the perceived deleterious biological consequences of RF-EMF exposure. This study assessed neuronal effects of RF-EMF on the cerebral cortex of the mouse brain as a proxy for cranial exposure during mobile phone use. C57BL/6 mice were exposed to 835 MHz RF-EMF at a specific absorption rate (SAR) of 4.0 W/kg for 5 hours/day during 12 weeks. The aim was to examine activation of autophagy pathway in the cerebral cortex, a brain region that is located relatively externally. Induction of autophagy genes and production of proteins including LC3B-II and Beclin1 were increased and accumulation of autolysosome was observed in neuronal cell bodies. However, proapoptotic factor Bax was down-regulted in the cerebral cortex. Importantly, we found that RF-EMF exposure led to myelin sheath damage and mice displayed hyperactivity-like behaviour. The data suggest that autophagy may act as a protective pathway for the neuronal cell bodies in the cerebral cortex during radiofrequency exposure. The observations that neuronal cell bodies remained structurally stable but demyelination was induced in cortical neurons following prolonged RF-EMF suggests a potential cause of neurological or neurobehavioural disorders.

https://www.ncbi.nlm.nih.gov/pubmed/28106136

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Extremely low-level microwaves attenuate immune imbalance induced by inhalation exposure to low-level toluene in mice

Novoselova EG, Glushkova OV, Khrenov MO, Novoselova TV, Lunin SM, Fesenko EE. Extremely low-level microwaves attenuate immune imbalance induced by inhalation exposure to low-level toluene in mice. Int J Radiat Biol. 2017 Jan 9:1-9. doi: 10.1080/09553002.2017.1270473. [Epub ahead of print]

Abstract

PURPOSE: To clarify whether extremely low-level microwaves (MW) alone or in combination with p38 inhibitor affect immune cell responses to inhalation exposure of mice to low-level toluene.

MATERIALS AND METHODS: The cytokine profile, heat shock proteins expression, and the activity of several signal cascades, namely, NF-κB, SAPK/JNK, IRF-3, p38 MAPK, and TLR4 were measured in spleen lymphocytes of mice treated to air-delivered toluene (0.6 mg/m3) or extremely low-level microwaves (8.15-18 GHz, 1μW/cm2, 1 Hz swinging frequency) or combined action of these two factors.

RESULTS: A single exposure to air-delivered low-level toluene induced activation of NF-κB, SAPK/JNK, IFR-3, p38 MAPK and TLR4 pathways. Furthermore, air toluene induced the expression of Hsp72 and enhanced IL-1, IL-6, and TNF-α in blood plasma, which is indicative of a pro-inflammatory response. Exposure to MW alone also resulted in the enhancement of the plasma cytokine values (e.g. IL-6, TNF-α, and IFN-γ) and activation of the NF-κB, MAPK p38, and especially the TLR4 pathways in splenic lymphocytes. Paradoxically, pre-exposure to MW partially recovered or normalized the lymphocyte parameters in the toluene-exposed mice, while the p38 inhibitor XI additionally increased protective activity of microwaves by down regulating MAPKs (JNK and p38), IKK, as well as expression of TLR4 and Hsp90-α.

CONCLUSIONS: The results suggest that exposure to low-intensity MW at specific conditions may recover immune parameters in mice undergoing inhalation exposure to low-level toluene via mechanisms involving cellular signaling.

EXCERPT: In the present study, we examined the effects of MW on the immunity of toluene-exposed mice. We hypothesized that MW exposure would protect mouse cells from the possible toxic effects of toluene. Indeed, we have previously demonstrated that the extremely low-level centimetre waves improved immunity of tumor-bearing mice, and this anti-tumor effect was mediated by TNF production (Novoselova et al. 2004Novoselova EG, Ogay VB, Sorokina OV, Glushkova OV, Sinotova OA, Fesenko EE.2004. The production of tumor necrosis factor in cells of tumor-bearing mice after total-body microwave irradiation and antioxidant diet. Elec Bio Med. 23:167–180.[Taylor & Francis Online], [Web of Science ®]). These results indicate the biologic activity of extremely low-level MW that might be used as a tolerable immunomodulatory factor. The present study demonstrated that the p38 Inhibitor XI increased the protective activity of MW via down-regulation of MAPKs (JNK and p38), IKK, as well as expression of TLR4 and Hsp90-α.

In conclusion, we focused on the changes of several signaling cascade activities, plasma cytokine values, TLR4 and heat shock protein expression in mice exposed to a low-level of toluene, with or without MW alone or in combination with p38 Inhibitor XI. Our data demonstrated that a single exposure to low-level air toluene induced a pro-inflammatory response, while MW alone or in combination with the inhibitor, partially recovered or normalized the studied parameters in the murine spleen.

Further studies using appropriate animal models are necessary to provide evidence-based support for new MW facilities to regulate the immune response following exposure to environmental toxins.

https://www.ncbi.nlm.nih.gov/pubmed/28067111

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Adverse and beneficial effects in Chinese hamster lung fibroblast cells following radiofrequency exposure

Sannino A, Zeni O, Romeo S, Massa R, Scarfi MR. Adverse and beneficial effects in Chinese hamster lung fibroblast cells following radiofrequency exposure.Bioelectromagnetics. 2017 Jan 10. doi: 10.1002/bem.22034. [Epub ahead of print]

Abstract

In this study, the effect of radiofrequency (RF) exposure to 1950 MHz, Universal Mobile Telecommunication System signal, was investigated in Chinese hamster lung fibroblast cell line (V79). Genotoxic and cytotoxic effects of 20-h exposure at specific absorption rate (SAR) values from 0.15 W/kg to 1.25 W/kg were measured by means of cytokinesis-block micronucleus (MN) assay. Exposure was carried out blinded under strictly controlled conditions of dosimetry and temperature. The effect of RF exposure alone at four SAR values was tested, that is, 0.15, 0.3, 0.6, and 1.25 W/kg. A statistically significant increase in MN frequency was found in

cultures exposed to 0.15 and 0.3 W/kg ($P < 0.05$) compared to sham-exposed ones, in the absence of cytotoxicity. SAR values of 0.6 and 1.25 W/kg did not exert any effect. Moreover, to evaluate the ability of RF to exert protective effects with respect to a chemical mutagen, cell cultures were also pre-exposed for 20 h at 0.3 or 1.25 W/kg, and then treated with 500 ng/ml of mitomycin-C (MMC). A significant reduction in the frequency of MN was detected in cultures pre-exposed to 1.25 W/kg compared to cultures treated with MMC alone ($P < 0.05$), indicating induction of adaptive response. Such a decrease was not induced by pre-exposure at 0.3 W/kg SAR. Taken together, our results indicated that V79 is a sensitive cell model to evidence either adverse or beneficial effects of RF exposure, depending on experimental conditions applied.

Excerpts

The results presented here indicated lack of MN increase in cultures exposed for 20 h to 1950 MHz, UMTS signal, at SAR values of 0.6 and 1.25 W/kg. On the contrary, exposure to 0.15 and 0.3 W/kg SAR resulted in a statistically significant increase in MN frequency ($P < 0.05$), compared to sham controls. Concerning 0.3 W/kg, such an increase was also detected in three more independent experiments, carried out to evaluate RF-induced AR (Table 3). On the whole, an average MN increase of 55% was gained on seven independent experiments, in absence of cytotoxicity, although some experimental variability was recorded.

The observed effect was non-thermal, since chromosomal damage has been recorded at 0.15 and 0.3 W/kg SAR but not at higher values (0.6 and 1.25 W/kg)....

Consistent with results presented here, Xu et al. [2013] identified Chinese hamster fibroblasts as a sensitive cell model in a comparative study where different cell types were exposed to RF. The authors exposed six cell types to 1800 MHz, GSM, 3 W/kg SAR, and 24 h exposure (5 min on/10 min off cycles), resulting in a significant increase in DNA damage, evaluated as gamma foci formation in Chinese hamster lung cells and human skin fibroblasts, but not in other cell types tested [Xu et al., 2013].

The dependency of the effect on cell type has been also reported by other authors, who demonstrated that the same RF exposure conditions resulted in affecting certain cell types but not others, when protein expression [Sanchez et al., 2006; Zimmerman et al., 2012; Lu et al., 2014], enzyme activity [Hoyto et al., 2007], oxidative stress [Lantow et al., 2006], or cell proliferation [Trillo et al., 2011] were investigated.

We do not have an explanation for the chromosomal damage detected in this investigation. Rather, due to dependence of the effect on SAR level, our findings seem in agreement with the theory of “window” effects, proposed to explain several non-linear results in bioelectromagnetic research [Postow and Swicord, 1986]. Effects have been reported at some frequencies but not at others, or at lower but not at higher SAR levels of the same frequency, or at certain modulations but not at others, either in vivo or in vitro [Dutta et al., 1992; Panagopoulos and Margaritis, 2010a,b].

https://www.ncbi.nlm.nih.gov/pubmed/28072461

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Study of potential health effects of electromagnetic fields of telephony and Wi-Fi, using chicken embryo development as animal model

Woelders H, de Wit A, Lourens A, Stockhofe N, Engel B, Hulsegge I, Schokker D, van Heijningen P, Vossen S, Bekers D, Zwamborn P. Study of potential health effects of electromagnetic fields of telephony and Wi-Fi, using chicken embryo development as animal model.Bioelectromagnetics. 2017 Jan 16. doi: 10.1002/bem.22026. [Epub ahead of print]

Abstract

The objective of this study is to investigate possible biological effects of radiofrequency electromagnetic fields

(RF-EMF) as used in modern wireless telecommunication in a well-controlled experimental environment using chicken embryo development as animal model. Chicken eggs were incubated under continuous experimental exposure to GSM (1.8 GHz), DECT (1.88 GHz), UMTS (2.1 GHz), and WLAN (5.6 GHz) radiation, with the appropriate modulation protocol, using a homogeneous field distribution at a field strength of approximately 3 V/m, representing the maximum field level in a normal living environment. Radiation-shielded exposure units/egg incubators were operating in parallel for exposed and control eggs in a climatized homogeneous environment, using 450 eggs per treatment in three successive rounds per treatment. Dosimetry of the exposure (field characteristics and specific absorption rate) were studied. Biological parameters studied included embryo death during incubation, hatching percentage, and various morphological and histological parameters of embryos and chicks and their organs, and gene expression profiles of embryos on day 7 and day 18 of incubation by microarray and qPCR. No conclusive evidence was found for induced embryonic mortality or malformations by exposure to the used EMFs, or for effects on the other measured parameters. Estimated differences between treatment groups were always small and the effect of treatment was not significant. In a statistical model that ignored possible interaction between rounds and exposure units, some of the many pairwise comparisons of exposed versus control had P-values lower than 0.05, but were not significant after correction for multiple testing.

https://www.ncbi.nlm.nih.gov/pubmed/28092407

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Effects of extremely low-frequency electromagnetic field on expression levels of some antioxidant genes in human MCF-7 cells

Mahmoudinasab H, Sanie-Jahromi F, Saadat M. Effects of extremely low-frequency electromagnetic field on expression levels of some antioxidant genes in human MCF-7 cells. Mol Biol Res Commun. 2016 Jun;5(2):77-85.

Abstract

In the past three decades, study on the biological effects of extremely low-frequency electromagnetic fields (ELF-EMFs) has been of interest to scientists. Although the exact mechanism of its effect is not fully understood, free radical processes has been proposed as a possible mechanism. This study was designed to evaluate the effect of 50-Hz EMFs on the mRNA levels of seven antioxidant genes (CAT, SOD1, SOD2, GSTO1, GSTM3, MSGT1, and MSGT3) in human MCF-7 cells. The EMF exposure patterns were: 1) 5 min field-on/5 min filed-off, 2) 15 min field-on/15 min field-off, 3) 30 min field-on continuously. In all three exposure conditions we tried to have total exposure time of 30 minutes. Control cultures were located in the exposure apparatus when the power was off. The experiments were done at two field intensities; 0.25 mT and 0.50 mT. The RNA extraction was done at two times; immediately post exposure and two hours post exposure. The mRNA levels were determined using quantitative real-time polymerase chain reaction. MTT assay for three exposure conditions in the two field intensities represented no cytotoxic effect on MCF-7 cells. Statistical comparison showed a significant difference between 0.25 mT and 0.50 mT intensities for "the 15 min field-on/15 min field-off condition" (Fisher's exact test, P=0.041), indicating that at 0.50 mT intensity field, the number of down-regulated and/or up-regulated genes increased compared with the other ones. However, there is no statistical significant difference between the field intensities for the two others EMF exposure conditions.

https://www.ncbi.nlm.nih.gov/pubmed/28097161

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Investigation of terahertz radiation influence on rat glial cells

Borovkova M, Serebriakova M, Fedorov V, Sedykh E, Vaks V, Lichutin A, Salnikova A, Khodzitsky M. Investigation of terahertz radiation influence on rat glial cells. Biomed Opt Express. 2016 Dec 14;8(1):273-280.

doi: 10.1364/BOE.8.000273. eCollection 2017.

Abstract

We studied an influence of continuous terahertz (THz) radiation (0.12 - 0.18 THz, average power density of 3.2 mW/cm2) on a rat glial cell line. A dose-dependent cytotoxic effect of THz radiation is demonstrated. After 1 minute of THz radiation exposure a relative number of apoptotic cells increased in 1.5 times, after 3 minutes it doubled. This result confirms the concept of biological hazard of intense THz radiation. Diagnostic applications of THz radiation can be restricted by the radiation power density and exposure time.

Excerpts

... It is known that THz radiation causes a variety of biological effects, including some at the cellular level. Detailed reviews on this issue can be found in papers [2–7]. Influence of THz radiation on cells is revealed in the change of genes activity and cell membrane status. It was also reported before, that THz radiation changes the electrical charge of the membrane of human red blood cells [8, 9], causes a violation of the adhesive properties of the nerve cell membrane of a snail and mollusk [10, 11]. An indication of the structural damage is the increase in membrane permeability, as it was shown in some experiments with human red blood cells and lymphocytes [12], and laboratory rats red blood cells [13, 14].

Among the cellular effects, the cytotoxic effect of THz radiation is also an issue of concern for many scientists. Currently, there is no consensus on this issue. Some studies have demonstrated that this effect does not occur [18–25], whereas in other works the effect was clearly displayed [10–12, 26–28]. Particularly, experiments in papers [19, 20, 25, 28] showed different results after exposure of THz radiation of approximately same frequency (0.10 – 0.15 THz) and power density (0.04 – 5 mW/cm2). In all mentioned experiments, registration of the effect was carried out using adequate methods; however, the samples under exposure were different. It is possible that presence or lack of the effect is associated with the properties and characteristics of some particular cells. For this investigation, glial cells were selected as the samples of the experiment. They are highly sensitive to the ionic changes in environment [29]. One of the mechanisms of THz radiation impact on living systems may be a disturbing effect on the status of the cell endogenous field, which will lead to changes in the ionic fluxes from a cell to environment and vice versa, and affect cell viability.

Conclusion In this investigation, we demonstrated a dose-dependent cytotoxic effect of THz radiation on rat glial cells. In the experiment, a C6 rat glial cell line was exposed by continuous THz radiation (0.12 – 0.18 THz) at average power density of 3.2 mW/cm^2. After one minute of exposure, a relative number of apoptotic cells increased by a factor of 1.5, after 5 minutes it became 2.4 times higher than the initial value. This result confirms the concept of biological hazard of intense THz radiation. Therefore, we claim that diagnostic applications of THz radiation can be restricted by the radiation power density and exposure time.

https://www.osapublishing.org/boe/abstract.cfm?uri=boe-8-1-273

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State of knowledge on biological effects at 40–60 GHz

Yves Le Dréan, Yonis Soubere Mahamoud, Yann Le Page, Denis Habauzit, Catherine Le Quément, Maxim Zhadobov, Ronan Sauleau. State of knowledge on biological effects at 40–60 GHz. Comptes Rendus Physique, 14(5):402-411. 2013.

Abstract

Millimetre waves correspond to the range of frequencies located between 30 and 300 GHz. Many applications exist and are emerging in this band, including wireless telecommunications, imaging and monitoring systems.

In addition, some of these frequencies are used in therapy in Eastern Europe, suggesting that interactions with the human body are possible. This review aims to summarise current knowledge on interactions between millimetre waves and living matter. Several representative examples from the scientific literature are presented. Then, possible mechanisms of interactions between millimetre waves and biological systems are discussed.

http://www.sciencedirect.com/science/article/pii/S1631070513000480

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Temperature distribution and Specific Absorption Rate inside a child's head

Vladimir Stanković, Dejan Jovanović, Dejan Krstić, Vera Marković, Nenad Cvetković. Temperature distribution and Specific Absorption Rate inside a child's head. International Journal of Heat and Mass Transfer, Volume 104, January 2017, Pages 559-565.

Highlights

• The numerical analysis of SAR and temperature distribution within a child head.
• Determination of SAR and increasing of temperature within biological tissues.
• Dependence of the SAR and temperature values on the distance.
• Comparison of results obtained by numerical calculation with experimental results.

Abstract

This paper represents the numerical analysis of Specific Absorption Rate (SAR) and temperature distribution within a real child head model exposed to mobile phone radiation at the frequency of f = 900 MHz. In this research the SAR and temperature distribution are obtained by numerical solutions of the equation of electromagnetic waves propagation and by bioheat equation, respectively, and are shown inside different biological tissues and organs during exposure to electromagnetic radiation from a mobile phone. As electromagnetic properties of tissues depend on the electromagnetic waves frequency, the value of SAR and temperature will be different for different tissues and organs. The maximum absorption of electromagnetic energy is in the surface layers of the model, whereby this value is greater than the maximum allowed value defined by standards. Furthermore, the increase in temperature is the highest in those biological tissues and organs that are closest to the source of radiation i.e. a mobile phone. Moving away from a mobile phone, the temperature decreases, but more slowly than the SAR values. In the analysis of the temperature rise resulting from tissues and organs heating due to the effects of electromagnetic fields on a child's head, special attention will be given to the maximum temperature increase in the brain.

Conclusion

This study investigated the distribution of SAR and temperature rise in the anatomical model of a child's head exposed to electromagnetic fields from mobile phones. It was determined that although the values of SAR and temperature decrease with the distance from the source of radiation, it is not possible to establish a direct connection between these quantities. This is primarily because the SAR represents instantaneous heating of tissue. The distribution of temperature will vary compared to the distribution of SAR due to different mechanisms of heat transfer in the thermal model of a child's head.

Although the value of SAR in the brain is below the maximum allowable values, the fact that the SAR levels in certain tissues and organs of the model are significantly above the maximum allowable value must not be disregarded. It is precisely these areas of a child's head that should be the focus of further research of possible unwanted effects of mobile phone radiation.

On the other hand, the temperature of the brain does not exceed 0.7 C, which is below the threshold for causing undesirable thermal effects on neurons [29], while in other parts of the head the temperature does not exceed 1 C.

Of course, it should be noted that the exposure to electromagnetic radiation for 15 min was simulated. Therefore, the obtained results suggest that, in addition to a dosimetry analysis, it is also necessary to perform the thermal analysis of the impact of mobile phone radiation.

http://bit.ly/2jcBjz9

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Personal radiofrequency electromagnetic field exposure measurements in Swiss adolescents

Roser K, Schoeni A, Struchen B, Zahner M, Eeftens M, Fröhlich J, Röösli M. Personal radiofrequency electromagnetic field exposure measurements in Swiss adolescents.Environ Int. 2016 Dec 27. pii: S0160-4120(16)30527-X. doi: 10.1016/j.envint.2016.12.008. [Epub ahead of print]

Abstract

BACKGROUND: Adolescents belong to the heaviest users of wireless communication devices, but little is known about their personal exposure to radiofrequency electromagnetic fields (RF-EMF).

OBJECTIVES: The aim of this paper is to describe personal RF-EMF exposure of Swiss adolescents and evaluate exposure relevant factors. Furthermore, personal measurements were used to estimate average contributions of various sources to the total absorbed RF-EMF dose of the brain and the whole body.

METHODS: Personal exposure was measured using a portable RF-EMF measurement device (ExpoM-RF) measuring 13 frequency bands ranging from 470 to 3600MHz. The participants carried the device for three consecutive days and kept a time-activity diary. In total, 90 adolescents aged 13 to 17years participated in the study conducted between May 2013 and April 2014. In addition, personal measurement values were combined with dose calculations for the use of wireless communication devices to quantify the contribution of various RF-EMF sources to the daily RF-EMF dose of adolescents.

RESULTS: Main contributors to the total personal RF-EMF measurements of 63.2μW/m2 (0.15V/m) were exposures from mobile phones (67.2%) and from mobile phone base stations (19.8%). WLAN at school and at home had little impact on the personal measurements (WLAN accounted for 3.5% of total personal measurements). According to the dose calculations, exposure from environmental sources (broadcast transmitters, mobile phone base stations, cordless phone base stations, WLAN access points, and mobile phones in the surroundings) contributed on average 6.0% to the brain dose and 9.0% to the whole-body dose.

CONCLUSIONS: RF-EMF exposure of adolescents is dominated by their own mobile phone use.

Environmental sources such as mobile phone base stations play a minor role.

https://www.ncbi.nlm.nih.gov/pubmed/28038972

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Where's Your Phone? A Survey of Where Women Aged 15-40 Carry Their Smartphone and Related Risk Perception: A Survey and Pilot Study

Redmayne M. Where's Your Phone? A Survey of Where Women Aged 15-40 Carry Their Smartphone and Related Risk Perception: A Survey and Pilot Study. PLoS One. 2017 Jan 6;12(1):e0167996. doi: 10.1371/journal.pone.0167996. eCollection 2017.

Abstract

Smartphones are now owned by most young adults in many countries. Installed applications regularly update while the phone is in standby. If it is kept near the body, this can lead to considerably higher exposure to radiofrequency electromagnetic radiation than occurred without internet access. Very little is known about current smartphone carrying habits of young women. This survey used an online questionnaire to ask about smartphone location under several circumstances to inform the power calculation for a women's health study. They were also asked about risk perceptions. Data was analysed using Pearson chi square. Three age categories were made: 15-20, 21-30, 31-40. Smartphones were generally kept on standby (96% by day, 83% at night). Of all participants, in the last week the most common locations of the phone when not in use or during passive use was off-body (86%), in the hand (58%), a skirt/trouser pocket (57%), or against the breast (15%). Pocket and near-the-breast storage were significant by age (χ215.04, $p = 0.001$ and χ210.96, $p = 0.04$, respectively), both positively influenced by the youngest group. The same influence lay in the association between holding the phone (χ211.082, $p = 0.004$) and pocket-storage (χ219.971, $p<0.001$) during passive use. For calls, 36.5% solely used the phone against the head. More than half kept the phone 20-50 cms from their head at night (53%), while 13% kept it closer than 20 cms. Many (36%) thought RF-EMR exposure was related to health problems while 16% did not. There was no relationship between thinking RF-EMR exposure causes health problems in general and carrying the phone against the upper or lower body ($p = 0.69$ and $p = 0.212$, respectively). However, calls with the phone against the head were positively related to perception of health risk (χ2 6.695, $p = 0.035$). Our findings can be used in the power calculation for a case-control study.

http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0167996

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Effect of cell phone-like electromagnetic radiation on primary human thyroid cells

Silva V, Hilly O, Strenov Y, Tzabari C, Hauptman Y, Feinmesser R. Effect of cell phone-like electromagnetic radiation on primary human thyroid cells. Int J Radiat Biol. 2016;92(2):107-15. doi: 10.3109/09553002.2016.1117678. Epub 2015 Dec 21.

Abstract

PURPOSE: To evaluate the potential carcinogenic effects of radiofrequency energy (RFE) emitted by cell

phones on human thyroid primary cells.

MATERIALS AND METHODS: Primary thyroid cell culture was prepared from normal thyroid tissue obtained from patients who underwent surgery at our department. Subconfluent thyroid cells were irradiated under different conditions inside a cell incubator using a device that simulates cell phone-RFE. Proliferation of control and irradiated cells was assessed by the immunohistochemical staining of antigen Kiel clone-67 (Ki-67) and tumor suppressor p53 (p53) expression. DNA ploidy and the stress biomarkers heat shock protein 70 (HSP70) and reactive oxygen species (ROS) was evaluated by fluorescence-activated cell sorting (FACS).

RESULTS: Our cells highly expressed thyroglobulin (Tg) and sodium-iodide symporter (NIS) confirming the origin of the tissue. None of the irradiation conditions evaluated here had an effect neither on the proliferation marker Ki-67 nor on p53 expression. DNA ploidy was also not affected by RFE, as well as the expression of the biomarkers HSP70 and ROS.

CONCLUSION: Our conditions of RFE exposure seem to have no potential carcinogenic effect on human thyroid cells. Moreover, common biomarkers usually associated to environmental stress also remained unchanged. We failed to find an association between cell phone-RFE and thyroid cancer. Additional studies are recommended.

https://www.ncbi.nlm.nih.gov/pubmed/26689947

Note: This study did not expose the cell samples to cell phone radiation. The RFE exposure in this simulation did not resemble cell phone radiation.

"Subconfluent thyroid cells were irradiated ... using a device consisting of a Radio Frequency (RF) generator (Fluke 60602A, manufactured by Fluke, Everett, WA) and an RF power amplifier (EMPower 7044, Holbrook, NY). The RF generator, located outside the incubator, was set to the desired power and connected to the power amplifier, which was connected to a panel antenna that was fixed inside the incubator."

"... an antenna was placed inside the cell incubator and set at 900 or 895 MHz and 80 or 210 μW/cm2 to simulate the radiation emitted by mobile phones."

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Environmental and health aspects of mobile phone production and use: Suggestions for innovation and policy

Senthil velmurugan Manivannan. Environmental and health aspects of mobile phone production and use: Suggestions for innovation and policy. Environmental Innovation and Societal Transitions, 21:69-79. December 2016.

Abstract

Mobile phones are universally popular due to their convenience. But their production and use can cause various environmental, energy and health effects. The present study addresses the adverse effects of mobile phones, and proposed remedies to overcome them. It pays special attention to the role of technical innovation. It is suggested that governments and the mobile telecommunication industry need to work together to develop realistic and effective regulations for design, manufacture, energy consumption, recycling and reuse of mobile phones so as to mitigate and minimize the various negative impacts.

http://www.sciencedirect.com/science/article/pii/S2210422416300260

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Effects of smartphone use with and without blue light at night in healthy adults: A randomized, double-blind, cross-over, placebo-controlled comparison

Jung-Yoon Heo, Kiwon Kim, Maurizio Fava, David Mischoulon, George I. Papakostas, Min-Ji Kim, Dong Jun Kim, Kyung-Ah Judy Chang, Yunhye Oh, Bum-Hee Yu, Hong Jin Jeon. Effects of smartphone use with and without blue light at night in healthy adults: A randomized, double-blind, cross-over, placebo-controlled comparison. Journal of Psychiatric Research. Available online 12 December 2016

Abstract

Smartphones deliver light to users through Light Emitting Diode (LED) displays. Blue light is the most potent wavelength for sleep and mood. This study investigated the immediate effects of smartphone blue light LED on humans at night. We investigated changes in serum melatonin levels, cortisol levels, body temperature, and psychiatric measures with a randomized, double-blind, cross-over, placebo-controlled design of two 3-day admissions. Each subject played smartphone games with either conventional LED or suppressed blue light from 7:30 to 10:00PM (150 min). Then, they were readmitted and conducted the same procedure with the other type of smartphone. Serum melatonin levels were measured in 60-min intervals before, during and after use of the smartphones. Serum cortisol levels and body temperature were monitored every 120 min. The Profile of Mood States (POMS), Epworth Sleepiness Scale (ESS), Fatigue Severity Scale (FSS), and auditory and visual Continuous Performance Tests (CPTs) were administered. Among the 22 participants who were each admitted twice, use of blue light smartphones was associated with significantly decreased sleepiness (Cohen's $d = 0.49$, $Z = 43.50$, $p = 0.04$) and confusion-bewilderment (Cohen's $d = 0.53$, $Z = 39.00$, $p = 0.02$), and increased commission error (Cohen's $d = -0.59$, $t = -2.64$, $p = 0.02$). Also, users of blue light smartphones experienced a longer time to reach dim light melatonin onset 50% (2.94 vs. 2.70 h) and had increases in body temperature, serum melatonin levels, and cortisol levels, although these changes were not statistically significant. Use of blue light LED smartphones at night may negatively influence sleep and commission errors, while it may not be enough to lead to significant changes in serum melatonin and cortisol levels.

Conclusion

In conclusion, this study suggests that nighttime exposure to the blue light LED display of smartphones may negatively affect sleep and commission errors. This was reflected by the suppression of melatonin production, as indicated by the prolonged time to melatonin onset, and the increase in body temperature, although these changes were not great enough to be statistically significant. These findings indicate that sleep and cognitive functions may be more sensitive markers of exposure of blue light from smartphone LED displays than the physiological changes of melatonin, cortisol, and body temperature.

http://www.sciencedirect.com/science/article/pii/S0022395616307786

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Radiofrequency exposure in the Neonatal Medium Care Unit

I. Calvente, A. Vázquez-Pérez, M.F. Fernández, M.I. Núñez, A. Múñoz-Hoyos. Radiofrequency exposure in the Neonatal Medium Care Unit. Environmental Research, 152:66-72. January 2017.

Highlights

· The increasing use of RF-EMF suggests an urgent need for more research in this field.
· Health consequences of RF-EMF exposure on infants are not well known.
· Description of RF-EMF exposure is vital in further study mechanisms on infant health.
· Considering newborns vulnerability, it is wise to adopt a prudent avoidance strategy.

Abstract

The aims of this study were to characterize electromagnetic fields of radiofrequency (RF-EMF) levels generated in a Neonatal Medium Care Unit and to analyze RF-EMF levels inside unit's incubators. Spot and long-term measurements were made with a dosimeter. The spot measurement mean was 1.51±0.48 V/m. Higher values were found in the proximity to the window and to the incubator evaluated. Mean field strength for the entire period of 17 h was 0.81 (±0.07) V/m and the maximum value was 1.58 V/m for long-term RF-EMF measurements in the incubator. Values found during the night period were higher than those found during the day period. It is important to consider RF-EMF exposure levels in neonatal care units, due to some evidence of adverse health effects found in children and adults. Characterization of RF-EMF exposure may be important to further investigate the mechanisms and underlying effects of electromagnetic fields (EMF) on infant health. A prudent avoidance strategy should be adopted because newborns are at a vulnerable stage of development and the actual impact of EMF on premature infants is unknown.

http://www.sciencedirect.com/science/article/pii/S0013935116306570

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Long-term recall accuracy for mobile phone calls in young Japanese people

Kiyohara K, Wake K, Watanabe S, Arima T, Sato Y, Kojimahara N, Taki M, Cardis E, Yamaguchi N. Long-term recall accuracy for mobile phone calls in young Japanese people: A follow-up validation study using software-modified phones. J Expo Sci Environ Epidemiol. 2016 Dec 21. doi: 10.1038/jes.2016.73. [Epub ahead of print]

Abstract

This study examined changes in recall accuracy for mobile phone calls over a long period. Japanese students' actual call statuses were monitored for 1 month using software-modified phones (SMPs). Three face-to-face interviews were conducted to obtain information regarding self-reported call status during the monitoring period: first interview: immediately after the monitoring period; second interview: after 10-12 months; third interview: after 48-55 months. Using the SMP records as the "gold standard", phone call recall accuracy was assessed for each interview. Data for 94 participants were analyzed. The number of calls made was underestimated considerably and the duration of calls was overestimated slightly in all interviews. Agreement between self-report and SMP records regarding the number of calls, duration of calls and laterality (i.e., use of the dominant ear while making calls) gradually deteriorated with the increase in the interval following the monitoring period (number of calls: first interview: Pearson's r=0.641, third interview: 0.396; duration of calls: first interview: Pearson's r=0.763, third interview: 0.356; laterality: first interview: weighted-κ=0.677, third interview: 0.448). Thus, recall accuracy for mobile phone calls would be consistently imperfect over a long period, and the results of related epidemiological studies should be interpreted carefully.

https://www.ncbi.nlm.nih.gov/pubmed/28000687

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Assessment of General Public Exposure to LTE signals compared to other Cellular Networks Present in Thessaloniki, Greece

Gkonis F, Boursianis A, Samaras T. Assessment of General Public Exposure to LTE signals compared to other Cellular Networks Present in Thessaloniki, Greece. Radiat Prot Dosimetry. 2016 Dec 15. [Epub ahead of print]

Abstract

To assess general public exposure to electromagnetic fields from Long Term Evolution (LTE) base stations, measurements at 10 sites in Thessaloniki, Greece were performed. Results are compared with other mobile cellular networks currently in use. All exposure values satisfy the guidelines for general public exposure of the International Commission on Non-Ionizing Radiation Protection (ICNIRP), as well as the reference levels by the Greek legislation at all sites. LTE electric field measurements were recorded up to 0.645 V/m. By applying the ICNIRP guidelines, the exposure ratio for all LTE signals is between 2.9 × 10-5 and 2.8 × 10-2 From the measurements results it is concluded that the average and maximum power density contribution of LTE downlink signals to the overall cellular networks signals are 7.8% and 36.7%, respectively.

https://www.ncbi.nlm.nih.gov/pubmed/27986964

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Numerical compliance testing of human exposure to electromagnetic radiation from smart-watches

Hong SE, Lee AK, Kwon JH, Pack JK. Numerical compliance testing of human exposure to electromagnetic radiation from smart-watches. Phys Med Biol. 2016 Oct 7;61(19):6975-6992. Epub 2016 Sep 20.

Abstract

In this study, we investigated the electromagnetic dosimetry for smart-watches. At present, the standard for compliance testing of body-mounted and handheld devices specifies the use of a flat phantom to provide conservative estimates of the peak spatial-averaged specific absorption rate (SAR). This means that the estimated SAR using a flat phantom should be higher than the SAR in the exposure part of an anatomical human-body model. To verify this, we numerically calculated the SAR for a flat phantom and compared it with the numerical calculation of the SAR for four anatomical human-body models of different ages. The numerical analysis was performed using the finite difference time domain method (FDTD). The smart-watch models were used in the three antennas: the shorted planar inverted-F antenna (PIFA), loop antenna, and monopole antenna. Numerical smart-watch models were implemented for cellular commutation and wireless local-area network operation at 835, 1850, and 2450 MHz. The peak spatial-averaged SARs of the smart-watch models are calculated for the flat phantom and anatomical human-body model for the wrist-worn and next to mouth positions. The results show that the flat phantom does not provide a consistent conservative SAR estimate. We concluded that the difference in the SAR results between an anatomical human-body model and a flat phantom can be attributed to the different phantom shapes and tissue structures.

https://www.ncbi.nlm.nih.gov/pubmed/?term=27648862

These results show that the flat phantom does not always yield a conservative estimate of the spatial peak SAR for the implemented smart-watch model at all exposure scenarios. A conservative exposure estimate for limb-worn device can be obtained by applying a multiplication factor between 1.1 and 2.6 to conventionally estimated values.

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Effects of Simulated Mobile Phone Electromagnetic Radiation on Fertilization and Embryo Development

Chen H, Qu Z, Liu W. Effects of Simulated Mobile Phone Electromagnetic Radiation on Fertilization and Embryo Development. Fetal Pediatr Pathol. 2016 Dec 16:1-7. [Epub ahead of print]

Abstract

This study investigated the effects of 935-MHz electromagnetic radiation (ER) on fertilization and subsequent embryonic development in mice. Ovulating mice were irradiated at three ER intensities for 4 h/day (d) or 2 h/d for three consecutive days; the ova were then harvested for in vitro fertilization to observe the 6-h fertilization rate (6-FR), 72-h morula rate (72-MR), and 110-h blastula rate (110-BR). Compared with the control group, the 6-FR, 72-MR, and 110-BR were decreased in the low ER intensity group, but the differences were not significant; in the mid- and high-intensity ER groups, 72-MR and 110-BR in the 4 h/d and 2 h/d subgroups were decreased, showing significant differences compared with the control group. Moreover, the comparison between 4 h/d and 2 h/d subgroups showed significant differences. Mid- and high-intensity ER at 935 MHz can reduce the fertilization rate in mice, and reduce the blastulation rate, thus reducing the possibility of embryo implantation.

https://www.ncbi.nlm.nih.gov/pubmed/27983879

Excerpts

Electromagnetic radiation devices consisted of four parts: a signal source (with frequency ranging from 935 to 960 MHz and magnetic field strength ranging from –15 db to +15 db), a rectifier (220 VAC/27 VDC; 300 W), a power amplifier, and a specific antenna with a length of 15 cm.

The mice were divided into seven groups by using a random table method: low-intensity (2 h/d and 4 h/d subgroups), mid-intensity (570 μW/cm^2: 2 h/d and 4 h/d subgroups), high-intensity (1400 μW/cm^2: 2 h/d and 4 h/d subgroups), and control groups.

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Chronic Nonmodulated Microwave Radiations in Mice Produce Anxiety-like and Depression-like Behaviours and Calcium- and NO-related Biochemical Changes in the Brain

Kumar M, Singh SP, Chaturvedi CM. Chronic Nonmodulated Microwave Radiations in Mice Produce Anxiety-like and Depression-like Behaviours and Calcium- and NO-related Biochemical Changes in the Brain. Exp Neurobiol. 2016 Dec;25(6):318-327. doi: 10.5607/en.2016.25.6.318. Epub 2016 Dec 19.

Abstract

The present study was aimed to investigate behavioural and biochemical effects of chronic exposure of amplitude modulated and non-modulated microwave radiation on laboratory mice. Chronic microwave exposures were executed with 2.45 GHz of either modulated (power density, 0.029 mW/cm2; specific absorption rate, 0.019 W/Kg with sinusoidal modulation of 400 Hz) or nonmodulated continuous sinusoidal wave (power density, 0.033 mW/cm2; specific absorption rate, 0.023 W/Kg) for 2 hrs daily for 1 month. Mice subjected to non-modulated microwave exposure had significantly increased acetylcholinesterase activity and increased intracellular calcium and nitric oxide levels in the cerebral cortex and hippocampus, and also had increased glucose and corticosterone levels in blood compared to control mice. These non-modulated microwave-exposed mice exhibited anxiety-like and depression-like behaviours. In contrast, mice exposed to modulated microwave for the same period did not show such changes in concomitant biochemical and behavioural analyses. These results suggest that chronic non-modulated microwave, but not modulated microwave, radiation may cause anxiety-like and depression-like behaviours and calcium- and NO-related biochemical changes in the brain.

Open Access: http://bit.ly/2hHU23D

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Pulsed magnetic field improves seed quality of aged green pea seeds by homeostasis of free radical content

Bhardwaj J, Anand A, Pandita VK, Nagarajan S. Pulsed magnetic field improves seed quality of aged green pea seeds by homeostasis of free radical content. J Food Sci Technol. 2016 Nov;53(11):3969-3977. doi: 10.1007/s13197-016-2392-8. Epub 2016 Nov 30.

Abstract

To elucidate the mechanism responsible for magnetic field induced seed invigoration in aged seeds an experiment was conducted on six year old garden pea seeds stored under controlled (20 °C and 40% RH) condition. Aged seeds were magnetoprimed by exposing to pulsed magnetic field (PMF) of 100 mT for 1 h in three pulsed modes. The 6 min on and off PMF showed significant improvement in germination (7.6%) and vigor (84.8%) over aged seeds. Superoxide and hydrogen peroxide production increased in germinating primed seeds by 27 and 52%, respectively, over aged seeds. Nicotinamide adenine dinucleotide (reduced) (NADH) peroxidase and superoxide dismutase involved in generation of hydrogen peroxide showed increased activity in PMF primed seeds. Increase in catalase, ascorbate peroxidase and glutathione reductase activity after 36 h of imbibition in primed seeds demonstrated its involvement in seed recovery during magnetopriming. An increase in total antioxidants also helped in maintaining the level of free radicals for promoting germination of magnetoprimed seeds. A 44% increase in level of protein carbonyls after 36 h indicated involvement of protein oxidation for counteracting and/or utilizing the production of ROS and faster mobilization of reserve proteins. Higher production of free radicals in primed seeds did not cause lipid peroxidation as malondialdehyde content was low. Lipoxygenase was involved in the germination associated events as the magnitude of activity was higher in primed aged seeds compared to aged seeds. Our study elucidated that PMF mediated improvement in seed quality of aged pea seeds was facilitated by fine tuning of free radicals by the antioxidant defense system and protein oxidation.

https://www.ncbi.nlm.nih.gov/pubmed/28035152

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Lennart Hardell's lecture at the Royal Society of Medicine

Hardell L. Using the Bradford Hill viewpoints to evaluate the evidence on radio frequency radiation from mobile phones to head tumours. London: Royal Society of Medicine, Oct 13, 2016.

Professor Lennart Hardell discusses the risks of brain tumours in relation to wireless and mobile phones. Professor Hardell also describes how Bradford Hill's 1965 presidential address on association or causation provided a helpful framework for the evaluation of the brain tumour risk from electromagnetic fields.

This 31 minute lecture was filmed at the 'Association or causation in miasmas and mixtures: current reflections on Bradford Hill's 1965 contribution to public health' meeting at the Royal Society of Medicine in London.

http://bit.ly/HardellRSM

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When theory and observation collide: Can non-ionizing radiation cause cancer?

Havas, M. When theory and observation collide: Can non-ionizing radiation cause cancer? Environmental Pollution (2016). http://dx.doi.org/10.1016/j.envpol.2016.10.018

Highlights

• There is sufficient scientific evidence of cellular damage caused by non-ionizing radiation well below thermal guidelines.
• Applying the ionization model to non-ionizing radiation is inappropriate as mechanisms of biological interactions differ.
• Free radicals can and do cause cancer and non-ionizing radiation can and does increase free-radicals.

Abstract

This paper attempts to resolve the debate about whether non-ionizing radiation (NIR) can cause cancer–a debate that has been ongoing for decades. The rationale, put forward mostly by physicists and accepted by many health agencies, is that, “since NIR does not have enough energy to dislodge electrons, it is unable to cause cancer.” This argument is based on a flawed assumption and uses the model of ionizing radiation (IR) to explain NIR, which is inappropriate. Evidence of free-radical damage has been repeatedly documented among humans, animals, plants and microorganisms for both extremely low frequency (ELF) electromagnetic fields (EMF) and for radio frequency (RF) radiation, neither of which is ionizing. While IR directly damages DNA, NIR interferes with the oxidative repair mechanisms resulting in oxidative stress, damage to cellular components including DNA, and damage to cellular processes leading to cancer. Furthermore, free radical damage explains the increased cancer risks associated with mobile phone use, occupational exposure to NIR (ELF EMF and RFR), and residential exposure to power lines and RF transmitters including mobile phones, cell phone base stations, broadcast antennas, and radar installations.

Summary

This paper presents a highly probable mechanism that involves an increase in free-radicals, which–in turn– explains the increased risk of cancers documented in epidemiological studies that are associated with environmental exposure to RFR and ELF-EMFs at levels well below international guidelines.

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Mechanism of low-level microwave radiation effect on nervous system

Hiie Hinrikus, Maie Bachmann, Denis Karai & Jaanus Lass. Mechanism of low-level microwave radiation effect on nervous system. Electromagnetic Biology and Medicine. Pages 1-11. Published online: 22 Nov 2016

Abstract

The aim of this study is to explain the mechanism of the effect of low-level modulated microwave radiation on brain bioelectrical oscillations. The proposed model of excitation by low-level microwave radiation bases on the influence of water polarization on hydrogen bonding forces between water molecules, caused by this the enhancement of diffusion and consequences on neurotransmitters transit time and neuron resting potential. Modulated microwave radiation causes periodic alteration of the neurophysiologic parameters and parametric excitation of brain bioelectric oscillations. The experiments to detect logical outcome of the mechanism on physiological level were carried out on 15 human volunteers. The 450-MHz microwave radiation modulated at 7, 40 and 1000 Hz frequencies was applied at the field power density of 0.16 mW/cm2. A relative change in the EEG power with and without radiation during 10 cycles was used as a quantitative measure. Experimental data demonstrated that modulated at 40 Hz microwave radiation enhanced EEG power in EEG alpha and beta frequency bands. No significant alterations were detected at 7 and 1000 Hz modulation frequencies. These results are in good agreement with the theory of parametric excitation of the brain bioelectric oscillations caused by the periodic alteration of neurophysiologic parameters and support the proposed mechanism. The proposed theoretical framework has been shown to predict the results of experimental study. The suggested mechanism, free of the restrictions related to field strength or time constant, is the first one providing explanation of low-level microwave radiation effects.

Conclusions

The proposed mechanism of low-level microwave radiation effect on nervous system bases on the existing knowledge: rotation of water molecules, related to that perturbation of hydrogen bonds and alteration in diffusion. Alterations in diffusion affect neurophysiologic parameters as neurotransmitters transit time and neuron resting potential. Periodic alteration of the neurophysiologic parameters caused by modulated microwave radiation is expected to result in parametric excitation of brain bioelectric oscillation. Experimental results with a low-level 450-MHz microwave radiation pulse-modulated at 7, 40 and 1000 Hz showed a statistically significant enhancement of the EEG power in alpha, beta1 and beta2 frequency bands at 40 Hz and no significant effect at 7 and 1000 Hz modulation frequencies. The experimental results are in agreement with the nonlinear theory of parametric excitation of the brain bioelectric oscillations inside first zones on instability. The proposed theoretical framework predicts the results of experimental study. The suggested mechanism, free of the restrictions related to field strength or time constant, is the first one providing explanation of low-level microwave radiation effects.

http://www.tandfonline.com/doi/full/10.1080/15368378.2016.1251451

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Long-term Electromagnetic Field Measurement and Assessment for a Shopping Mall

Engiz BK, Kurnaz C. Long-term Electromagnetic Field Measurement and Assessment for a Shopping Mall. Radiat Prot Dosimetry. 2016 Nov 24. [Epub ahead of print]

Abstract

As a result of the dense deployment of wireless devices and base stations, measuring and evaluating the electromagnetic (EM) exposure levels they emit have become important to human health especially if they exceed the limits defined in the standards. Base stations, Wi-Fi equipment and other electronic devices are used heavily, especially in densely crowded places like shopping centers. In this study, electric field strength (E) measurements were conducted at one of the largest shopping malls in Turkey. Broadband E measurements were performed using PMM 8053 EM field strength meter for 24 h a day for the duration of one week while frequency selective measurements were carried out with SRM-3006 EM field strength meter. It is concluded from the measurements that the mean measured total E in the band between 100 kHz and 3 GHz is 0.59 V/m while the maximum E is 7.88 V/m, which are both below the limit determined by International Commission on Non-Ionizing Radiation Protection. Evolutions show that E can increase by up to 55% during the daytime. Analyses demonstrate that 71.3% of total E is caused by UMTS2100, 16.3% is produced by GSM900, 6.2% by LTE, 3.5% by Wi-Fi, and 2.7% is generated by devices that use the remaining frequency bands. Based on the detailed statistical analysis of long-term E measurement results, it can be concluded that the measured E levels are not in normal distribution and that they are statistically different with respect to days. Furthermore, distribution of E can be best modeled with the non-parametric approach.

https://www.ncbi.nlm.nih.gov/pubmed/27885087

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Multiple assessment methods of prenatal exposure to RF radiation from telecommunication in the Mothers and Children's Environmental Health (MOCEH) study

Choi KH, Ha M, Burm E, Ha EH, Park H, Kim Y, Lee AK, Kwon JH, Choi HD, KimN. Multiple assessment methods of prenatal exposure to radio frequency radiation from telecommunication in the Mothers and Children's Environmental Health (MOCEH) study. Int J Occup Med Environ Health. 2016 Nov 18;29(6):959-972. doi: 10.13075/ijomeh.1896.00803. Epub 2016 Nov 3.

Abstract

OBJECTIVES: To evaluate prenatal exposure to radiofrequency radiation (RFR) from telecommunication using a mobile phone questionnaire, operator data logs of mobile phone use and a personal exposure meter (PEM).

MATERIAL AND METHODS: The study included 1228 mother-infants pairs from the Mothers and Children's Environmental Health (MOCEH) study - a multicenter prospective cohort study ongoing since 2006, in which participants were enrolled at ≤ 20 weeks of pregnancy, with a follow-up of a child birth and growth to assess the association between prenatal environmental exposure and children's health. The questionnaire included the average calling frequency per day and the average calling time per day. An EME Spy 100 PEM was used to measure RFR among 269 pregnant women from November 2007 to August 2010. The operators' log data were obtained from 21 participants. The Spearman's correlation test was performed to evaluate correlation coefficient and 95% confidence intervals between the mobile phone use information from the questionnaire, operators' log data, and data recorded by the PEM.

RESULTS: The operators' log data and information from the self-reported questionnaire showed significantly high correlations in the average calling frequency per day ($\rho = 0.6$, $p = 0.004$) and average calling time per day ($\rho = 0.5$, $p = 0.02$). The correlation between information on the mobile phone use in the self-reported questionnaire and exposure index recorded by the PEM was poor. But correlation between the information of the operators' log data and exposure index for transmission of mobile communication was significantly high: correlation coefficient (p-value) was 0.44 (0.07) for calling frequency per day, and it was 0.49 (0.04) for calling time per day.

CONCLUSIONS: The questionnaire information on the mobile phone use showed moderate to high quality. Using multiple methods for exposure assessment might be better than using only one method.

https://www.ncbi.nlm.nih.gov/pubmed/27869246?dopt=Abstract

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Mobile phone signal exposure triggers a hormesis-like effect in Atm+/+ and Atm-/- mouse embryonic fibroblasts

Sun C, Wei X, Fei Y, Su L, Zhao X, Chen G, Xu Z. Mobile phone signal exposure triggers a hormesis-like effect in Atm+/+ and Atm-/- mouse embryonic fibroblasts. Sci Rep. 2016 Nov 18;6:37423. doi: 10.1038/srep37423.

Abstract

Radiofrequency electromagnetic fields (RF-EMFs) have been classified by the International Agency for Research on Cancer as possible carcinogens to humans; however, this conclusion is based on limited epidemiological findings and lacks solid support from experimental studies. In particular, there are no consistent data regarding the genotoxicity of RF-EMFs. Ataxia telangiectasia mutated (ATM) is recognised as a chief guardian of genomic stability. To address the debate on whether RF-EMFs are genotoxic, we compared the effects of 1,800 MHz RF-EMF exposure on genomic DNA in mouse embryonic fibroblasts (MEFs) with proficient (Atm+/+) or deficient (Atm-/-) ATM. In Atm+/+ MEFs, RF-EMF exposure for 1 h at an average special absorption rate of 4.0 W/kg induced significant DNA single-strand breaks (SSBs) and activated the SSB repair mechanism. This effect reduced the DNA damage to less than that of the background level after 36 hours of exposure. In the Atm-/- MEFs, the same RF-EMF exposure for 12 h induced both SSBs and double-strand breaks and activated the two repair processes, which also reduced the DNA damage to less than the control level after prolonged exposure. The observed phenomenon is similar to the hormesis of a toxic substance at a low dose. To the best of our knowledge, this study is the first to report a hormesis-like effect of an RF-EMF.

https://www.ncbi.nlm.nih.gov/pubmed/27857169?dopt=Abstract

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Effects of exposure to 2100 MHz GSM-like RF EMF on auditory system of rats

Çeliker M, Özgür A, Tümkaya L, Terzi S, Yılmaz M, Kalkan Y, Erdoğan E. Effects of exposure to 2100MHz GSM-like radiofrequency electromagnetic field on auditory system of rats. Braz J Otorhinolaryngol. 2016 Nov 5. pii: S1808-8694(16)30222-1. doi: 10.1016/j.bjorl.2016.10.004.

Abstract

INTRODUCTION: The use of mobile phones has become widespread in recent years. Although beneficial from the communication viewpoint, the electromagnetic fields (EMF) generated by mobile phones may cause unwanted biological changes in the human body.

OBJECTIVE: In this study, we aimed to evaluate the effects of 2100MHz Global System for Mobile communication (GSM-like) electromagnetic field (EMF), generated by an EMF generator, on the auditory system of rats by using electrophysiological, histopathologic and immunohistochemical methods.

METHODS: Fourteen adult Wistar albino rats were included in the study. The rats were divided randomly into two groups of seven rats each. The study group was exposed continuously for 30days to a 2100MHz EMF with a signal level (power) of 5.4dBm (3.47mW) to simulate the talk mode on a mobile phone. The control group was not exposed to the aforementioned EMF. After 30days, the Auditory Brainstem Responses (ABRs) of both groups were recorded and the rats were sacrificed. The cochlear nuclei were evaluated by histopathologic and immunohistochemical methods.

RESULTS: The ABR records of the two groups did not differ significantly. The histopathologic analysis showed increased degeneration signs in the study group ($p=0.007$). In addition, immunohistochemical analysis revealed increased apoptotic index in the study group compared to that in the control group ($p=0.002$).

CONCLUSION: The results support that long-term exposure to a GSM-like 2100MHz EMF causes an increase in neuronal degeneration and apoptosis in the auditory system.

https://www.ncbi.nlm.nih.gov/pubmed/27865708?dopt=Abstract

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Protective Role of Vitamin C on the Metabolic and Enzymatic Activities of the Liver in Male Rats After Exposure to Wi-Fi Routers

Shekoohi-Shooli F, Mortazavi SM, Shojaei-Fard MB, Nematollahi S, Tayebi M. Evaluation of the Protective Role of Vitamin C on the Metabolic and Enzymatic Activities of the Liver in the Male Rats After Exposure to 2.45 GHz Of Wi-Fi Routers. J Biomed Phys Eng. 2016 Sep 1;6(3):157-164. eCollection 2016.

Abstract

BACKGROUND: The use of devices emitted microwave radiation such as mobile phones, wireless fidelity (Wi-Fi) routers, etc. is increased rapidly. It has caused a great concern; the researchers should identify its effects on people's health. We evaluated the protective role of Vitamin C on the metabolic and enzymatic activities of the liver after exposure to Wi-Fi routers.

MATERIAL AND METHODS: 70 male Wistar rats weighing 200-250 g were randomly divided into 7 groups (10 rats in each group).The first stage one-day test: Group A (received vitamin C 250 mg/kg/day orally together

with 8- hour/day Wi-Fi exposure). Group B (exposed to Wi-Fi radiation). Group C (received vitamin C). Group D or Control (was neither exposed to radiation of Wi-Fi modem nor did receive vitamin C). The second phase of experiment had done for five consecutive days. It involved Group E (received vitamin C), Group F (exposed to Wi-Fi radiation), Group G (received vitamin C together with Wi-Fi radiation). The distance between animals' restrainers was 20 cm away from the router antenna. Finally, blood samples were collected and assayed the level of hepatic enzymes including alkaline phosphatase (ALP), alanine amino transferase (ALT) aspartate amino transferase (ASL), gamma glutamyl transferase (GGT) and the concentration of Blood Glucose, Cholesterol, Triglyceride (TG), High density lipoprotein (HDL) and low density lipoprotein (LDL).

RESULTS: Data obtained from the One day test showed an increase in concentration of blood glucose, decrease in Triglyceride level and GGT factor ($P<0.05$), however no observed significant difference on the Cholesterol, HDL, LDL level and hepatic enzymes activities in compare to control group. Groups of the five-day test showed reduction in the amount of blood glucose, elevation of cholesterol level and LDL relative to control group ($P<0.05$).

CONCLUSION: WiFi exposure may exert alternations on the metabolic parameters and hepatic enzymes activities through stress oxidative and increasing of free radicals, but the use of vitamin C protects them from changing induced. Also taking optimum dose of vitamin C is essential for radioprotective effect and maintaining optimum health.

https://www.ncbi.nlm.nih.gov/pubmed/27853723?dopt=Abstract

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Development of a source-exposure matrix for occupational EMF exposure assessment in the INTEROCC study

Vila J, Bowman JD, Figuerola J, Moriña D, Kincl L, Richardson L, Cardis E. Development of a source-exposure matrix for occupational exposure assessment of electromagnetic fields in the INTEROCC study. J Expo Sci Environ Epidemiol. 2016 Nov 9. doi: 10.1038/jes.2016.60.

Abstract

To estimate occupational exposures to electromagnetic fields (EMF) for the INTEROCC study, a database of source-based measurements extracted from published and unpublished literature resources had been previously constructed. The aim of the current work was to summarize these measurements into a source-exposure matrix (SEM), accounting for their quality and relevance. A novel methodology for combining available measurements was developed, based on order statistics and log-normal distribution characteristics. Arithmetic and geometric means, and estimates of variability and maximum exposure were calculated by EMF source, frequency band and dosimetry type. The mean estimates were weighted by our confidence in the pooled measurements. The SEM contains confidence-weighted mean and maximum estimates for 312 EMF exposure sources (from 0 Hz to 300 GHz). Operator position geometric mean electric field levels for radiofrequency (RF) sources ranged between 0.8 V/m (plasma etcher) and 320 V/m (RF sealer), while magnetic fields ranged from 0.02 A/m (speed radar) to 0.6 A/m (microwave heating). For extremely low frequency sources, electric fields ranged between 0.2 V/m (electric forklift) and 11,700 V/m (high-voltage transmission line-hotsticks), whereas magnetic fields ranged between 0.14 μT (visual display terminals) and 17 μT (tungsten inert gas welding). The methodology developed allowed the construction of the first EMF-SEM and may be used to summarize similar exposure data for other physical or chemical agents.

https://www.ncbi.nlm.nih.gov/pubmed/27827378

Excerpt

This work allowed the construction of a SEM containing estimated exposure statistics for the most common occupational sources of EMF exposure, identified through the INTEROCC study questionnaire. This database represents a new approach for occupational exposure assessment, based on EMF sources independent of occupation. The SEM will be available online as a free-access tool at http://www.crealradiation.com/index.php/es/databases. Although the current version does not include all possible EMF sources, it can be updated with new or newly identified measurements and sources.

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Impact of RF EMF on cucumber and tomato plants

F. Al-Kathiri, K. Al-Raisi, K. Al-Hinai, M. Al-Droushi, M. Khan, Z. Nadir. Impact of RF electromagnetic field on cucumber and tomato plants. Information Technology, Electronics and Mobile Communication Conference (IEMCON), 2016 IEEE 7th Annual. 13-15 Oct 2016.

Abstract

Agriculture sector is one of the essential sectors to any nation. This sector is a challenging domain worldwide due to multiple biotic and abiotic stresses. The search for finding new agricultural technologies to enhance the crop productivity is a prime goal. Exposure of crop seeds or plants from short to longer term radio frequency and electromagnetic fields may have positive or negative effects on plant growth/development and final productivity. The focus of the research work was to study the impact of fixed radio frequency and electromagnetic field exposures on cucumber and tomato plants growth/development and leaf membrane stability. Initial results of studies showed that the electromagnetic field treatment generated a little stressed environment to crop plants. Both crop plants demonstrated reduced plant growth and development with impaired membrane. This phenomenon was more distinct as the treatment time proceeded. The higher electrolyte leakage coupled with reduced plant growth and development may be a function of free radical processes prompted by the EMF environment.

http://ieeexplore.ieee.org/document/7746234/

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An Investigation on the Effect of ELF Pulsed Electromagnetic Fields on Human Electrocardiograms

Fang Q, Mahmoud SS, Yan J, Li H. An Investigation on the Effect of Extremely Low Frequency Pulsed Electromagnetic Fields on Human Electrocardiograms (ECGs). Int J Environ Res Public Health. 2016 Nov 23;13(11). pii: E1171.

Abstract

For this investigation, we studied the effects of extremely low frequency pulse electromagnetic fields (ELF-PEMF) on the human cardiac signal. Electrocardiograms (ECGs) of 22 healthy volunteers before and after a short duration of ELF-PEMF exposure were recorded. The experiment was conducted under single-blind conditions. The root mean square (RMS) value of the recorded data was considered as comparison criteria. We also measured and analysed four important ECG time intervals before and after ELF-PEMF exposure. Results revealed that the RMS value of the ECG recordings from 18 participants (81.8% of the total participants) increased with a mean value of 3.72%. The increase in ECG voltage levels was then verified by a second experimental protocol with a control exposure. In addition to this, we used hyperbolic T-distributions (HTD) in the analysis of ECG signals to verify the change in the RR interval. It was found that there were small shifts in the frequency-domain signal before and after EMF exposure. This shift has an influence on all frequency components of the ECG signals, as all spectrums were shifted. It is shown from this investigation that a short time exposure to ELF-PEMF can affect the properties of ECG signals. Further study is needed to consolidate this finding and discover more on the biological effects of ELF-PEMF on human physiological processes.

https://www.ncbi.nlm.nih.gov/pubmed/27886102

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Effects of ELF pulsed electromagnetic fields on glioblastoma cells

Zeinab Akbarnejad, Hossein Eskandary, Cristian Vergallo, Seyed Noureddin Nematollahi-Mahani, Luciana Dini, Fatemeh Darvishzadeh-Mahani & Ahmadi Meysam. Effects of extremely low-frequency pulsed electromagnetic fields (ELF-PEMFs) on glioblastoma cells (U87)
Pages 1-10. Published online: 22 Nov 2016. http://dx.doi.org/10.1080/15368378.2016.1251452

Abstract

The impact of extremely low-frequency pulsed electromagnetic fields (ELF-PEMFs) at various frequencies and amplitudes was investigated on cell cycle, apoptosis and viability of the Glioblastoma Multiforme (GBM) cell line (U87), in vitro. The GBM is a malignant brain tumor with high mortality in humans and poorly responsive to the most common type of cancer treatments, such as surgery, chemotherapy and radiation therapy. U87 cells with five experimental groups (I–V) were exposed to various ELF-PEMFs for 2, 4 and 24 h, as follows: (I) no exposure, control; (II) 50 Hz 100 ± 15 G; (III) 100 Hz 100 ± 15 G; (IV) 10 Hz 50 ± 10 G; (V) 50 Hz 50 ± 10 G. The morphology properties, cell viability and gene expression of proteins involved in cell cycle regulation (Cyclin-D1 and P53) and apoptosis (Caspase-3) were investigated. After 24 h, the cell viability and Cyclin-D1 expression increased in Group II (30%, 45%), whereas they decreased in Groups III (29%, 31%) and IV (21%, 34%); P53 and Caspase-3 elevated only in Group III; and no significant difference was observed in Group V, respectively, compared with the control ($p < 0.05$). The data suggest that the proliferation and apoptosis of human GBM are influenced by exposure to ELF-PEMFs in different time-dependent frequencies and amplitudes. The fact that some of the ELF-PEMFs frequencies and amplitudes favor U87 cells proliferation indicates precaution for the use of medical devices related to the MFs on cancer patients. On the other hand, some other ELF-PEMFs frequencies and intensities arresting U87 cells growth could open the way to develop novel therapeutic approaches.

Conclusion

In conclusion, our findings showed that the antiproliferative and proliferative effects of ELF-PEMFs depend on frequency, amplitude and exposure time. There is no doubt that other MF properties should be further addressed. However, our results can offer significant preliminary indication on the appropriateness of the applied range to prevent cell proliferation and induce cell death in cancer patients. Thus, the up- and downregulation of Cyclin-D1, P53 and Caspase-3 in the presence of ELF-PEMF can be a starting point for further investigations on the relationship between ELF-PEMF exposure and cancer cells as well as the exploration of their possible adjuvant use in anticancer therapies.

http://www.tandfonline.com/doi/full/10.1080/15368378.2016.1251452

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Exposure of children to ELF magnetic fields in France: Results of the EXPERS study

Magne I, Souques M, Bureau I, Duburcq A, Remy E, Lambrozo J. Exposure of children to extremely low frequency magnetic fields in France: Results of the EXPERS study. J Expo Sci Environ Epidemiol. 2016 Nov 9. doi: 10.1038/jes.2016.59.

Abstract

The assessment of magnetic field exposure in children is an important point in the context of epidemiological

issues. EXPERS is the first study ever carried out measuring personal exposure to extremely low frequency magnetic fields at a national scale, involving 977 French children with 24 h personal measurements. Descriptive statistical analyses were performed for all the children, and only for children where no alarm clock was identified, as in some cases this requirement of the measurement protocol was not respected. The proportion of children with a 24 h arithmetic mean of ≥0.4 μT was 3.1% when considering all children and 0.8% when excluding alarm clocks. The alarm clocks were the main variable linked to the child exposure measurements. Magnetic field exposure increased when the home was located close to a high voltage power line. However, none of the 0.8% of children living at <125 m to a 225 kV line or <200 m to a 400 kV overhead line had a personal exposure of >0.4 μT. A multiple correspondence analysis showed the difficulty to build a statistical model predicting child exposure. The distribution of child personal exposure was significantly different from the distribution of exposure during sleep, questioning the exposure assessment in some epidemiological studies.

https://www.ncbi.nlm.nih.gov/pubmed/27827377

Conclusion

The EXPERS study is the first study of magnetic field personal exposure of children, with a significant number of subjects, at the scale of a country. It is also the first study on this subject in France. We looked for a relationship between the subjects' characteristics and their exposure, and observed differences depending on the indicator chosen (AM, GM or median). We studied the AM in more detail and found a strong correlation between the highest exposures and alarm clocks because of non-respect of the measurement protocol. That is why we performed two analyses, one over all the children, and one over the children for whom no alarm clock was identified on the magnetic field measurements during the night. The proportion of children with an AM ≥0.4 μT was 3.1% when considering all children and 0.8% when excluding those with alarm clocks.

The magnetic field exposure was found to be correlated and increased when the home was located close to a 63 to 400 kV overhead line. However, few children were concerned and none of them had a personal exposure of >0.4 μT.

On the contrary, the magnetic field exposure was found to be correlated and decreased when the home was located close to a MV overhead line. We hypothesize that this result is an artifact, because these grids are mainly found in rural areas, and the exposure was inversely correlated with the size of urban areas.

We looked for correlations between the 24 h exposure (AM, GM and median). Excepted the alarm clocks, no other variable was significantly linked to the child exposure. This result was confirmed by a multiple correspondence analysis that showed that it would be difficult to build a model to predict the child exposure from the collected variables.

The distribution of the 24 h AM, which is the personal exposure of children, was found to be significantly different from the distribution of the AM during the sleep of children, or of the TWA that was calculated from AM during sleep and school periods. This result questions the exposure assessment in some epidemiological studies.

The same work will be done for the adults of the EXPERS study. More detailed focus will be done for electric grids.

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Effects of repeated 9 and 30-day exposure to ELF EMF on social recognition behavior & estrogen receptors expression in olfactory bulb of female rats

Bernal-Mondragón C, Arriaga-Avila V, Martínez-Abundis E, Barrera-Mera B, Mercado-Gómez O, Guevara-

Guzmán R. Effects of repeated 9 and 30-day exposure to extremely low-frequency electromagnetic fields on social recognition behavior and estrogen receptors expression in olfactory bulb of Wistar female rats. Neurol Res. 2016 Nov 28:1-11. [Epub ahead of print]

Abstract

OBJECTIVE: We investigated the short- and long-term effects of extremely low-frequency electromagnetic fields (EMF) on social recognition behavior and expression of α- and β-estrogen receptors (ER).

METHODS: Rats were exposed to 60-Hz electromagnetic fields for 9 or 30 days and tested for social recognition behavior. Immunohistochemistry and western blot assays were performed to evaluate α- and β-ER expression in the olfactory bulb of intact, ovariectomized (OVX), and ovariectomized+estradiol (E2) replacement (OVX+E2).

RESULTS: Ovariectomization showed impairment of social recognition after 9 days of EMF exposure and a complete recovery after E2 replacement and so did those after 30 days. Short EMF exposure increased expression of β-ER in intact, but not in the others. Longer exposure produced a decrease in intact but an increase in OVX and OVX+E2.

DISCUSSION: Our findings suggest a significant role for β-estrogen receptors and a lack of effect for α-estrogen receptors on a social recognition task.

ABBREVIATIONS: EMF: extremely low frequency electromagnetic fields; ERs: estrogen receptors; OB: olfactory bulb; OVX: ovariectomized; OVX + E2: ovariectomized + estradiol replacement; IEI: interexposure interval; β-ER: beta estrogen receptor; E2: replacement of estradiol; GAPDH: glyceraldehyde-3-phosphate dehydrogenase; WB: Western blot; PBS: phosphate-buffer saline; PB: phosphate-buffer.

https://www.ncbi.nlm.nih.gov/pubmed/27892794

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Self-reported mobile phone use and semen parameters among men from a fertility clinic

Lewis RC, Mínguez-Alarcón L, Meeker JD, Williams PL, Mezei G, Ford JB, Hauser R; EARTH Study Team. Self-reported mobile phone use and semen parameters among men from a fertility clinic. Reprod Toxicol. 2016 Nov 9. pii: S0890-6238(16)30408-7.

Abstract

There is increasing concern that use of mobile phones, a source of low-level radio-frequency electromagnetic fields, may be associated with poor semen quality, but the epidemiologic evidence is limited and conflicting. The relationship between mobile phone use patterns and markers of semen quality was explored in a longitudinal cohort study of 153 men that attended an academic fertility clinic in Boston, Massachusetts. Information on mobile phone use duration, headset or earpiece use, and the body location in which the mobile phone was carried was ascertained via nurse-administered questionnaire. Semen samples (n=350) were collected and analyzed onsite. To account for multiple semen samples per man, linear mixed models with random intercepts were used to investigate the association between mobile phone use and semen parameters. Overall, there was no evidence for a relationship between mobile phone use and semen quality.

Conflict of Interest: Ryan Lewis and Gabor Mezei work for Exponent, Inc., a company that provides consultation on the potential human health risks associated with exposure to environmental agents, including RF- EMFs. All other authors declare no conflict of interest.

Acknowledgement: This research was supported by grant R01 ES009718 from the National Institute of Environmental Health Sciences, National Institutes of Health, and project 1-SP0239 from the **Electric Power Research Institute**.

https://www.ncbi.nlm.nih.gov/pubmed/27838386

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International Commission on Non-Ionizing Radiation Protection: Two announcements

Oct 2016

Update HF Guidelines

ICNIRP has been working on its new high-frequency (HF) guidelines, which will cover the 100 kHz – 300 GHz range of the non-ionizing radiation (NIR) spectrum. This will replace the HF portion of the 1998 ICNIRP guidelines. A draft of the new HF guidelines was presented at ICNIRP's 8th International NIR Workshop in Cape Town, South Africa, in May 2016. This provided an opportunity to share the direction of the ICNIRP thinking, and to obtain preliminary comments from the Workshop participants. At that time ICNIRP was planning to have a public consultation document ready by the end of 2016. However, as some of the issues that were raised regarding the HF guidelines are requiring considerable additional thought and development, this time frame is no longer feasible. ICNIRP will provide updates on the progress in due course.

http://www.icnirp.org/en/activities/news/news-article/update-on-hf-guidelines.html

Upcoming Workshop

An International Workshop on Non-Ionizing Radiation Protection will take place on 2nd December 2016 in Tokyo, Japan. ICNIRP technically co-sponsors the workshop which is financially sponsored by National Institute of Information and Communications Technology (NICT). The main topics of the workshop are the revision of the ICNIRP HF guidelines and NIR protection related to 5G system. The workshop is opened for scientific experts of NIR. Please contact nict-nir-ws@stage.ac, if you consider attending the workshop. Further information regarding the program will be posted shortly.

http://www.icnirp.org/en/activities/news/news-article/tokyo-workshop-2016.html

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Intracranial Distribution of Gliomas in Relation to Mobile Phone Exposure: Analyses From the INTERPHONE Study

Grell, K., Frederiksen, K., Schutz, J., Cardis, E., Armstrong, B., Siemiatycki, J., Krewski, D. R., McBride, M. L., Johansen, C.,Auvinen, A., Hours, M., Blettner, M., Sadetzki, S., Lagorio, S., Yamaguchi, N., Woodward, A., Tynes, T., Feychting, M., Fleming, S. J., Swerdlow, A. J., Andersen, P. K. The Intracranial Distribution of Gliomas in Relation to Exposure From Mobile Phones: Analyses From the INTERPHONE Study. Am J Epidemiol 2016 0: p. kww082v1-11.

Abstract

When investigating the association between brain tumors and use of mobile telephones, accurate data on tumor position are essential, due to the highly localized absorption of energy in the human brain from the radio-frequency fields emitted. We used a point process model to investigate this association using information that included tumor localization data from the INTERPHONE Study (Australia, Canada, Denmark, Finland, France,

Germany, Israel, Italy, Japan, New Zealand, Norway, Sweden, and the United Kingdom). Our main analysis included 792 regular mobile phone users diagnosed with a glioma between 2000 and 2004. Similar to earlier results, we found a statistically significant association between the intracranial distribution of gliomas and the self-reported location of the phone. When we accounted for the preferred side of the head not being exclusively used for all mobile phone calls, the results were similar. The association was independent of the cumulative call time and cumulative number of calls. However, our model used reported side of mobile phone use, which is potentially influenced by recall bias. The point process method provides an alternative to previously used epidemiologic research designs when one is including localization in the investigation of brain tumors and mobile phone use.

Excerpts

... the INTERPHONE Study (6) ... is the largest investigation of mobile phone use and brain tumors to have been carried out to date. INTERPHONE observed no increased glioma risk in mobile phone users except for the decile with the highest reported cumulative call time (>1,640 hours), with uncertain interpretation (6).

... increased occurrence of tumors in the part of the brain closest to the phone would be expected if there were a causal association.

... our aim was to use the 3-dimensional point process model of Grell et al. (31) to analyze the INTERPHONE localization data for glioma and thereby further investigate the association between glioma and mobile phone use. Our use of a case-only approach removed possible differential bias between cases and controls ...

Overall, levels of use were low compared with today's levels due to the period of data collection, 2000–2004, when mobile phones were less common.

The 3-dimensional distribution of gliomas within the brain was skewed towards the self-reported preferred ear for mobile phone use.

Our results concur with the observation of a statistically significant excess of gliomas on the self-reported side of mobile phone use (28).

Taken together, our results suggest that ever using a mobile phone regularly is associated with glioma localization in the sense that more gliomas occurred closer to the ear on the side of the head where the mobile phone was reported to have been used the most. However, this trend was not related to amount of mobile phone use, making it less likely that the association observed is caused by a relationship between mobile phone use and cancer risk. We cannot draw firm conclusions about cause and effect, but our approach has several strengths in comparison with traditional epidemiologic approaches. Our results may have been affected by recall bias in the reported side of phone use. Nevertheless, it provides an alternative for future research related to mobile phone use.

http://aje.oxfordjournals.org/cgi/content/abstract/kww082v1

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Inferring the 1985–2014 impact of mobile phone use on selected brain cancer subtypes

Frank de Vocht. Inferring the 1985–2014 impact of mobile phone use on selected brain cancer subtypes using Bayesian structural time series and synthetic controls. Environment International. 97:100-107. December 2016.

Highlights

• English brain cancer subtypes incidences were compared to synthetic control trends.

• No evidence of increases in GBM, glioma and parietal lobe neoplasms not predicted.
• Malignant neoplasms of the temporal lobe however, have increased faster than expected.
• This corresponded to additional 35% increase, or 188 (95%CI 48–324) cases annually.
• Tumour location and temporal associations correspond with mobile phone use as risk factor.

Abstract

Background Mobile phone use has been increasing rapidly in the past decades and, in parallel, so has the annual incidence of certain types of brain cancers. However, it remains unclear whether this correlation is coincidental or whether use of mobile phones may cause the development, promotion or progression of specific cancers. The 1985–2014 incidence of selected brain cancer subtypes in England were analyzed and compared to counterfactual 'synthetic control' timeseries.

Methods Annual 1985–2014 incidence of malignant glioma, glioblastoma multiforme, and malignant neoplasms of the temporal and parietal lobes in England were modelled based on population-level covariates using Bayesian structural time series models assuming 5,10 and 15 year minimal latency periods. Post-latency counterfactual 'synthetic England' timeseries were nowcast based on covariate trends. The impact of mobile phone use was inferred from differences between measured and modelled time series.

Results There is no evidence of an increase in malignant glioma, glioblastoma multiforme, or malignant neoplasms of the parietal lobe not predicted in the 'synthetic England' time series. Malignant neoplasms of the temporal lobe however, have increased faster than expected. A latency period of 10 years reflected the earliest latency period when this was measurable and related to mobile phone penetration rates, and indicated an additional increase of 35% (95% Credible Interval 9%:59%) during 2005–2014; corresponding to an additional 188 (95%CI 48–324) cases annually.

Conclusions A causal factor, of which mobile phone use (and possibly other wireless equipment) is in agreement with the hypothesized temporal association, is related to an increased risk of developing malignant neoplasms in the temporal lobe.

http://www.sciencedirect.com/science/article/pii/S0160412016303865

Excerpts

The annual incidence of malignant neoplasms of the temporal lobe however, has been increasing faster than expected, with a period of 10 years post-1995 reflecting the earliest latency period when this additional increase was measurable. Post-2005 an additional increase of 35% (95%CI 9%:59%) was evident compared to the counterfactual time series in the 'synthetic England'; corresponding to an average of an additional 188 (95%CI 48–324) cases of malignant neoplasms of the temporal lobe annually. Addition of mobile phone penetration in the models showed a reduction of 15% in the effect size for 5-year latency (Table 2), indicating observed increased incidence can, at least in part, by attributed to mobile phone use (Note that unfortunately longer latencies cannot be explored in these time series).

These analyses indicate excess brain cancer risk is observed in the lobes where most of the electromagnetic energy is absorbed (depending on side of the head where the phone is held when calling) (Cardis et al., 2008), which has been observed previously (Barchana et al., 2012 and Khurana et al., 2009). As such, it does not specifically exclude a specific association with gliomas (if these occur in the temporal lobe), which was reported in Interphone (Interphone Study Group, 2010), and of which about one in three occur in the temporal lobe (Larjavaara et al., 2007). A stronger causal argument could have been made if these analyses could have been stratified by laterality, with ipsilateral RF exposure having been linked to increased cerebral blood flow (Huber et al., 2005) and glucose metabolism (Volkow et al., 2011), as well as to increased risk of glioma in the temporal lobe (Barchana et al., 2012 and Hardell and Carlberg, 2015), although not in all studies (Hartikka et al., 2009 and Larjavaara et al., 2011), but this was not possible.

In summary, these analyses indicate that a causal factor, of which mobile phone use (and possibly other wireless equipment) is in agreement with the hypothesized spatial and temporal associations, is related to an increased risk of developing a malignant neoplasm in the temporal lobe. More specifically, if the calculated population impact is interpreted as a causal effect and is completely contributed to mobile phone use, then the population impact is an additional 188 cases annually in England; corresponding to about 1700 cases (range 436 to 2918) in the period 2005–2014 that would not have occurred otherwise. For reference, this corresponds to 0.02%–0.12% of new cancers during this period. If the relative effect is interpreted as a population relative risk, then a very moderate 1.35 (95%CI 1.09:1.59) is observed after a minimum 10-year latency.

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Electrosmog and Autoimmune Disease

Marshall, T.G. & Heil, T.J.R. Electrosmog and Autoimmune Disease. Immunol Res (2016). doi:10.1007/s12026-016-8825-7

Abstract

Studies in mice have shown that environmental electromagnetic waves tend to suppress the murine immune system with a potency similar to NSAIDs, yet the nature of any Electrosmog effects upon humans remains controversial. Previously, we reported how the human Vitamin-D receptor (VDR) and its ligand, 1,25-dihydroxyvitamin-D (1,25-D), are associated with many chronic inflammatory and autoimmune diseases. We have shown how olmesartan, a drug marketed for mild hypertension, acts as a high-affinity partial agonist for the VDR, and that it seems to reverse disease activity resulting from VDR dysfunction. We here report that structural instability of the activated VDR becomes apparent when observing hydrogen bond behavior with molecular dynamics, revealing that the VDR pathway exhibits a susceptibility to Electrosmog. Further, we note that characteristic modes of instability lie in the microwave frequency range, which is currently populated by cellphone and WiFi communication signals, and that the susceptibility is ligand dependent. A case series of 64 patient-reported outcomes subsequent to use of a silver-threaded cap designed to protect the brain and brain stem from microwave Electrosmog resulted in 90% reporting “definite” or “strong” changes in their disease symptoms. This is much higher than the 3–5% rate reported for electromagnetic hypersensitivity in a healthy population and suggests that effective control of environmental Electrosmog immunomodulation may soon become necessary for successful therapy of autoimmune disease.

https://www.ncbi.nlm.nih.gov/pubmed/27412293

Excerpt

There is no reason to suspect that a pulsed electromagnetic wave of 1 ls duration (1000 times slower than a typical molecular response) might cause any less damage to biology than a continuous wave of the same magnitude. It is therefore important to have very-fast-acting peak reading signal level meters when measuring the biological interaction potential of electromagnetic waves. Much of the research literature in this field is criticized as not being sufficiently authoritative because experiments have not been conducted under the current pragma of placebo control and simplistic ($p = 0.05$) analysis of results. Research in this area will only move forward when critics start to examine qualitative study outcomes—for example, observations which might indicate that a Faraday cage should have been an element of a study’s experimental methodology, or that a 2–3 days acclimatization or immune—washout might have changed the study results.

Furthermore, it seems likely that signals a million times lower than those currently being used in research may be sufficient to elicit a tangible change in human biology. In order to better understand the amplitude at which bioeffects become apparent, it is important that experimental guidelines be delineated which ensure that Electrosmog does not confound a study’s results.

Finally, we need to plan how to handle subjects whose symptoms become untenable (due to immunopathology) during acclimatization to an Electrosmog-quiet environment, or during immune washout. We cannot ignore the increasing body of evidence showing electromagnetic effects on the immune system. The ‘‘controversial’’ nature of electromagnetic hypersensitivity will not diminish until we grasp the complexity of the task we face in defining exactly how electromagnetic waves interact with human biology.

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A cross-sectional study of the association between mobile phone use and symptoms of ill health

Cho YM, Lim HJ, Jang H, Kim K, Choi JW, Shin C, Lee SK, Kwon JH, Kim N. A cross-sectional study of the association between mobile phone use and symptoms of ill health. Environ Health Toxicol. 2016 Oct 26. doi: 10.5620/eht.e2016022. [Epub ahead of print]

Abstract

Objectives: This study analyzed the associations between mobile phone call frequency and duration with non-specific symptoms.

Methods: This study was conducted with a population group including 532 non-patient adults established by the Korean Genome Epidemiology Study. The pattern of phone call using a mobile phone was investigated through face-to-face interview. Structured methods applied to quantitatively assess health effects are Headache Impact Test-6 (HIT-6), Psychosocial Well-being Index-Short Form, Beck Depression Inventory, Korean-Instrumental Activities of Daily Living, Perceived Stress Scale (PSS), Pittsburgh Sleep Quality Index, and 12-Item Short Form Health Survey where a higher score represents a higher greater health effect.

Results: The average daily phone call frequency showed a significant correlation with the PSS score in female subjects. Increases in the average duration of one phone call were significantly correlated with increases in the severity of headaches in both sexes. The mean (standard deviation) HIT-6 score in the subgroup of subjects whose average duration of one phone call was 5 minutes or longer was 45.98 (8.15), as compared with 42.48 (7.20) in those whose average duration of one phone call was <5 minutes. The severity of headaches was divided into three levels according to the HIT-6 score (little or no impact/moderate impact/substantial or severe impact), and a logistic regression analysis was performed to investigate the association between an increased phone call duration and the headache severity. When the average duration of one phone call was 5 minutes or longer, the odds ratio (OR) and the 95% confidence intervals (CI) for the moderate impact group were 2.22 and 1.18-4.19, respectively. The OR and 95% CI for the substantial or severe impact group were 4.44 and 2.11-8.90, respectively.

Conclusions: Mobile phone call duration was not significantly associated with stress, sleep, cognitive function, or depression, but was associated with the severity of headaches.

https://www.ncbi.nlm.nih.gov/pubmed/27802500?dopt=Abstract

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Association Between Portable Screen-Based Media Device Access or Use and Sleep Outcomes: A Systematic Review and Meta-analysis

Carter B, Rees P, Hale L, Bhattacharjee D, Paradkar MS. Association Between Portable Screen-Based Media Device Access or Use and Sleep Outcomes: A Systematic Review and Meta-analysis.JAMA Pediatr. 2016 Oct 31. doi: 10.1001/jamapediatrics.2016.2341. [Epub ahead of print]

Abstract

Importance: Sleep is vital to children's biopsychosocial development. Inadequate sleep quantity and quality is a

public health concern with an array of detrimental health outcomes. Portable mobile and media devices have become a ubiquitous part of children's lives and may affect their sleep duration and quality.

Objective: To conduct a systematic review and meta-analysis to examine whether there is an association between portable screen-based media device (eg, cell phones and tablet devices) access or use in the sleep environment and sleep outcomes.

Data Sources: A search strategy consisting of gray literature and 24 Medical Subject Headings was developed in Ovid MEDLINE and adapted for other databases between January 1, 2011, and June 15, 2015. Searches of the published literature were conducted across 12 databases. No language restriction was applied.

Study Selection: The analysis included randomized clinical trials, cohort studies, and cross-sectional study designs. Inclusion criteria were studies of school-age children between 6 and 19 years. Exclusion criteria were studies of stationary exposures, such as televisions or desktop or personal computers, or studies investigating electromagnetic radiation.

Data Extraction and Synthesis: Of 467 studies identified, 20 cross-sectional studies were assessed for methodological quality. Two reviewers independently extracted data.

Main Outcomes and Measures: The primary outcomes were inadequate sleep quantity, poor sleep quality, and excessive daytime sleepiness, studied according to an a priori protocol.

Results: Twenty studies were included, and their quality was assessed. The studies involved 125 198 children (mean [SD] age, 14.5 [2.2] years; 50.1% male). There was a strong and consistent association between bedtime media device use and inadequate sleep quantity (odds ratio [OR], 2.17; 95% CI, 1.42-3.32) ($P < .001$, $I2 = 90\%$), poor sleep quality (OR, 1.46; 95% CI, 1.14-1.88) ($P = .003$, $I2 = 76\%$), and excessive daytime sleepiness (OR, 2.72; 95% CI, 1.32-5.61) ($P = .007$, $I2 = 50\%$). In addition, children who had access to (but did not use) media devices at night were more likely to have inadequate sleep quantity (OR, 1.79; 95% CI, 1.39-2.31) ($P < .001$, $I2 = 64\%$), poor sleep quality (OR, 1.53; 95% CI, 1.11-2.10) ($P = .009$, $I2 = 74\%$), and excessive daytime sleepiness (OR, 2.27; 95% CI, 1.54-3.35) ($P < .001$, $I2 = 24\%$).

Conclusions and Relevance: To date, this study is the first systematic review and meta-analysis of the association of access to and the use of media devices with sleep outcomes. Bedtime access to and use of a media device were significantly associated with the following: inadequate sleep quantity, poor sleep quality, and excessive daytime sleepiness. An integrated approach among teachers, health care professionals, and parents is required to minimize device access at bedtime, and future research is needed to evaluate the influence of the devices on sleep hygiene and outcomes.

https://www.ncbi.nlm.nih.gov/pubmed/27802500?dopt=Abstract

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Mapping of RF EMF exposure levels in outdoor environment and comparing with reference levels for general public health

Cansiz M, Abbasov T, Kurt MB, Celik AR. Mapping of radio frequency electromagnetic field exposure levels in outdoor environment and comparing with reference levels for general public health. J Expo Sci Environ Epidemiol. 2016 Nov 2. doi: 10.1038/jes.2016.64. [Epub ahead of print].

Abstract

In this study, radio frequency electromagnetic field exposure levels were measured on the main streets in the city center of Diyarbakır, Turkey. Measured electric field levels were plotted on satellite imagery of Diyarbakır and were compared with exposure guidelines published by the International Commission on Non-Ionizing

Radiation Protection (ICNIRP). Exposure measurements were performed in dense urban, urban and suburban areas each day for 7 consecutive days. The measurement system consisted of high precision and portable spectrum analyzer, three-axis electric field antenna, connection cable and a laptop which was used to record the measurement samples as a data logger. The highest exposure levels were detected for two places, which are called Diclekent and Batıkent. It was observed that the highest instantaneous electric field strength value for Batıkent was 7.18 V/m and for Diclekent was 5.81 V/m. It was statistically determined that the main contributor band to the total exposure levels was Universal Mobile Telecommunications System band. Finally, it was concluded that all measured exposure levels were lower than the reference levels recommended by ICNIRP for general public health.

https://www.ncbi.nlm.nih.gov/pubmed/27805622?dopt=Abstract

Excerpt

There are several reasons for why these two places have the highest exposure levels. Each place has a base station for mobile phone and these two base stations have common features. They have both GSM and UMTS antennas, which were installed on the first floor level. Moreover, these base stations are very close to the main streets. As seen in Figure 2, one base station is 115 m far away from Batıkent point and the other one is 165 m far away from Diclekent point. Therefore, exposure levels around these places were measured high. On the contrary, FM and terrestrial TV transmitters were far away from the streets where mobile measurements were taken.

The RF EMF exposure levels on the main streets in the city center of Diyarbakır were shown on the satellite map and then two highest RF EMF exposure levels were detected. By means of this method, considering these thematic maps for public health, RF planning engineers who work for mobile network operators may avoid the installation of new base stations in locations where existing RF exposure levels are already very high.

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The influence of prenatal 10 GHz microwave radiation exposure on a developing mice brain

Sharma A, Kesari KK, Saxena VK, Sisodia R. The influence of prenatal 10 GHz microwave radiation exposure on a developing mice brain.Gen Physiol Biophys. 2016 Oct 27. [Epub ahead of print]

Abstract

Our objective was to investigate alterations in the developing mice brain after intrauterine microwave exposure from different gestation days (0.25 and 11.25) till term. Pregnant mice from 0.25 and 11.25 days of gestation were isolated from an inbred colony and divided into sham-exposed (control) and microwave-exposed (10 GHz) groups. The follow-up study of mice at 3 weeks of age showed significant reduction in the brain and body weight of microwave-exposed group. Results showed an increased level of lipid peroxidation, decreased level of glutathione and protein after microwave exposure on both 0.25 and 11.25 day of gestation. Moreover, changes in cytoarchitechure of hippocampus and cerebellum of the brain and reduction in Purkinje cell number were observed statistically significant after microwave exposure from both 0.25 and 11.25 days of gestation. In conclusion, the degree of severity of damage in neonatal mice brain was much higher, when exposure started from 0.25 day of gestation compared to 11.25 days of gestation.

https://www.ncbi.nlm.nih.gov/pubmed/27787231

Also see: http://www.saferemr.com/2014/06/joint-statement-on-pregnancy-and.html

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Thermal Response of Human Skin to Microwave Energy: A Critical Review

Foster KR, Ziskin MC, Balzano Q.Thermal Response of Human Skin to Microwave Energy: A Critical Review. Health Phys. 2016 Dec;111(6):528-541.

Abstract

This is a review/modeling study of heating of tissue by microwave energy in the frequency range from 3 GHz through the millimeter frequency range (30-300 GHz). The literature was reviewed to identify studies that reported RF-induced increases in skin temperature. A simple thermal model, based on a simplified form of Pennes' bioheat equation (BHTE), was developed, using parameter values taken from the literature with no further adjustment. The predictions of the model were in excellent agreement with available data. A parametric analysis of the model shows that there are two heating regimes with different dominant mechanisms of heat transfer. For small irradiated areas (less than about 0.5-1 cm in radius) the temperature increase at the skin surface is chiefly limited by conduction of heat into deeper tissue layers, while for larger irradiated areas, the steady-state temperature increase is limited by convective cooling by blood perfusion. The results support the use of this simple thermal model to aid in the development and evaluation of RF safety limits at frequencies above 3 GHz and for millimeter waves, particularly when the irradiated area of skin is small. However, very limited thermal response data are available, particularly for exposures lasting more than a few minutes to areas of skin larger than 1-2 cm in diameter. The paper concludes with comments about possible uses and limitations of thermal modeling for setting exposure limits in the considered frequency range.

https://www.ncbi.nlm.nih.gov/pubmed/27798477?dopt=Abstract

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Magnetic Fields Modulate Blue-Light-Dependent Regulation of Neuronal Firing by Cryptochrome

Giachello CN, Scrutton NS, Jones AR, Baines RA. Magnetic Fields Modulate Blue-Light-Dependent Regulation of Neuronal Firing by Cryptochrome. J Neurosci. 2016 Oct 19;36(42):10742-10749.
https://www.ncbi.nlm.nih.gov/pubmed/27798129?dopt=Abstract

Abstract

Many animals are able to sense the Earth's geomagnetic field to enable behaviors such as migration. It is proposed that the magnitude and direction of the geomagnetic field modulates the activity of cryptochrome (CRY) by influencing photochemical radical pair intermediates within the protein. However, this proposal will remain theoretical until a CRY-dependent effect on a receptor neuron is shown to be modified by an external magnetic field (MF). It is established that blue-light (BL) photoactivation of CRY is sufficient to depolarize and activate Drosophila neurons. Here, we show that this CRY-dependent effect is significantly potentiated in the presence of an applied MF (100 mT). We use electrophysiological recordings from larval identified motoneurons, in which CRY is ectopically expressed, to show that BL-dependent depolarization of membrane potential and increased input resistance are markedly potentiated by an MF. Analysis of membrane excitability shows that these effects of MF exposure evoke increased action potential firing. Almost nothing is known about the mechanism by which a magnetically induced change in CRY activity might produce a behavioral response. We further report that specific structural changes to the protein alter the impact of the MF in ways that are strikingly similar to those from recent behavioral studies into the magnetic sense of Drosophila These observations provide the first direct experimental evidence to support the hypothesis that MF modulation of CRY activity is capable of influencing neuron activity to allow animal magnetoreception.

SIGNIFICANCE STATEMENT: The biophysical mechanism of animal magnetoreception is still unclear. The photoreceptor protein cryptochrome has risen to prominence as a candidate magnetoreceptor molecule based on multiple reports derived from behavioral studies. However, the role of cryptochrome as a magnetoreceptor remains controversial primarily because of a lack of direct experimental evidence linking magnetic field (MF) exposure to a change in neuronal activity. Here, we show that exposure to an MF (100 mT) is sufficient to potentiate the ability of light-activated cryptochrome to increase neuronal action potential firing. Our results provide critical missing evidence to show that the activity of cryptochrome is sensitive to an external MF that is capable of modifying animal behavior.

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Athermal effects of continuous microwave irradiation on growth and antibiotic sensitivity of Pseudomonas aeruginosa PAO1

Nakouti I, Hobbs G, Teethaisong Y, Phipps D. A demonstration of athermal effects of continuous microwave irradiation on the growth and antibiotic sensitivity of Pseudomonas aeruginosa PAO1. Biotechnol Prog. 2016 Oct 28. doi: 10.1002/btpr.2392. [Epub ahead of print]

Abstract

Stress, caused by exposure to microwaves (2.45GHz) at constant temperature (37± 0.5o C), alters the growth profile of Pseudomonas aeruginosa PAO1. In the absence of microwave treatment a simple, highly reproducible growth curve was observed over 24 hours or more. Microwave treatment caused no reduction in growth during the first 6 hours, but at a later stage (>12hours) the growth was markedly different to the controls. Secondary growth, typical of the presence of persisters clearly became apparent, as judged by both the dissolved oxygen and the cell density profiles. These treated cells showed distinct morphological changes, but on re-growth these cells reverted to normal. The Microwave Induced Persisters were subject to antibiotic challenge (tobramycin) and showed increased sensitivity when compared to the un-stressed planktonic cells. This is in marked contrast to antibiotic induced persisters which show increased resistance. This provides evidence for both a non-thermal effect of microwaves

https://www.ncbi.nlm.nih.gov/pubmed/27792273

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Exposure to extremely low frequency electromagnetic fields alters the behaviour, physiology and stress protein levels of desert locusts

Wyszkowska J, Shepherd S, Sharkh S, Jackson CW, Newland PL.Exposure to extremely low frequency electromagnetic fields alters the behaviour, physiology and stress protein levels of desert locusts.Sci Rep. 2016 Nov 3;6:36413. doi: 10.1038/srep36413.

Abstract

Electromagnetic fields (EMFs) are present throughout the modern world and are derived from many man-made sources including overhead transmission lines. The risks of extremely-low frequency (ELF) electromagnetic fields are particularly poorly understood especially at high field strengths as they are rarely encountered at ground level. Flying insects, however, can approach close to high field strength transmission lines prompting the question as to how these high levels of exposure affect behaviour and physiology. Here we utilise the accessible nervous system of the locust to ask how exposure to high levels of ELF EMF impact at multiple levels. We show that exposure to ELF EMFs above 4 mT leads to reduced walking. Moreover, intracellular recordings from an identified motor neuron, the fast extensor tibiae motor neuron, show increased spike latency and a broadening of its spike in exposed animals. In addition, hind leg kick force, produced by

stimulating the extensor tibiae muscle, was reduced following exposure, while stress-protein levels (Hsp70) increased. Together these results suggest that ELF EMF exposure has the capacity to cause dramatic effects from behaviour to physiology and protein expression, and this study lays the foundation to explore the ecological significance of these effects in other flying insects.

https://www.ncbi.nlm.nih.gov/pubmed/27808167?dopt=Abstract

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Environmental risk factors for dementia: a systematic review

Lewis O. J. Killin, John M. Starr, Ivy J. Shiue, Tom C. Russ. Environmental risk factors for dementia: a systematic review. BMC Geriatrics. DOI: 10.1186/s12877-016-0342-y. Published: 12 October 2016

Abstract

Background Dementia risk reduction is a major and growing public health priority. While certain modifiable risk factors for dementia have been identified, there remains a substantial proportion of unexplained risk. There is evidence that environmental risk factors may explain some of this risk. Thus, we present the first comprehensive systematic review of environmental risk factors for dementia.

Methods We searched the PubMed and Web of Science databases from their inception to January 2016, bibliographies of review articles, and articles related to publically available environmental data. Articles were included if they examined the association between an environmental risk factor and dementia. Studies with another outcome (for example, cognition), a physiological measure of the exposure, case studies, animal studies, and studies of nutrition were excluded. Data were extracted from individual studies which were, in turn, appraised for methodological quality. The strength and consistency of the overall evidence for each risk factor identified was assessed.

Results We screened 4784 studies and included 60 in the review. Risk factors were considered in six categories: air quality, toxic heavy metals, other metals, other trace elements, occupational-related exposures, and miscellaneous environmental factors. Few studies took a life course approach. There is at least moderate evidence implicating the following risk factors: air pollution; aluminium; silicon; selenium; pesticides; vitamin D deficiency; and electric and magnetic fields.

Conclusions Studies varied widely in size and quality and therefore we must be circumspect in our conclusions. Nevertheless, this extensive review suggests that future research could focus on a short list of environmental risk factors for dementia. Furthermore, further robust, longitudinal studies with repeated measures of environmental exposures are required to confirm these associations.

Excerpt: Two systematic reviews examined low and extremely low frequency **electric and magnetic fields** and, while the evidence is mixed, there seems to be an association with dementia risk and this was corroborated by a prospective study in Switzerland which found that living close to power lines for over 15 years was associated with a doubling of Alzheimer's disease mortality (but not the occupational study mentioned above [63]) [73, 74]. Its findings are difficult to interpret, but a prospective study in Denmark found that **mobile phone** subscription was associated with a decreased risk of subsequent hospital admission with dementia [75].

http://bmcgeriatr.biomedcentral.com/articles/10.1186/s12877-016-0342-y

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RF EMF exposures in kindergarten children

Bhatt CR, Redmayne M, Billah B, Abramson MJ, Benke G.Radiofrequency-electromagnetic field exposures in kindergarten children.J Expo Sci Environ Epidemiol. 2016 Oct 19. doi: 10.1038/jes.2016.55.

Abstract

The aim of this study was to assess environmental and personal radiofrequency-electromagnetic field (RF-EMF) exposures in kindergarten children. Ten children and 20 kindergartens in Melbourne, Australia participated in personal and environmental exposure measurements, respectively. Order statistics of RF-EMF exposures were computed for 16 frequency bands between 88 MHz and 5.8 GHz. Of the 16 bands, the three highest sources of environmental RF-EMF exposures were: Global System for Mobile Communications (GSM) 900 MHz downlink (82 mV/m); Universal Mobile Telecommunications System (UMTS) 2100MHz downlink (51 mV/m); and GSM 900 MHz uplink (45 mV/m). Similarly, the three highest personal exposure sources were: GSM 900 MHz downlink (50 mV/m); UMTS 2100 MHz downlink, GSM 900 MHz uplink and GSM 1800 MHz downlink (20 mV/m); and Frequency Modulation radio, Wi-Fi 2.4 GHz and Digital Video Broadcasting-Terrestrial (10 mV/m). The median environmental exposures were: 179 mV/m (total all bands), 123 mV/m (total mobile phone base station downlinks), 46 mV/m (total mobile phone base station uplinks), and 16 mV/m (Wi-Fi 2.4 GHz). Similarly, the median personal exposures were: 81 mV/m (total all bands), 62 mV/m (total mobile phone base station downlinks), 21 mV/m (total mobile phone base station uplinks), and 9 mV/m (Wi-Fi 2.4 GHz). The measurements showed that environmental RF-EMF exposure levels exceeded the personal RF-EMF exposure levels at kindergartens.

https://www.ncbi.nlm.nih.gov/pubmed/27759027?dopt=Abstract

Excerpt

In conclusion, this study provides evidence to support that of the 16 frequency bands measured the mobile phone base station DL exposure of GSM 900 MHz is the largest contributor to the total environmental and personal RF-EMF exposures in kindergartens in Melbourne. Wi-Fi exposure was found to be very low compared with mobile phone base station exposure. Environmental exposure levels at kindergartens located <300 m away from the nearest base station were higher compared with those located >300 m. The measurements suggested that the personal RF-EMF exposure levels were lower compared with the environmental RF-EMF levels at kindergartens.

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Personal exposure from RF EMF in Australia and Belgium using on-body calibrated exposimeters

Bhatt CR, Thielens A, Billah B, Redmayne M, Abramson MJ, Sim MR, Vermeulen R, Martens L, Joseph W, Benke G.Assessment of personal exposure from radiofrequency-electromagnetic fields in Australia and Belgium using on-body calibrated exposimeters.Environ Res. 2016 Nov;151:547-563. doi: 10.1016/j.envres.2016.08.022.

Abstract

The purposes of this study were: i) to demonstrate the assessment of personal exposure from various RF-EMF sources across different microenvironments in Australia and Belgium, with two on-body calibrated exposimeters, in contrast to earlier studies which employed single, non-on-body calibrated exposimeters; ii) to systematically evaluate the performance of the exposimeters using (on-body) calibration and cross-talk measurements; and iii) to compare the exposure levels measured for one site in each of several selected microenvironments in the two countries. A human subject took part in an on-body calibration of the exposimeter in an anechoic chamber. The same subject collected data on personal exposures across 38 microenvironments (19 in each country) situated in urban, suburban and rural regions. Median personal RF-EMF exposures were estimated: i) of all microenvironments, and ii) across each microenvironment, in two

countries. The exposures were then compared across similar microenvironments in two countries (17 in each country). The three highest median total exposure levels were: city center (4.33V/m), residential outdoor (urban) (0.75V/m), and a park (0.75V/m) [Australia]; and a tram station (1.95V/m), city center (0.95V/m), and a park (0.90V/m) [Belgium]. The exposures across nine microenvironments in Melbourne, Australia were lower than the exposures across corresponding microenvironments in Ghent, Belgium ($p<0.05$). The personal exposures across urban microenvironments were higher than those for rural or suburban microenvironments. Similarly, the exposure levels across outdoor microenvironments were higher than those for indoor microenvironments.

https://www.ncbi.nlm.nih.gov/pubmed/?term=27588949

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November/December 2016 issue of the *Journal of Exposure Science & Environmental Epidemiology:* three EMF papers

Kosuke Kiyohara, Kanako Wake, Soichi Watanabe, Takuji Arima, Yasuto Sato, Noriko Kojimahara, Masao Taki and Naohito Yamaguchi.Recall accuracy of mobile phone calls among Japanese young people. J Expo Sci Environ Epidemiol 26: 566-574; advance online publication, March 18, 2015; doi:10.1038/jes.2015.13.
https://www.ncbi.nlm.nih.gov/pubmed/?term=25783661

Benjamin Struchen, Ilaria Liorni, Marta Parazzini, Stephanie Gängler, Paolo Ravazzani and Martin Röösli. Analysis of personal and bedroom exposure to ELF-MFs in children in Italy and Switzerland. J Expo Sci Environ Epidemiol 26: 586-596; advance online publication, December 16, 2015; doi:10.1038/jes.2015.80.
https://www.ncbi.nlm.nih.gov/pubmed/?term=26669849

Madhuri Sudan, Jørn Olsen,Torben Sigsgaard and Leeka Kheifets. Trends in cell phone use among children in the Danish national birth cohort at ages 7 and 11 years. J Expo Sci Environ Epidemiol 26: 606-612; advance online publication, March 23, 2016; doi:10.1038/jes.2016.17.
https://www.ncbi.nlm.nih.gov/pubmed/?term=27005743

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Electromagnetic Shielding of Building Walls: From Roman times to the present age

Davide Micheli, Paolo Gianola, Giorgio Bertin, Andrea Delfini, Roberto Pastore, Mario Marchetti, Roberto Diana. Electromagnetic Shielding of Building Walls: From Roman times to the present age. IEEE Antennas and Propagation Magazine. 58(5). Oct. 2016.

Abstract

We have investigated the electromagnetic (EM) shielding effectiveness (SE) of building walls built in different ages. The measurements were carried out in the city of Rome, analyzing different building typologies from Roman Empire historical ruins up to modern reinforced concrete and steel/glass buildings. The method consisted of a measurement performed by means of a portable two-port vector network analyzer (VNA) connected to a couple of light antennas located in opposite positions with respect to the middle wall. The explored frequencies were in the range of 0.7-5.0 GHz, which many countries have currently adopted for mobile-phone radio access network (RAN) and satellite positioning services. The SE measurements showed values of up to 100 dB, and the analysis of the results showed that ancient Romans building walls and steel/glass building structures have the highest shielding capability. A numerical simulation of the outdoor-to-indoor transition attenuation and a statistical analysis of the signal code power in the live RAN of Telecom Italia integrate the discussion of the results.

http://ieeexplore.ieee.org/document/7551182/

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Biological and health effects of radiofrequency fields: Good study design and quality publications

Vijayalaxmi. Biological and health effects of radiofrequency fields: Good study design and quality publications. http://dx.doi.org/10.1016/j.mrgentox.2016.09.007.

Highlights

- Good study design for in vitro, in vivo and human investigations.
- Methods for statistical analyses.
- Check-list in quality publications.
- Conclusions.

Abstract

During recent decades, researchers have used several different parameters to evaluate the biological and health effects of in vitro and in vivo exposure to non-ionizing radiofrequency fields in animals, humans and their isolated cells. The data reported in many of publications in peer-reviewed scientific journals were reviewed by the international and national expert groups of scientists for human risk assessment of exposure to radiofrequency fields. The criteria used for such assessment depended on the study design, methodology and reporting of the data in the publication. This paper describes the requirements for good study design and quality publications, and provides guidance and a checklist for researchers studying radiofrequency fields and other environmental agents.

Conclusions

Investigations on the biological and health effects of RF exposure require close collaboration between biologists and engineers who have expertise in RF exposure assessment. The design of the studies as well as reporting the data in peer-reviewed publications should be of high quality. Detailed description of RF dosimetry is crucial and essential. Independent investigators should be able to replicate/confirm the observations under the same/improved experimental conditions. Such data are invaluable in strengthening the scientific knowledge which is essential for international and national evaluation of risk from RF exposure.

http://www.sciencedirect.com/science/article/pii/S1383571816302376

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Preliminary evidence that nanoparticle devices protect against EMR by reducing oxidative stress & inflammatory status

Francisco Ortiz, Beatriz I. Fernández-Gil, Ana Guerra-Librero, Luis C. López, Darío Acuña-Castroviejo, Germaine Escames. Preliminary evidence suggesting that nonmetallic and metallic nanoparticle devices protect against the effects of environmental electromagnetic radiation by reducing oxidative stress and inflammatory status. European Journal of Integrative Medicine, 8(5):835-840, October 2016.

Abstract

Introduction There is increasing interest in evaluating the potential health risks and biologic effects of exposure to extremely low-frequency magnetic fields (ELF-MF) and electromagnetic radiation (EMR), like those associated with personal computers, cellular phones, and environmental radiation (e.g., cellular towers, high-voltage power lines, radar). ELF-MF may generate free radicals in biological organisms, which leads to hyperoxidative status. Here, we investigated the potential efficacy of protective devices constructed with

nonmetallic and metallic nanoparticles, which are conductors and semiconductors of electromagnetic energy.

Methods In a before and after study, 20 healthy subjects who regularly used cellular phones and were exposed to typical environmental EMF were given one of three different (ELF-MF) protective devices. Blood samples were drawn at baseline and one month after using the devices to examine redox and inflammatory status.

Results We found that, 30 days after using the devices, plasma levels of lipid peroxidation, nitrites, and interferon-γ decreased significantly. Furthermore, the disulfide glutathione/glutathione ratio decreased, which indicated reduced intracellular oxidative damage. These data suggested that continuous use of devices that contain nonmetallic and metallic nanoparticles could protect healthy subjects from EMF-induced oxidative/inflammatory damage.

Conclusion Thus, for the first time, we have shown that the devices tested could be useful in counteracting the deleterious effects of EMF pollution by neutralizing harmful radiation before it reaches the body.

Funding. This work was partially supported by Pranan Technologies Ltd. (Pamplona, Spain). This study was partially supported by grants from Pranan Technologies (Navarra, Spain) and from the Consejería de Innovación, Ciencia, y Empresa, Junta de Andalucía, Spain (CTS-101).

http://www.sciencedirect.com/science/article/pii/S1876382016301111

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The electromagnetic basis of social interactions

A. R. Liboff. The electromagnetic basis of social interactions. Electromagnetic Biology & Medicine. Published online: 27 Oct 2016 http://dx.doi.org/10.1080/15368378.2016.1241180

Abstract

It has been established that living things are sensitive to extremely low-frequency magnetic fields at vanishingly small intensities, on the order of tens of nT. We hypothesize, as a consequence of this sensitivity, that some fraction of an individual's central nervous system activity can be magnetically detected by nearby individuals. Even if we restrict the information content of such processes to merely simple magnetic cues that are unconsciously received by individuals undergoing close-knit continuing exposure to these cues, it is likely that they will tend to associate these cues with the transmitting individual, no less than would occur if such signals were visual or auditory. Furthermore, following what happens when one experiences prolonged exposure to visual and like sensory inputs, it can be anticipated that such association occurring magnetically will eventually also enable the receiving individual to bond to the transmitting individual. One can readily extrapolate from single individuals to groups, finding reasonable explanations for group behavior in a number of social situations, including those occurring in families, animal packs, gatherings as found in concerts, movie theaters and sports arenas, riots and selected predatory/prey situations. The argument developed here not only is consistent with the notion of a magnetic sense in humans, but also provides a new approach to electromagnetic hypersensitivity, suggesting that it may simply result from sensory overload.

http://www.tandfonline.com/doi/full/10.1080/15368378.2016.1241180

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Protozoa: A Method for Monitoring of the Morphofunctional Disorders in Cells Exposed in the Cell Phone EMF

Uskalova DV, Igolkina YV, Sarapultseva EI. Intravital Computer Morphometry on Protozoa: A Method for

Monitoring of the Morphofunctional Disorders in Cells Exposed in the Cell Phone Communication Electromagnetic Field. Bull Exp Biol Med. 2016 Aug;161(4):554-7. doi: 10.1007/s10517-016-3459-2. Epub 2016 Sep 3.

Abstract

Morphofunctional disorders in unicellular aquatic protozoa - Spirostomum ambiguum infusorians after 30-, 60-, and 360-min exposure in electromagnetic field at a radiation frequency of 1 GHz and energy flow density of 50 μW/cm(2) were analyzed by intravital computer morphometry. Significant disorders in morphometric values correlated with low mobility of the protozoa. The results suggested the use of intravital computer morphometry on the protozoa for early diagnosis of radiation-induced effects of the mobile communication electromagnetic field, for example, low mobility of spermatozoa.

Excerpt

In 2003 sanitary epidemiological regulations and Sanitary Regulations and Standards 2.1.8/2.2.4.1190-03 were introduced in Russia. These regulations set up the **most stringent in the world maximal allowable values for energy flow density (EFD) – 10 μW/cm**2 **at a frequency of 900-1800 MHz for whole-body absorbed energy flow (SAR0 of 44 mW/kg**) [5]. These standards are based on observations carried out with participation of few volunteers and in model experiments on warm-blooded animals, cultured cells, lower animals, and plants [13]. It should be noted that communication network operators use several technologies and wireless communication standards simultaneously, as a result of which the mean EMF levels in the Moscow region increased by an order of magnitude higher than the allowed values [2].

https://www.ncbi.nlm.nih.gov/pubmed/?term=27591872

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Microwaves and Alzheimer's disease

Zhang X, Huang WJ, Chen WW. Microwaves and Alzheimer's disease. Exp Ther Med. 2016 Oct;12(4):1969-1972.

Abstract

Alzheimer's diseases (AD) is the most common type of dementia and a neurodegenerative disease that occurs when the nerve cells in the brain die. The cause and treatment of AD remain unknown. However, AD is a disease that affects the brain, an organ that controls behavior. Accordingly, anything that can interact with the brain may affect this organ positively or negatively, thereby protecting or encouraging AD. In this regard, modern life encompasses microwaves for all issues including industrial, communications, medical and domestic tenders, and among all applications, the cell phone wave, which directly exposes the brain, continues to be the most used. Evidence suggests that microwaves may produce various biological effects on the central nervous system (CNS) and many arguments relay the possibility that microwaves may be involved in the pathophysiology of CNS disease, including AD. By contrast, previous studies have reported some beneficial cognitive effects and that microwaves may protect against cognitive impairment in AD. However, although many of the beneficial effects of microwaves are derived from animal models, but can easily be extrapolated to humans, whether microwaves cause AD is an important issue that is to be addressed in the current review.

Open Access Paper: http://bit.ly/ADwireless

Also see: http://www.saferemr.com/2016/10/does-wireless-radiation-from-cell.html

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Environmental risk factors for dementia: a systematic review

Lewis O. J. Killin, John M. Starr, Ivy J. Shiue, Tom C. Russ. Environmental risk factors for dementia: a systematic review. BMC Geriatrics. 12 October 2016. DOI: 10.1186/s12877-016-0342-y

Abstract

Background Dementia risk reduction is a major and growing public health priority. While certain modifiable risk factors for dementia have been identified, there remains a substantial proportion of unexplained risk. There is evidence that environmental risk factors may explain some of this risk. Thus, we present the first comprehensive systematic review of environmental risk factors for dementia.

Methods We searched the PubMed and Web of Science databases from their inception to January 2016, bibliographies of review articles, and articles related to publically available environmental data. Articles were included if they examined the association between an environmental risk factor and dementia. Studies with another outcome (for example, cognition), a physiological measure of the exposure, case studies, animal studies, and studies of nutrition were excluded. Data were extracted from individual studies which were, in turn, appraised for methodological quality. The strength and consistency of the overall evidence for each risk factor identified was assessed.

Results We screened 4784 studies and included 60 in the review. Risk factors were considered in six categories: air quality, toxic heavy metals, other metals, other trace elements, occupational-related exposures, and miscellaneous environmental factors. Few studies took a life course approach. There is at least moderate evidence implicating the following risk factors: air pollution; aluminium; silicon; selenium; pesticides; vitamin D deficiency; and electric and magnetic fields.

Conclusions Studies varied widely in size and quality and therefore we must be circumspect in our conclusions. Nevertheless, this extensive review suggests that future research could focus on a short list of environmental risk factors for dementia. Furthermore, further robust, longitudinal studies with repeated measures of environmental exposures are required to confirm these associations.

http://bmcgeriatr.biomedcentral.com/articles/10.1186/s12877-016-0342-y

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Review paper: Proteomic impacts of electromagnetic fields on the male reproductive system

Sepehrimanesh, M. & Davis, D.L. Proteomic impacts of electromagnetic fields on the male reproductive system. Comp Clin Pathol (2016). doi:10.1007/s00580-016-2342-x Published online Oct 13, 2016.

Abstract

The use of mobile phones and other wireless transmitting devices is increasing dramatically in developing and developed countries, as is the rate of infertility. A number of respected infertility clinics in Australia, India, USA, and Iran are reporting that those who regularly use mobile phones tend to have reduced sperm quantity and quality. Some experimental studies have found that human sperm exposed to electromagnetic fields (EMF), either simulated or from mobile phones, developed biomarkers of impaired structure and function, as well as reduced quantity. These encompass pathological, endocrine, and proteomic changes. Proteins perform a vast array of functions within living organisms, and the proteome is the entire array of proteins—the ultimate biomolecules in the pathways of DNA transcription to translation. Proteomics is the art and science of studying all proteins in cells, using different techniques. This paper reviews proteomic experimental and clinical evidence that EMF acts as a male-mediated teratogen and contributor to infertility.

http://link.springer.com/article/10.1007%2Fs00580-016-2342-x

Not yet archived in PubMed.

Also see: http://www.saferemr.com/2015/09/effect-of-mobile-phones-on-sperm.html

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Investigation of bias related to differences between case and control interview dates in five INTERPHONE countries

Michelle C. Turner, Siegal Sadetzki, Chelsea E. Langer, Rodrigo Villegas, Jordi Figuerola, Bruce K. Armstrong, Angela Chetrit, Graham G. Giles,
Daniel Krewski, Martine Hours, Mary L. McBride, Marie-Elise Parent, Lesley Richardson, Jack Siemiatycki, Alistair Woodward, Elisabeth Cardis.
Investigation of bias related to differences between case and control interview dates in five INTERPHONE countries. Annals of Epidemiology. http://dx.doi.org/10.1016/j.annepidem.2016.09.013, Epub first Oct 8, 2016.

Abstract

Purpose Associations between cellular telephone use and glioma risk have been examined in several epidemiological studies including the 13-country INTERPHONE study. Although results showed no positive association between cellular telephone use and glioma risk overall, no increased risk for long term users, and no exposure-response relationship, there was an elevated risk for those in the highest decile of cumulative call time. However, results may be biased as data were collected during a period of rapidly increasing cellular telephone use, and as controls were usually interviewed later in time than cases.

Methods Further analyses were conducted in a subset of five INTERPHONE study countries (Australia, Canada, France, Israel, New Zealand) using a post-hoc matching strategy to optimize proximity of case to control interview dates and age.

Results Though results were generally similar to the original INTERPHONE study, there was some attenuation of the reduced odds ratios and stronger positive associations among long term users and those in the highest categories for cumulative call time and number of calls (8-9th and 10th decile).

Conclusions Proximity and symmetry in timing of case to control interviews should be optimized when exposure patterns are changing rapidly with time.

http://www.sciencedirect.com/science/article/pii/S1047279716303702

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Carl Blackman discusses ELF and RF health effects

Carl F. Blackman.Comment on “Milham & Stetzer (2016) Tumor-specific frequencies and ocular melanoma.” Electromag Biol Med http://dx.doi.org/10.1080/15368378.2016.1234390
http://www.tandfonline.com/doi/full/10.1080/15368378.2016.1234390

Bio

Dr. Blackman is a biophysicist who worked as a research scientist in the US Environmental Protection Agency (EPA) from 1970 until his recent retirement. He researched electric and magnetic field interactions with biological systems until the U.S. Congress cut off EPA funding for EMF research in the 1990's. His work resulted in several discoveries including multiple effect "windows" of intensity and frequency, and the demonstration that the earth's magnetic field was involved in biological responses to EMF. He collaborated on the development of math models used to predict EMF conditions that cause biological responses. He and his colleagues discovered that melatonin can modulate gap junction intercellular communication and partially oppose the action of tumor-promoting agents to close this communication.They also demonstrated that the biological action of melatonin can be altered by magnetic field exposure. He is one of six founders of the Bioelectromagnetics Society (BEMS) in 1978, served as president in 1990-1991, and as a member of the editorial board of the Society's journal for 14 years. He served on the WHO committee to evaluate the health implications of radiofrequency radiation exposure (Environmental Health Criteria #137, 1993), and on an IARC committee that evaluated the carcinogenic potential of low frequency electric and magnetic fields in 2001 (Volume 80, 2002). In 2014 he received the BEMS d'Arsonval Award to recognize extraordinary accomplishment in bioelectromagnetics.

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RF Exposure Amongst Employees of Mobile Network Operators and Broadcasters

Ian Litchfield, Martie van Tongeren, Tom Sorahan. Radiofrequency Exposure Amongst Employees of Mobile Network Operators and Broadcasters. Radiation Protection Dosimetry. *doi: 10.1093/rpd/ncw283* First published online: October 13, 2016

Abstract

Little is known about personal exposure to radiofrequency (RF) fields amongst employees in the telecommunications industry responsible for installing and maintaining transmitters. IARC classified RF exposure as a possible carcinogen, although evidence from occupational studies was judged to be inadequate. Hence, there is a need for improved evidence of any potentially adverse health effects amongst the workforce occupationally exposed to RF radiation. In this study, results are presented from an exposure survey using data from personal monitors used by employees in the broadcasting and telecommunication industries of the UK. These data were supplemented by spot measurements using broadband survey metres and information on daily work activities provided by employee questionnaires. The sets of real-time personal data were categorised by four types of site determined by the highest powered antenna present (high, medium or low power and ground-level sites). For measurements gathered at each type of site, the root mean square and a series of box plots were produced. Results from the daily activities diaries suggested that riggers working for radio and television broadcasters were exposed to much longer periods as compared to colleagues working for mobile operators. Combining the results from the measurements and daily activity diaries clearly demonstrate that exposures were highest for riggers working for broadcasting sites. This study demonstrates that it is feasible to carry out exposure surveys within these populations that will provide reliable estimates of exposure that can be used for epidemiological studies of occupational groups exposed to RF fields.

Open Access Paper: http://m.rpd.oxfordjournals.org/content/early/2016/10/13/rpd.ncw283.full

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Treatment of Neuropathic Pain Using Pulsed Radiofrequency: A Meta-analysis

Shi Y, Wu W. Treatment of Neuropathic Pain Using Pulsed Radiofrequency: A Meta-analysis.Pain Physician. 2016 Sep-Oct;19(7):429-44.

Abstract

BACKGROUND: Neuropathic pain (NP) is a major public health problem worldwide. Because of the unclear mechanism of NP, its treatment is one of the most difficult medical problems. As a targeted, noninvasive, safe therapy, pulsed radiofrequency (PRF) provides a new method for the treatment of NP; however, its effect on this treatment still lacks support from evidence-based medicine.

OBJECTIVE: To conduct a meta-analysis of available randomized controlled trials and to evaluate the

effectiveness and clinical utility of PRF for the treatment of NP.

STUDY DESIGN: Meta-analysis.

SETTING: All selected studies were randomized controlled trials.

METHOD: A systematic and comprehensive database search was performed of the PubMed, CENTRAL, EMBASE.com, Cochrane Library, Chinese Biomedical Literature, and Wanfang databases for literature published from the establishment of the databases to December 19, 2015. According to inclusion and exclusion criteria, the results of randomized controlled trials supporting PRF for NP treatment were collected. The risk of bias tool described in the Cochrane Handbook version 5.1.0 was used to assess the quality of each trial. Meta-analysis was performed using RevMan 5.3 software.

RESULTS: A total of 12 randomized controlled trials involving 592 patients met the inclusion criteria. Overall, the results of the meta-analysis showed that, compared with the control group, PRF had a better effect on postherpetic neuralgia (PHN) in terms of pain score (one week, one month, and 3 months), excellent and good rate (one day, one month), and efficiency rate (one day). But PRF did not have a better effect on radicular pain in pain score (3 months). Side effects were less frequently found with the PRF treatment.

LIMITATIONS: Although we repeatedly tested the key words and used a manual method to prevent the loss of studies, due to the limitation of the included studies, some of the data were insufficient to complete the meta-analysis, and we were unable to obtain the original data from some studies. Some studies did not report the blind design, which decreased the quality of the current study.

CONCLUSION: PRF did not have a better effect on radicular pain, and PRF is an effective and safe therapeutic alternative for the analgesia of PHN. However, for a high recurrence rate over a long period, repeated PRF treatment has limitations.

https://www.ncbi.nlm.nih.gov/pubmed/27676660?dopt=Abstract

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Effect of Electromagnetic Interference on Human Body Communication

Jung-Hwan Hwang ; Tae-Wook Kang ; Jong-Hwa Kwon ; Seong-Ook Park. Effect of Electromagnetic Interference on Human Body Communication.
IEEE Transactions on Electromagnetic Compatibility. PP(99):1-10. 22 September 2016.DOI: 10.1109/TEMC.2016.2598582

Abstract

In human body communication (HBC), the human body is used as a medium for transmitting data between devices as a replacement for wired and wireless technologies. The human body functions as an antenna in the low-frequency band used by HBC. Owing to this antenna function, electromagnetic waves radiating from electronic devices or wireless services cause electromagnetic interference (EMI) in HBC devices. This paper addresses such EMI in HBC devices. The interference signal caused by EMI was measured while the human subject, who was using an HBC device, was exposed to a general EMI environment at multiple sites. Using the interference model obtained from the measured interference signals, bit-error-rate degradation caused by the interference signal was simulated. The interference model presented in this paper can be effectively used to achieve reliable data communication in various HBC devices.

http://ieeexplore.ieee.org/document/7574274/

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Effect of DECT non-ionizing radiation on cultivated plants of Arabidopsis thaliana

Aikaterina L. Stefia, Lukas H. Margaritisb, Nikolaos S. Christodoulakisa. The effect of the non-ionizing radiation on cultivated plants of Arabidopsis thaliana (Col.). Flora - Morphology, Distribution, Functional Ecology of Plants. Volume 223, August 2016, Pages 114–120. http://dx.doi.org/10.1016/j.flora.2016.05.008

Highlights

• Arabidopsis thaliana plants grow under long term microwave radiation.
• Minor structural changes observed.
• Chloroplast number affected.
• Photosynthetic pigment content affected.
• Total biomass reduced.

Abstract

A series of experiments was carried out to investigate any structural or biochemical alterations on Arabidopsis thaliana (Col.) plants after a long term exposure to non ionizing radiation emitted from the base unit of a cordless DECT system. Exposed plants, compared to their control counterparts, seem to be affected concerning their biomass and leaf structure. Their leaves are thinner and possess fewer chloroplasts. SEM observations of the exposed leaves reveal that the only feature affected is the pubescence which almost disappears while TEM investigation revealed minor structural effects in the chloroplasts. The reduction in the number of chloroplasts as well as the decrease of stroma thylakoids and photosynthetic pigments are probably the main reasons for a weak photosynthetic potential and a consequent reduction of the biomass production.

http://www.sciencedirect.com/science/article/pii/S0367253016300780?np=y

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RF radiation (900 MHz)-induced DNA damage and cell cycle arrest in testicular germ cells in mice

Pandey N, Giri S, Das S, Upadhaya P. Radiofrequency radiation (900 MHz)-induced DNA damage and cell cycle arrest in testicular germ cells in swiss albino mice. Toxicol Ind Health. 2016 Oct 13. pii: 0748233716671206.

Abstract

Even though there are contradictory reports regarding the cellular and molecular changes induced by mobile phone emitted radiofrequency radiation (RFR), the possibility of any biological effect cannot be ruled out. In view of a widespread and extensive use of mobile phones, this study evaluates alterations in male germ cell transformation kinetics following RFR exposure and after recovery. Swiss albino mice were exposed to RFR (900 MHz) for 4 h and 8 h duration per day for 35 days. One group of animals was terminated after the exposure period, while others were kept for an additional 35 days post-exposure. RFR exposure caused depolarization of mitochondrial membranes resulting in destabilized cellular redox homeostasis. Statistically significant increases in the damage index in germ cells and sperm head defects were noted in RFR-exposed animals. Flow cytometric estimation of germ cell subtypes in mice testis revealed 2.5-fold increases in spermatogonial populations with significant decreases in spermatids. Almost fourfold reduction in spermatogonia to spermatid turnover (1C:2C) and three times reduction in primary spermatocyte to spermatid turnover (1C:4C) was found indicating arrest in the premeiotic stage of spermatogenesis, which resulted in loss of post-meiotic germ cells apparent from testis histology and low sperm count in RFR-exposed animals. Histological alterations such as sloughing of immature germ cells into the seminiferous tubule lumen,

epithelium depletion and maturation arrest were also observed. However, all these changes showed recovery to varied degrees following the post-exposure period indicating that the adverse effects of RFR on mice germ cells are detrimental but reversible. To conclude, RFR exposure-induced oxidative stress causes DNA damage in germ cells, which alters cell cycle progression leading to low sperm count in mice.

https://www.ncbi.nlm.nih.gov/pubmed/27738269?dopt=Abstract

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Effects of long-term exposure to 900 MHz EMF on heart morphology and biochemistry of male adolescent rats

Kerimoğlu G, Mercantepe T, Erol HS, Turgut A, Kaya H, Çolakoğlu S, Odacı E. Effects of long-term exposure to 900 megahertz electromagnetic field on heart morphology and biochemistry of male adolescent rats. Biotech Histochem. 2016 Aug 11:1-10.

Abstract

The pathological effects of exposure to an electromagnetic field (EMF) during adolescence may be greater than those in adulthood. We investigated the effects of exposure to 900 MHz EMF during adolescence on male adult rats. Twenty-four 21-day-old male rats were divided into three equal groups: control (Cont-Gr), sham (Shm-Gr) and EMF-exposed (EMF-Gr). EMF-Gr rats were placed in an EMF exposure cage (Plexiglas cage) for 1 h/day between postnatal days 21 and 59 and exposed to 900 MHz EMF. Shm-Gr rats were placed inside the Plexiglas cage under the same conditions and for the same duration, but were not exposed to EMF. All animals were sacrificed on postnatal day 60 and the hearts were extracted for microscopic and biochemical analyses. Biochemical analysis showed increased levels of malondialdehyde and superoxide dismutase, and reduced glutathione and catalase levels in EMF-Gr compared to Cont-Gr animals. Hematoxylin and eosin stained sections from EMF-Gr animals exhibited structural changes and capillary congestion in the myocardium. The percentage of apoptotic myocardial cells in EMF-Gr was higher than in either Shm-Gr or Cont-Gr animals. Transmission electron microscopy of myocardial cells of EMF-Gr animals showed altered structure of Z bands, decreased myofilaments and pronounced vacuolization. We found that exposure of male rats to 900 MHz EMF for 1 h/day during adolescence caused oxidative stress, which caused structural alteration of male adolescent rat heart tissue.

https://www.ncbi.nlm.nih.gov/pubmed/27715326?dopt=Abstract

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Effect of Radiofrequency Radiation on Human Hematopoietic Stem Cells

Gläser K, Rohland M, Kleine-Ostmann T, Schrader T, Stopper H, Hintzsche H. Effect of Radiofrequency Radiation on Human Hematopoietic Stem Cells. Radiat Res. 2016 Oct 6.

Abstract

Exposure to electromagnetic fields in the radiofrequency range is ubiquitous, mainly due to the worldwide use of mobile communication devices. With improving technologies and affordability, the number of cell phone subscriptions continues to increase. Therefore, the potential effect on biological systems at low-intensity radiation levels is of great interest. While a number of studies have been performed to investigate this issue, there has been no consensus reached based on the results. The goal of this study was to elucidate the extent to which cells of the hematopoietic system, particularly human hematopoietic stem cells (HSC), were affected by mobile phone radiation. We irradiated HSC and HL-60 cells at frequencies used in the major technologies, GSM (900 MHz), UMTS (1,950 MHz) and LTE (2,535 MHz) for a short period (4 h) and a long period (20 h/66 h), and with five different intensities ranging from 0 to 4 W/kg specific absorption rate (SAR). Studied end

points included apoptosis, oxidative stress, cell cycle, DNA damage and DNA repair. In all but one of these end points, we detected no clear effect of mobile phone radiation; the only alteration was found when quantifying DNA damage. Exposure of HSC to the GSM modulation for 4 h caused a small but statistically significant decrease in DNA damage compared to sham exposure. To our knowledge, this is the first published study in which putative effects (e.g., genotoxicity or influence on apoptosis rate) of radiofrequency radiation were investigated in HSC. Radiofrequency electromagnetic fields did not affect cells of the hematopoietic system, in particular HSC, under the given experimental conditions.

https://www.ncbi.nlm.nih.gov/pubmed/27710704?dopt=Abstract

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Effects of ELF EMF and cisplatin on mRNA levels of some DNA repair genes

Sanie-Jahromi F, Saadat 2, Saadat M. Effects of extremely low frequency electromagnetic field and cisplatin on mRNA levels of some DNA repair genes. Life Sci. 2016 Oct 6. pii: S0024-3205(16)30588-4. doi: 10.1016/j.lfs.2016.10.006.

Highlights

• Extremely-low frequency electromagnetic field (ELF-EMF) can affect gene expression.
• mRNA levels of seven genes involved in DNA repair pathways were evaluated.
• The examined genes had tendency to be down-regulated in the cells treated with EMF.
• *GADD45A* mRNA levels in cells co-treated with cisplatin (CDDP) + EMF were increased.
• Co-treatment of CDDP + EMF enhances down-regulation of the genes of NHEJ pathway.
• Elevation in IC_{50} of CDDP when cells co-treated with CDDP + EMF was observed.

Abstract

AIMS: It has been shown that exposure to extremely-low frequency (<300Hz) oscillating electromagnetic field (EMF) can affect gene expression. The effects of different exposure patterns of 50-Hz EMF and co-treatment of EMF plus cisplatin (CDDP) on mRNA levels of seven genes involved in DNA repair pathways (GADD45A, XRCC1, XRCC4, Ku70, Ku80, DNA-PKcs and LIG4) were evaluated.

MAIN METHODS: Two 50-Hz EMF intensities (0.25 and 0.50mT), three exposure patterns (5min field-on/5min field-off, 15min field-on/15min field-off, 30min field-on continuously) and two cell lines (MCF-7 and SH-SY5Y) were used. The mRNA levels were measured using quantitative real-time PCR.

KEY FINDINGS: The examined genes had tendency to be down-regulated in MCF-7 cells treated with EMF. In the pattern of 15min field-on/15min field-off of the 0.50mT EMF, no increase in mRNA levels were observed, but the mRNA levels of GADD45A, XRCC1, XRCC4, Ku80, Ku70, and LIG4 were down-regulated. A significant elevation in IC50 of CDDP was observed when MCF-7 and SH-SY5Y cells were co-treated with CDDP+EMF in comparison with the cells treated with CDDP alone. GADD45A mRNA levels in MCF-7 and SH-SY5Y cells co-treated with CDDP+EMF were increased and at the same time the mRNA levels of XRCC4, Ku80, Ku70 and DNA-PKcs were down-regulated.

SIGNIFICANCE: Present study provides evidence that co-treatment of CDDP+EMF can enhance down-regulation of the genes involved in non-homologous end-joining pathway. It might be suggested that co-treatment of CDDP+EMF could be more promising for sensitizing cancer cells to DNA double strand breaks.

https://www.ncbi.nlm.nih.gov/pubmed/27721000?dopt=Abstract

Research Compilation; Abstracts of 15 New Studies,
Dr. Joel Moskowitz PhD., 2016

From: **Joel MOSKOWITZ** <jmm@berkeley.edu>
Date: Mon, Sep 26, 2016 at 2:46 PM
Subject: 15 new studies on electromagnetic fields and biology or health
To: CHE-EMF <cheemf@lists. healthandenvironment.org>

A review on Electromagnetic fields (EMFs) and the reproductive system

Asghari A, Khaki AA, Rajabzadeh A, Khaki A. A review on Electromagnetic fields (EMFs) and the reproductive system. Electron Physician. 2016 Jul 25;8(7):2655-62. doi: 10.19082/2655. eCollection 2016.

Abstract

Environmental factors, such as electromagnetic waves, induce biological and genetic effects. One of the most important physiological systems involved with electromagnetic fields (EMFs) is the genital system. This paper reviews the effects of EMFs on human reproductive organs, female animals, fetus development and the importance of two types of natural antioxidants, i.e., vitamin E and fennel. The studies presented in this review referred to the effects of different exposures to EMFs on the reproductive system, and we tried to show the role of natural antioxidants in reducingthe effects of the exposures. Many studies have been done on the effects of ionizing and non-ionizing electromagnetic waves on the cell line of spermatogenesis, sexual hormones, and the structure of the testes. Also, about the hormonal cycle, folliculogenesis and female infertility related to EMF have been given more consideration. In particular, attention is directed to pregnant women due to the importance of their fetuses. However, in addition to the studies conducted on animals, further epidemiological research should be conducted.

Conclusions

Many studies have shown that electromagnetic fields can have destructive effects on sex hormones, gonadal function, fetal development, and pregnancy. So people must be aware of the negative effects of EMFs. Although the impact of the waves varied at different frequencies, it is better to stay as far away as possible from their origin because of the risks associated with exposures to these waves. In addition, people can use natural antioxidants to help reduce the effects of these waves.

Open Access Paper: https://www.ncbi.nlm.nih.gov/p mc/articles/PMC5014506/

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Effects of electromagnetic fields emitted by GSM phones on working memory: a meta-analysis

Zubko O, Gould RL, Gay HC, Cox HJ, Coulson MC, Howard RJ. Effects of electromagnetic fields emitted by GSM phones on working memory: a meta-analysis.Int J Geriatr Psychiatry. 2016 Sep 20. doi: 10.1002/gps.4581. [Epub ahead of print]

Abstract

BACKGROUND AND OBJECTIVE: Current treatments for Alzheimer's Disease (AD) do not affect the course of the illness and brain stimulation techniques are increasingly promoted as potential therapeutic interventions for AD. This study reviews the effects of electromagnetic field (EMF) exposure versus sham exposure on working memory (WM) performance of healthy human participants.

METHOD: Online literature databases and previous systematic reviews were searched for studies of EMF and WM in participants without reported memory problems. Two thousand eight hundred and fifty seven studies

were identified, and 10 studies met the inclusion criteria. An assessment of study quality was completed, and separate, random effects meta-analyses were conducted for each of the three WM tasks included: n-back, substitution and digit span forward.

RESULTS: No differences were found between participants exposed to active EMF versus sham conditions in any of the three working memory tasks examined.

CONCLUSION: Results indicate that EMF does not affect WM during the n-back, substitution and digit-span tasks. Future studies should focus on the possible effects of chronic exposure to EMF in older adults with AD using a battery of comparable WM and attention tasks, before EMF can be seriously considered as a potential modulator of WM in AD.

http://www.ncbi.nlm.nih.gov/pu bmed/27645289?dopt=Abstract

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Exposure to Visible Light Emitted from Smartphones and Tablets Increases the Proliferation of S. aureus: Can this be Linked to Acne?

MJ Mortazavi, M Taheri, M Darabian, Izadbakhsh, F Nouri, Masoud Haghani, SAR Mortazavi, Ghazal Mortazavi, SMJ Mortazavi, M Moradi. Exposure to Visible Light Emitted from Smartphones and Tablets Increases the Proliferation of S. aureus: Can this be Linked to Acne? Journal of Biomedical Physics and Engineering (JBPE), in press. Published on September 24, 2016

Abstract

The exponential rise in the use of handheld devices such as smartphones and tablets has raised global concerns about the safety of these devices. Smartphones, tablets, laptops, and other LED screens can emit high levels of short-wavelength visible light (blue region in the light spectrum). Over the past several years, the biological effects of exposure to shortwavelength visible light emitted from smartphones and tablets on the eye and skin (premature skin aging) have been widely studied. However, to the best of our knowledge, the effect of exposure to light emitted from these devices on the proliferation of Staphylococcus aureus and the possible association of its exposure to light and acne pathogenesis has not been investigated yet. In this study, the effect of exposure to visible light emitted from the screens of a commercial smartphone (Sony Xperia) and a commercial tablet (Samsung Galaxy Note 10.1) on the growth rate of Staphylococcus aureus bacteria (ATCC No. 25923) is investigated. Some studies show that Staphylococcus aureus can intensify the symptoms in chronic inflammatory skin diseases. Acne vulgaris has been reported to be the most common human skin disorder. This skin disorder was reported to be persistent in 80% of the women (58% of these women had an ongoing need for treatment). All experiments were performed at 37°C in a separate incubator and bacteria were grown in 20 ml Brain Heart Infusion Broth (BHI) 10 cm plates. Then, in a dark environment, bacteria were exposed to the light of the smartphone and tablet at a distance of 2-3 mm (common distance between the smartphones and facial skin). The brightness of the displays of these devices was set at 50%. The control samples were exposed to the same intensity of light generated by a conventional incandescent light bulb.The growth rate of bacteria was examined by measuring the optical density (OD) at 625 nm (UNICO UV-2100 spectrophotometer) before the light exposure and after 30, 60, 90, 120, 150, 180, 210, 240, 300, and 330 minutes of light exposure. The growth rates of bacteria in both smartphone and tablet groups were higher than that of the control group and the maximum smartphone/control and tablet/control growth ratios were observed in samples exposed to digital screens' light for 300 min (3.71 and 3.95, respectively). These ratios declined in samples exposed to screens' light for durations higher than 300 min. Altogether, these findings show that exposure to short-wavelength visible light emitted from smartphones and tablets can increase the proliferation of Staphylococcus aureus. Due to limitations of this study, further studies are needed to shed more light on the dark corners of the effect of digital screens' light on different microorganisms and to verify if these exposures can be linked to acne

pathogenesis.

https://www.linkedin.com/pulse /exposure-visible-light-emitte d-from-smartphones-aureus-smj- mortazavi

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Use of Signal-Transduction & Metabolic Pathways to Predict Human Disease Targets from EMF Using in vitro Data in Human Cell Lines

Parham F, Portier CJ, Chang X, Mevissen M.The Use of Signal-Transduction and Metabolic Pathways to Predict Human Disease Targets from Electric and Magnetic Fields Using in vitro Data in Human Cell Lines. Front Public Health. 2016 Sep 7;4:193. doi: 10.3389/fpubh.2016.00193. eCollection 2016.

Abstract

Using in vitro data in human cell lines, several research groups have investigated changes in gene expression in cellular systems following exposure to extremely low frequency (ELF) and radiofrequency (RF) electromagnetic fields (EMF). For ELF EMF, we obtained five studies with complete microarray data and three studies with only lists of significantly altered genes. Likewise, for RF EMF, we obtained 13 complete microarray datasets and 5 limited datasets. Plausible linkages between exposure to ELF and RF EMF and human diseases were identified using a three-step process: (a) linking genes associated with classes of human diseases to molecular pathways, (b) linking pathways to ELF and RF EMF microarray data, and (c) identifying associations between human disease and EMF exposures where the pathways are significantly similar. A total of 60 pathways were associated with human diseases, mostly focused on basic cellular functions like JAK-STAT signaling or metabolic functions like xenobiotic metabolism by cytochrome P450 enzymes. ELF EMF datasets were sporadically linked to human diseases, but no clear pattern emerged. Individual datasets showed some linkage to cancer, chemical dependency, metabolic disorders, and neurological disorders. RF EMF datasets were not strongly linked to any disorders but strongly linked to changes in several pathways. Based on these analyses, the most promising area for further research would be to focus on EMF and neurological function and disorders.

Open Access Paper: https://www.ncbi.nlm.nih.gov/p mc/articles/PMC5013261/

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RF radiation at Stockholm Central Railway Station in Sweden and some medical aspects on public exposure to RF fields

Hardell L, Koppel T, Carlberg M, Ahonen M, Hedendahl L. Radiofrequency radiation at Stockholm Central Railway Station in Sweden and some medical aspects on public exposure to RF fields.Int J Oncol. 2016 Aug 12. doi: 10.3892/ijo.2016.3657. [Epub ahead of print]

Abstract

The Stockholm Central Railway Station in Sweden was investigated for public radiofrequency (RF) radiation exposure. The exposimeter EME Spy 200 was used to collect the RF exposure data across the railway station. The exposimeter covers 20 different radiofrequency bands from 88 to 5,850 MHz. In total 1,669 data points were recorded. The median value for total exposure was 921 µW/m2 (or 0.092 µW/cm2; 1 µW/m2=0.0001 µW/cm2) with some outliers over 95,544 µW/m2 (6 V/m, upper detection limit). The mean total RF radiation level varied between 2,817 to 4,891 µW/m2 for each walking round. High mean measurements were obtained for GSM + UMTS 900 downlink varying between 1,165 and 2,075 µW/m2. High levels were also obtained for UMTS 2100 downlink; 442 to 1,632 µW/m2. Also LTE 800 downlink, GSM 1800 downlink, and LTE 2600

downlink were in the higher range of measurements. Hot spots were identified, for example close to a wall mounted base station yielding over 95,544 µW/m2 and thus exceeding the exposimeter's detection limit. Almost all of the total measured levels were above the precautionary target level of 3-6 µW/m2 as proposed by the BioInitiative Working Group in 2012. That target level was one-tenth of the scientific benchmark providing a safety margin either for children, or chronic exposure conditions. We compare the levels of RF radiation exposures identified in the present study to published scientific results reporting adverse biological effects and health harm at levels equivalent to, or below those measured in this Stockholm Central Railway Station project. It should be noted that these RF radiation levels give transient exposure, since people are generally passing through the areas tested, except for subsets of people who are there for hours each day of work.

http://www.ncbi.nlm.nih.gov/pu bmed/27633090?dopt=Abstract

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Exposure to electromagnetic fields aboard high-speed electric multiple unit trains

Niu D, Zhu F, Qiu R, Niu Q. Exposure to electromagnetic fields aboard high-speed electric multiple unit trains. J Biol Regul Homeost Agents. 2016 Jul-Sep;30(3):727-731.

Abstract

High-speed electric multiple unit (EMU) trains generate high-frequency electric fields, low-frequency magnetic fields, and high-frequency wideband electromagnetic emissions when running. Potential human health concerns arise because the electromagnetic disturbances are transmitted mainly into the car body from windows, and from there to passengers and train staff. The transmission amount and amplitude distribution characteristics that dominate electromagnetic field emission need to be studied, and the exposure level of electromagnetic field emission to humans should be measured. We conducted a series of tests of the on board electromagnetic field distribution on several high-speed railway lines. While results showed that exposure was within permitted levels, the possibility of long-term health effects should be investigated.

https://www.ncbi.nlm.nih.gov/p ubmed/27655489?dopt=Abstract

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Tumor-specific frequencies and ocular melanoma

Milham S, Stetzer D. Tumor-specific frequencies and ocular melanoma. Electromagn Biol Med. 2016 Aug 23:1-5. [Epub ahead of print]

Abstract

Specific kilohertz frequencies in the environment from variable frequency drives on electric motors at a liquid natural gas compressor and storage station on a natural gas pipeline seem to be associated with the development of a very rare cancer, ocular melanoma, at a high school and in individuals living or working in a neighborhood near the plant. Primary neutral-to-earth oscilloscope voltage waveforms and spectra measured near the high school were nearly identical to the ground voltage 2.3 miles away at the gas pipeline. Peak frequencies of 7440 and 19,980 Hz were found at both places. The electric utility practice of using the earth as a conduit for return currents facilitated this exposure.

Conclusion

We believe that specific kilohertz frequencies in the environment from VFDs on electric motors at a liquid natural gas plant caused a very rare cancer, OM, in the neighborhood of the plant. The electric utility practice of using the earth as a conduit for return currents facilitated this exposure. Other single cancer clusters should be examined similarly.

https://www.ncbi.nlm.nih.gov/p ubmed/27552371

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Review: Weak radiofrequency radiation exposure from mobile phone radiation on plants

Halgamuge MN. Review: Weak radiofrequency radiation exposure from mobile phone radiation on plants.Electromagn Biol Med. 2016 Sep 20:1-23. [Epub ahead of print]

Abstract

AIM: The aim of this article was to explore the hypothesis that non-thermal, weak, radiofrequency electromagnetic fields (RF-EMF) have an effect on living plants.

SUBJECT AND METHODS: In this study, we performed an analysis of the data extracted from the 45 peer-reviewed scientific publications (1996-2016) describing 169 experimental observations to detect the physiological and morphological changes in plants due to the non-thermal RF-EMF effects from mobile phone radiation. Twenty-nine different species of plants were considered in this work.

RESULTS: Our analysis demonstrates that the data from a substantial amount of the studies on RF-EMFs from mobile phones show physiological and/or morphological effects (89.9%, $p < 0.001$). Additionally, our analysis of the results from these reported studies demonstrates that the maize, roselle, pea, fenugreek, duckweeds, tomato, onions and mungbean plants seem to be very sensitive to RF-EMFs. Our findings also suggest that plants seem to be more responsive to certain frequencies, especially the frequencies between (i) 800 and 1500 MHz ($p < 0.0001$), (ii) 1500 and 2400 MHz ($p < 0.0001$) and (iii) 3500 and 8000 MHz ($p = 0.0161$).

CONCLUSION: The available literature on the effect of RF-EMFs on plants to date observed the significant trend of radiofrequency radiation influence on plants. Hence, this study provides new evidence supporting our hypothesis. Nonetheless, this endorses the need for more experiments to observe the effects of RF-EMFs, especially for the longer exposure durations, using the whole organisms. The above observation agrees with our earlier study, in that it supported that it is not a well-grounded method to characterize biological effects without considering the exposure duration. Nevertheless, none of these findings can be directly associated with human; however, on the other hand, this cannot be excluded, as it can impact the human welfare and health, either directly or indirectly, due to their complexity and varied effects (calcium metabolism, stress proteins, etc.). This study should be useful as a reference for researchers conducting epidemiological studies and the long-term experiments, using whole organisms, to observe the effects of RF-EMFs.

http://www.ncbi.nlm.nih.gov/pu bmed/27650031?dopt=Abstract

Excerpt

... our review shows that there is a substantial amount of studies which indicate that plants have experienced physiological or morphological changes due to radiofrequency radiation and show statistically significant changes for the short-term exposure duration (up to 13 weeks). In contrast, the results obtained from the long-term exposure studies (two publications using nine different exposures with exposure duration between 3 months to 6 years) support no physiological effects on plants when exposed to radiofrequency radiation from mobile phone radiation. This would bring a remarkable point to the discussion about the apparent absence of response to the long-term exposure that may be interpreted as adaptations. On the other hand, phenotypic plasticity of plants will permit them to change their structure and function; hence, plants to adapt to environmental change (Nicotra et al., 2010). Plants are naturally affected by environmental stresses due to their immobility. Plants could respond to the environmental factors of wind, rain, electric field and ultraviolet radiation and adjust its physiological condition to adapt to the change of environment (Braam and Davis, 1990; Braam et al., 1996; Mary and Braam, 1997) .... our previous findings (Halgamuge et al., 2015) indicate that the biological effects considerably relied on field strength and amplitude modulation of the applied field.

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Effects of Long Term Exposure of 900-1800 MHz Radiation Emitted from 2G Mobile Phone on Mice Hippocampus- A Histomorphometric Study

Mugunthan N, Shanmugasamy K, Anbalagan J, Rajanarayanan S, Meenachi S. Effects of Long Term Exposure of 900-1800 MHz Radiation Emitted from 2G Mobile Phone on Mice Hippocampus- A Histomorphometric Study. J Clin Diagn Res. 2016 Aug;10(8):AF01-6. doi: 10.7860/JCDR/2016/21630.8368. Epub 2016 Aug 1.

Abstract

INTRODUCTION: The advancement in the telecommunications technology with multi-functional added features in mobile phone, attracts more users of all age group. It is alarming to note that, the mobile phone use has increased amongst children and they are exposed to potentially harmful radiofrequency radiation in their lifetime.

AIM: To investigate the long term exposure of 900 to 1800 MHz radiations emitted from 2G mobile phone in mice hippocampus at histomorphometric level.

MATERIALS AND METHODS: With due approval from institutional animal ethics committee, 36 mice were exposed to 2G mobile phone radiation, 48 minutes per day for a period of 30-180 days. The control group was kept under similar conditions without 2G exposure. Mice were sacrificed and the brain was removed from the first month to six months period. Brain was removed from the cranial cavity and hippocampus region was dissected out carefully and processed for routine histological study. Random serial sections were analysed under microscope for histomorphometric changes. For statistical analysis, independent t-test was used for comparing control and 2G exposed groups.

RESULTS: The mean density of neurons in the hippocampus regions CA1, CA2 and DGDB from first to sixth month was significantly lower in the 2G exposed groups; however, in CA3 and DGVB, the 2G exposed mice showed significantly higher density of neurons. The mean nuclear diameter of neurons in the hippocampus region of CA1, CA2, CA3, DGDB and DGVB from first to sixth months showed lower nuclear diameter in 2G exposed mice.

CONCLUSION: The long term exposure to 900-1800 MHz frequency radiations emitted from 2G mobile phone could cause significantly reduced neuron density and decreased nuclear diameter in the hippocampus neurons of mice.

https://www.ncbi.nlm.nih.gov/p ubmed/27656427?dopt=Abstract

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Effects of radiofrequency field exposure on glutamate-induced oxidative stress in mouse hippocampal HT22 cells

Kim JY, Kim HJ, Kim N, Kwon JH, Park MJ. Effects of radiofrequency field exposure on glutamate-induced oxidative stress in mouse hippocampal HT22 cells.Int J Radiat Biol. 2016 Sep 20:1-22. [Epub ahead of print]

Abstract

PURPOSE: To define the impact of radiofrequency (RF) under in vitro experimental Alzheimer's disease conditions, we investigated the effect of RF radiation on glutamate-induced oxidative stress in mouse hippocampal neuronal HT22 cells.

MATERIALS AND METHODS: Cell survival rate was measured by MTT and trypan blue exclusion assays. Cell cycle distribution, cell death, and ROS production were analyzed using flow cytometry. Expression of proteins was analyzed by Western blot.

RESULTS: RF exposure alone had a marginal impact on cell proliferation, however significantly enhanced glutamate-induced cytotoxicity in HT22 cells. Glutamate augmented the subG1 fraction of cell cycle, annexin/propidium iodide positive cell population, and expression of cleaved poly (ADP ribose) polymerase, which were further increased by RF exposure. Glutamate induced reactive oxygen species (ROS) generation and RF exposure further upregulated it. N-acetylcysteine (NAC) treatment completely abrogated glutamate- and RF-induced ROS production followed by cell death and restored cell proliferation in HT22 cells. Finally, glutamate phosphorylated c-Jun N-terminal kinase (JNK) and RF increased this event further. Treatment with NAC and inhibitor of JNK decreased JNK phosphorylation and restored cell proliferation, respectively.

CONCLUSIONS: Our results demonstrate that RF exposure enhanced glutamate-induced cytotoxicity by further increase of ROS production in HT22 cells.

http://www.ncbi.nlm.nih.gov/pu bmed/27648632?dopt=Abstract

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Adverse effects in lumbar spinal cord morphology and tissue biochemistry in Sprague Dawley male rats following exposure to a continuous 1-h a day 900-MHz electromagnetic field throughout adolescence

Kerimoğlu G, Aslan A, Baş O, Çolakoğlu S, Odacı E. Adverse effects in lumbar spinal cord morphology and tissue biochemistry in Sprague Dawley male rats following exposure to a continuous 1-h a day 900-MHz electromagnetic field throughout adolescence. J Chem Neuroanat. 2016 Sep 17. pii: S0891-0618(16)30135-1. doi: 10.1016/j.jchemneu.2016.09.007 . [Epub ahead of print]

Abstract

Cell phones, an indispensable element of daily life, are today used at almost addictive levels by adolescents. Adolescents are therefore becoming increasingly exposed to the effect of the electromagnetic field (EMF) emitted by cell phones. The purpose of this study was to investigate the effect of exposure to a 900-MHz EMF throughout adolescence on the lumbar spinal cord using histopathological, immunohistochemical and biochemical techniques. Twenty-four Sprague Dawley (28.3-43.9g) aged 21days were included in the study. These were divided equally into three groups - control (CG), sham (SG) and electromagnetic (ELMAG). No procedure was performed on the CG rats until the end of the study. SG and ELMAG rats were kept inside an EMF cage (EMFC) for 1h a day every day at the same time between postnatal days 22 and 60. During this time, ELMAG rats were exposed to the effect of a 900-MHz EMF, while the SG rats were kept in the EMFC without being exposed to EMF. At the end of the study, the lumbar regions of the spinal cords of all rats in all groups were extracted. Half of each extracted tissue was stored at -80°C for biochemical analysis, while the other half was used for histopathological and immunohistochemical analyses. In terms of histopathology, a lumbar spinal cord with normal morphology was observed in the other groups, while morphological irregularity in gray

matter, increased vacuolization and infiltration of white matter into gray matter were pronounced in the ELMAG rats. The cytoplasm of some neurons in the gray matter was shrunken and stained dark, and vacuoles were observed in the cytoplasms. The apoptotic index of glia cells and neurons were significantly higher in ELMAG compared to the other groups. Biochemical analysis revealed a significantly increased MDA value in ELMAG compared to CG, while SOD and GSH levels decreased significantly. In conclusion, our study results suggest that continuous exposure to a 900-MHz EMF for 1h a day through all stages of adolescence can result in impairments at both morphological and biochemical levels in the lumbar region spinal cords of Sprague Dawley rats.

http://www.ncbi.nlm.nih.gov/pu bmed/27650207?dopt=Abstract

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Exposure of ELF-EMF and RF-EMF Increase the Rate of Glucose Transport and TCA Cycle in Budding Yeast

Lin KW, Yang CJ, Lian HY, Cai P.Exposure of ELF-EMF and RF-EMF Increase the Rate of Glucose Transport and TCA Cycle in Budding Yeast. Front Microbiol. 2016 Aug 31;7:1378. doi: 10.3389/fmicb.2016.01378. eCollection 2016.

Abstract

In this study, we investigated the transcriptional response to 50 Hz extremely low frequency electromagnetic field (ELF-EMF) and 2.0 GHz radio frequency electromagnetic field (RF-EMF) exposure by Illumina sequencing technology using budding yeast as the model organism. The transcription levels of 28 genes were upregulated and those of four genes were downregulated under ELF-EMF exposure, while the transcription levels of 29 genes were upregulated and those of 24 genes were downregulated under RF-EMF exposure. After validation by reverse transcription quantitative polymerase chain reaction (RT-qPCR), a concordant direction of change both in differential gene expression (DGE) and RT-qPCR was demonstrated for nine genes under ELF-EMF exposure and for 10 genes under RF-EMF exposure. The RT-qPCR results revealed that ELF-EMF and RF-EMF exposure can upregulate the expression of genes involved in glucose transportation and the tricarboxylic acid (TCA) cycle, but not the glycolysis pathway. Energy metabolism is closely related with the cell response to environmental stress including EMF exposure. Our findings may throw light on the mechanism underlying the biological effects of EMF.

https://www.ncbi.nlm.nih.gov/p mc/articles/PMC5005349/

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Effect of mobile phone radiation on pentylenetetrazole-induced seizure threshold in mice

Kouchaki E, Motaghedifard M, Banafshe HR.Effect of mobile phone radiation on pentylenetetrazole-induced seizure threshold in mice.
Iran J Basic Med Sci. 2016 Jul;19(7):800-3.

Abstract

OBJECTIVES: Scientific interest in potential mobile phone impact on human brain and performance has significantly increased in recent years. The present study was designed to evaluate the effects of mobile phone radiation on seizure threshold in mice.

MATERIALS AND METHODS: BALB/c male mice were randomly divided into three groups: control, acute,

and chronic mobile phone radiation for 30, 60, and 90 min with frequency 900 to 950 MHz and pulse of 217 Hz. The chronic group received 30 days of radiation, while the acute group received only once. The intravenous infusion of pentylenetetrazole (5 mg/ml) was used to induce seizure signs.

RESULTS: Although acute mobile radiation did not change seizure threshold, chronic radiation decreased the clonic and tonic seizure thresholds significantly.

CONCLUSION: Our data suggests that the continued and prolonged contact with the mobile phone radiation might increase the risk of seizure attacks and should be limited.

http://www.ncbi.nlm.nih.gov/pu bmed/27635206?dopt=Abstract

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Modification of p21 level and cell cycle distribution by 50 Hz magnetic fields in human SH-SY5Y neuroblastoma cells

Luukkonen J, Höytö A, Sokka M, Liimatainen A, Syväoja J, Juutilainen J, Naarala J.Modification of p21 level and cell cycle distribution by 50 Hz magnetic fields in human SH-SY5Y neuroblastoma cells.Int J Radiat Biol. 2016 Sep 20:1-27. [Epub ahead of print]

Abstract

PURPOSE: In our previous studies, exposure to extremely low frequency (ELF) magnetic fields (MFs) altered responses to DNA damage caused by menadione. The aim of this study was to evaluate possible ELF MF induced changes in proteins involved in DNA damage responses and in cell cycle distribution.

MATERIALS AND METHODS: Based on our previous studies, the exposure protocol included pre-exposure of human SH-SY5Y neuroblastoma cells to a 50 Hz, 100 μT MF for 24 h prior to a 3-h menadione treatment. As DNA damage responses are relatively fast processes, a 1-h menadione treatment was also included in the experiments. The menadione concentrations used were 1, 10, 15, 20, and 25 μM. Immunoblotting was used to assess the levels of DNA damage response-related proteins (γ-H2AX, Chk1, phospho-Chk1, p21, p27, and p53), while the level of DNA damage was assessed by the alkaline Comet assay. Cell cycle distribution was assayed by SYTOX Green staining followed by flow cytometry analysis.

RESULTS: The main findings in MF-exposed cells were decreased p21 protein level after the 1-h menadione treatment, as well as increased proportion of cells in the G1 phase and decreased proportion of S phase cells after the 3-h menadione treatment. These effects were detectable also in the absence of menadione.

CONCLUSIONS: The results indicate that MF exposure can alter the G1 checkpoint response and that the p21 protein may be involved in early responses to MF exposure.

http://www.ncbi.nlm.nih.gov/pu bmed/27646005?dopt=Abstract

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The effect of extremely low-frequency magnetic field (50-60 Hz) exposure on spontaneous apoptosis: The results of a meta-analysis

Mansourian M, Marateb HR, Vaseghi G. The effect of extremely low-frequency magnetic field (50-60 Hz) exposure on spontaneous apoptosis: The results of a meta-analysis. Adv Biomed Res. 2016 Aug 30;5:141. doi: 10.4103/2277-9175.187375. eCollection 2016.

Abstract

BACKGROUND: This paper is a meta-analysis of the published data from in vitro studies to evaluate whether spontaneous apoptosis might be influenced by extremely low frequency (ELF) magnetic fields (MFs).

MATERIALS AND METHODS: A comprehensive scientific literature search in electronic databases was conducted and studies covering the period 2000-2010 were selected. Then, published studies involving the desired topic were retrieved. The inclusion criteria were percentage of apoptosis in the cells exposed to 50-60 Hz ELF-MFs. The statistical analysis was performed by comprehensive meta-analysis version 2.

RESULTS: The summary measure of association (95% confidence interval) for all 18 effect estimated from 8 studies was 1.18 (1.15, 1.20). Heterogeneity among studies was found. There was no evidence of publication bias for the association between exposure to MF and apoptosis risk.

CONCLUSION: Our meta-analysis provided conclusive data that ELF-MFs can increase apoptosis in cancer and normal cells. Furthermore, there is a possibly individual intensity and time range with maximum created effect according to window effect.

Open Access Paper: https://www.ncbi.nlm.nih.gov/p mc/articles/PMC5025908/

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Electromagnetic Radiation Safety

Website: http://www.saferemr.com
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Research Compilation; Studies and Documents; City of Pinole, CA

Any Document Originally Produced By the City and Resubmitted As Part of A Citizen Comment Is Not Included in the Attached Files

Name of Author	Content of Comments
Anthony Gutierrez 1-25	Comments on changes to Telecom Ordinance. • DOI comments to FCC • Study on cancer risk near cell phone transmission station by Egor et. al. • Study on cancer risk near cell phone transmission station by Wolf.
Anthony Gutierrez 1-26 (email #1)	Comments on notice and RF exposure. • Study on effects of microwaves on physical and biological variables by Belyaev. • Study on mobile telephony radiation effects by Panagopoulous • Studies on effects of electromagnetic fields on living matter. Edited by Giuliani & Soffritti
Anthony Gutierrez 1-26 (email #2)	• Anthropogenic Radio Frequency Electro-Magnetic Fields Threat to Wildlife, • OSU Article Steelhead Trout • CDFW letter to Friends of Pinole Creek • Science of the Total Environment • Press Release - DOI Attacks FCC
Anthony Gutierrez 1-27 (pt. 1)	Comments on changes to Telecom Ordinance. • Copies of the current and previous version of the Telecom Ordinance
Anthony Gutierrez 1-27 (pt. 2)	Comments regarding, hydrology, landslides, visual impacts, alternative sights, RF exposure. • Letter from American Academy of Pediatrics to FCC discussing RF
Anthony Gutierrez 1-27 (pt. 3)	Comments regarding visual impacts and new chimney design
Anthony Gutierrez: "A Little History" 1-27	Timeline of events related to the cell tower. • Video of various portions of various City Council meetings

	• Verizon financial documents and SEC filings • Minutes of 2/21/12 Council Meeting • 8/25/13 Letter to Council from "Pinole Citizens concerned about Verizon Cell Tower" • Agendas for 2/21/12, 9/11/13, 10/1/13 Council Meetings • 10/1/13 Report from City Manager regarding meeting with California State Parks • 9/11/13 Staff Report re: responses to Citizen questions regarding Verizon lease • 2/5/13 Report from City Manager regarding ground lease with Verizon
Anthony Gutierrez 2-3-16	Verizon Coverage Maps
David Ruport Jr. 12-22-15	Letter Re: Cell Tower Appeal
David Ruport Jr. 01-26-16	Comments regarding legal standards for review, visual impact, landslides, alternative sites. Includes excerpts from draft initial study and responses to comments.
David Ruport Jr. (2/3/16)	Comments to City Attorney re: Settlement Agreement
Elaine Jaymot (1/27/16)	Comments on visual impact, landslides, fire hazard from diesel generator, and strength of road.
Elaine Jaymot 2-3-16	Comments re: flood & landslide and insurance exclusions
Julie Maier 1-27	Comments regarding landslides, alternative sites, property values, EMR, and potential legal costs.
Amy Thomsen 1-28-16	Supports denial of CUP
Sal Spataro 1-27-16	Comments on location of tower, landslides, review process
Susan Varela 1-27-16	Comments on drainage issues, landslides, fire hazard of diesel generator, visual impacts, RF exposure.
Susan Varela 2-3-16	Comments re: residential dwelling insurance exclusions
Steven Vinje & Dean, Attorney	Resubmittal of a letter by attorney Dana Dean
Wilke 2-2-16	Comments on landslides.

	• Resubmittal of letter by Vanessa Wilke • CD with video and pictures of previous landslide in 1998 along Pinole Valley Creek

The Influence of Being Physically Near to a Cell Phone Transmission Mast on the Incidence of Cancer

Horst Eger, Klaus Uwe Hagen, Birgitt Lucas, Peter Vogel, Helmut Voit

Published in *Umwelt·Medizin·Gesellschaft* 17,4 2004, as:
'Einfluss der räumlichen Nähe von Mobilfunksendeanlagen auf die Krebsinzidenz'

Summary

Following the call by Wolfram König, President of the Bundesamt für Strahlenschutz (Federal Agency for radiation protection), to all doctors of medicine to collaborate actively in the assessment of the risk posed by cellular radiation, the aim of our study was to examine whether people living close to cellular transmitter antennas were exposed to a heightened risk of taking ill with malignant tumors.

The basis of the data used for the survey were PC files of the case histories of patients between the years 1994 and 2004. While adhering to data protection, the personal data of almost 1,000 patients were evaluated for this study, which was completed without any external financial support. It is intended to continue the project in the form of a register.

The result of the study shows that the proportion of newly developing cancer cases was significantly higher among those patients who had lived during the past ten years at a distance of up to 400 metres from the cellular transmitter site, which has been in operation since 1993, compared to those patients living further away, and that the patients fell ill on average 8 years earlier.

In the years 1999-2004, *ie* after five years' operation of the transmitting installation, the relative risk of getting cancer had trebled for the residents of the area in the proximity of the installation compared to the inhabitants of Naila outside the area.

Key words: cellular radiation, cellular transmitter antennas, malignant tumours

The rapid increase in the use of mobile telephony in the last few years has led to an increasing number of cell phone transmission masts being positioned in or near to residential areas. With this in mind, the president of the German governmental department for protection against electromagnetic radiation (Bundesamtes für Strahlenschutz) Wolfram König, has challenged all doctors to actively help in the work to estimate the risks from such cell phone masts. The goal of this investigation was therefore to prove whether on not people living near to cell phone masts have a higher risk of developing cancerous tumours.

The basic data was taken from the medical records held by the local medical authority (Krankenkasse) for the years 1994 to 2004. This material is stored on computer. In this voluntary study the records of roughly 1,000 patients from Naila (Oberfranken) were used, respecting the associated data protection laws. The results from this study show a significantly increased likelihood of developing cancer for the patients that have lived within 400 metres of the cell phone transmission mast (active since 1993) over the last ten years, in comparison to those patients that live further away. In addition, the patients that live within 400 metres tend to develop the cancers at a younger age. For the years 1999 to 2004 (*ie* after five or more years of living with the cell phone transmission mast), the risk of developing cancer for those living within 400 metres of the mast in comparison to those living outside this area, was three times as high.

Introduction

A series of studies available before this investigation provided strong evidence of health risks and increased cancer risk associated with physical proximity to radio transmission masts. Haider *et al.* reported in 1993 in the Moosbrunn study frequent psychovegetive symptoms below the current safety limit for electromagnetic waves (1). In 1995, Abelin *et al.* in the Swiss- Schwarzenburg study found dose dependent sleep problems (5:1) and depression (4:1) at a shortwave transmitter station that has been in operation since 1939 (2).

In many studies an increased risk of developing leukaemia has been found; in children near transmitter antennas for Radio and Television in Hawaii (3); increased cancer cases and general mortality in the area of Radio and Television transmitter antennas in Australia (4); and in England, 9 times more leukaemia cases were diagnosed in people who live in a nearby

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area to the Sutton Coldfield transmitter antennas (5). In a second study, concentrating on 20 transmitter antennas in England, a significant increased leukaemia risk was found (6). The Cherry study (7) indicates an association between an increase in cancer and living in proximity to a transmitter station. According to a study of the transmitter station of Radio Vatican, there were 2.2 times more leukaemia cases in children within a radius of 6 km, and adult mortality from leukaemia also increased (8).

In 1997 Goldsmith published the Lilienfeld-study that indicated 4 times more cancer cases in the staff of the American Embassy in Moscow following microwave radiation during the cold war. The dose was low and below the German limit (9).

The three studies of symptoms indicated a significant correlation between illness and physical proximity to radio transmission masts. A study by Santini *et al.* in France resulted in an association between irritability, depression, dizziness (within 100m) and tiredness within 300m of a cell phone transmitter station (10).

In Austria there was an association between field strength and cardiovascular symptoms (11) and in Spain a study indicates an association between radiation, headache, nausea, loss of appetite, unwellness, sleep disturbance, depression, lack of concentration and dizziness (12).

The human body physically absorbs microwaves. This leads to rotation of dipole molecules and to inversion transitions (13), causing a warming effect. The fact that the human body transmits microwave radiation at a very low intensity means that since every transmitter represents a receiver and transmitter at the same time, we know the human body also acts as a receiver.

In Germany, the maximum safe limit for high frequency microwave radiation is based on purely thermal effects. These limits are one thousand billion times higher than the natural radiation in these frequencies that reaches us from the sun.

The following study examines whether there is also an increased cancer risk close to cellular transmitter antennas in the frequency range 900 to 1800 MHz. Prior to this study there were no published results for long-term exposure (10 years) for this frequency range and its associated effects to be revealed. So far, no follow-up monitoring of the state of health of such a residential population has been systematically undertaken.

Materials and Methods

Study area

In June 1993, cellular transmitter antennas were permitted by the Federal Postal Administration in the Southern German city of Naila and became operational in September 1993.

The GSM transmitter antenna has a power of 15 dbW per channel in the 935MHz frequency range. The total

Fig. 1: Schematic plan of the antenna sites

transmission time for the study period is ca. 90,000 hours. In December 1997 there followed an additional installation from another company. The details are found in an unpublished report, appendix page 1-3 (14).

To compare results an ‘inner’ and ‘outer’ area were defined. The inner area covered the land that was within a distance of 400 metres from the cellular transmitter site. The outer area covered the land beyond 400 metres. The average distance of roads surveyed in the inner area (nearer than 400m) was 266m and in the outer area (further than 400m) 1,026m. Fig. 1 shows the position of the cellular transmitter sites I and 2, surrounded by circle of radius 400 metres. The geographical situation shows the transmitter sites (560m) are the highest point of the landscape, which falls away to 525m at a distance of 450m. From the height and tilt angle of the transmitter it is possible to calculate the distance where the transmitter’s beam of greatest intensity strikes the ground (see Fig. 2).

The highest radiation values are in areas of the main

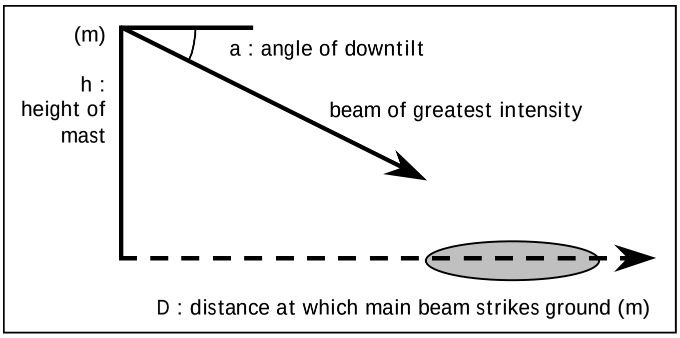

Fig. 2: From the mast height h and the downtilt angle a, the distance D at which the main beam reaches ground is given by D = tan(90-a) × h

beam where it hits the ground and from the expected associated local reflection; from this point the intensity of radiation falls off with the square of the distance from the transmitter.

In Naila the main beam hits the ground at 350m with a beam angle of 6 degrees (15). In the inner area, additional emissions are caused by the secondary lobes of the transmitter; this means in comparison that from purely mathematical calculations the outer area has significantly reduced radiation intensity.

The calculations from computer simulations and the measurements from the Bavaria agency for the environmental protection, both found that the intensity of radiation was a factor of 100 higher in the inner area as compared to the outer area. The measurements of all transmitter stations show that the intensity of radiation from the cell phone transmitter station in Naila in the inner area was higher than the other measurement shown in the previous studies of electromagnetic fields from radio, television or radar (14).

The study StSch 4314 from the ECOLOG Institute indicates an association between a vertical and horizontal distance from the transmitter station and expected radiation intensity on the local people (16). The reason for setting a distance of 400m for the differentiation point is partly due to physical considerations, and partly due to the study of Santini *et al.* who chose 300m (10).

Data Gathering

Similar residential streets in the inner area and outer areas were selected at random. The large old people's home in the inner area was excluded from the study because of the age of the inhabitants. Data gathering covered nearly 90% of the local residents, because all four GPs in Naila took part in this study over 10 years. Every team researched the names of the patients from the selected streets that had been ill with tumours since 1994. The condition was that all patients had been living during the entire observation time of 10 years at the same address.

The data from patients was handled according to data protection in an anonymous way. The data was evaluated for gender, age, tumour type and start of illness. All cases in the study were based on concrete results from tissue analysis. The selection of patents for the study was always done in exactly the same way. Self-selection was not allowed. Also the subjective opinion of patients that the radio mast detrimentally affected their health has not affected this study. Since patients with cancer do not keep this secret from GPs, it was possible to gain a complete data set.

Population study

In the areas where data was collected 1,045 residents were registered in 31.12.2003. The registration statistics for Naila at the beginning of the study (1.1.1994) show the number of old people in the inner and outer areas, as shown in Table 1. The average age at the beginning

	female	male	total
Inner area	41.48	38.70	40.21
Outer area	41.93	38.12	40.20
Naila total	43.55	39.13	41.45

Table 1 : Overview of average ages at the beginning of the study in 1994

1994	inner 22.4%	outer 2.8%	Naila total 24.8%
2004	inner 26.3%	outer 26.7%	

Table 2 : Proportion of patients aged over 60

of the study (1.1.1994) in both the inner and outer areas was 40.2 years. In the study period between 1994-2004, 34 new cases of cancer where documented out of 967 patients (Table 3). The study covered nearly 90% of local residents.

The average age of the residents in Naila is one year more than that of the study due to the effects of the old people's home. From the 9,472 residents who are registered in Naila, 4,979 (52.6%) are women and 4,493 (47.4%) are men. According to the register office, in 1.1.1994 in the outer area, the percentage was 45.4% male and 54.5% female, and in the inner area 45.3% male and 54.6% female. The number of people who are over 60 years old is shown in Table 2.

The social differences in Naila are small. Big social differences like in the USA do not exist here. There is also no ethnic diversity. In 1994 in Naila the percentage of foreigners was 4%. Naila has no heavy industry, and in the inner area there are neither high voltage cable nor electric trains.

Results

Results are first shown for the entire 10 year period from 1994 until 2004. Secondly, the last five-year period 1999 to 2004 is considered separately.

Period 1994 to 2004

As a null hypothesis it was checked to see if the physical distance from the mobile transmission mast had no effect on the number cancer cases in the selected population, *ie* that for both the group nearer than 400 metres and the group further than 400 metres the chance of developing cancer was the same. The relative frequencies of cancer in the form of a matrix are shown in Table 3. The statistical test method used on this data was the chi-squared test with Yates's correction. Using this method we obtained the value of 6.27, which is over the critical value of 3.84 for a

Period 1994-2004	Inner area	Outer area	total
new cases of cancers	18	16	34
with no new cancer	302	631	933
total	320	647	967

Table 3 : numbers of patients with and without cancers, 1994-2004

statistical significance of 0.05).

This means the null hypothesis that both groups within the 400-metre radius of the mast and beyond the 400 metre radius, have the same chance of developing cancer, can be rejected with a 95% level of confidence. With a statistical significance of 0.05, an even more significant difference was observed in the rate of new cancer cases between the two groups.

Calculating over the entire study period of 1994 until 2004, based on the incidence matrix (Table 3) we arrive at a relative risk factor of 2.27 (quotient of proportion for each group, *eg* 18/320 in the strongly exposed inner area, against 16/647 in the lower exposed comparison group). If expressed as an odds ratio, the relationship of the chance of getting cancer between strongly exposed and the less exposed is 2.35.

The following results show clearly that inhabitants who live close to transmitter antennas compared to inhabitants who live outside the 400m zone, double their risk of developing cancer. In addition, the average age of developing cancer was 64.1 years in the inner area whereas in the outer area the average age was 72.6 years, a difference of 8.5 years. That means during the 10 year study that in the inner area (within 400 metres of the radio mast) tumours appear at a younger age.

In Germany the average age of developing cancer is approximately 66.5 years, among men it is approximately 66 and among women, 67 (18).

Over the years of the study the time trend for new cancer cases shows a high annual constant value (Table 4). It should be noted that the number of people in the inner area is only half that of the outer area, and therefore the absolute numbers of cases is smaller.

Table 7 shows the types of tumour that have developed in the cases of the inner area.

Period 1994 to 1999

No. of cases of tumours per year of study	inner area: of the 320 people		outer area: of the 647 people	
	total cases	per 1,000	total cases	per 1,000
1994	–	–	I	1.5
1995	–	–	–	–
1996	II	6.3	I	1.5
1997	I	3.1	III	4.6
1998	II	6.3	III	4.6
1999	II	6.3	I	1.5
2000	IIIII	15.6	I	1.5
2001	II	6.3	II	3.1
2002	II	6.3	II	3.1
2003-3/2004	II	6.3	II	3.1

Table 4 : Summary of the total tumours occurring per year (no. and per thousand)

Period 1994-1999	Inner area	Outer area	total
new cases of cancers	5	8	13
with no new cancer	315	639	954
total	320	647	967

Table 5 : numbers of patients with and without cancers, 1994-1999

For the first five years of the radio transmission mast operation (1994-1998) there was no significant increased risk of getting cancer within the inner area as compared to the outer area (Table 5).

Period 1999 to 2004

Under the biologically plausible assumption that cancer caused by detrimental external factors will require a time of several years before it will be diagnosed, we now concentrate on the last five years of the study between 1999 and 2004. At the start of this period the transmitter had been in operation for 5 years. The results for this period are shown in Table 6. The chi-squared test result for this data (with Yates's correction) is 6.77 and is over the critical value of 6.67 (statistical significance 0.01). This means, with 99% level of confidence, that there is a statistically proven difference between development of cancer between the inner group and outer group. The relative risk of 3.29 revealed that there was 3 times more risk of developing cancer in the inner area than the outer area during this time period.

Period 1999-2004	Inner area	Outer area	total
new cases of cancers	13	8	31
with no new cancer	307	639	946
total	320	647	967

Table 6 : numbers of patients with and without cancers, 1999-2004

The odds-ratio 3.38 (VI 95% 1.39-8.25, 99% 1.05-10.91) allows us with 99% confidence to say that the difference observed here is not due to some random statistical effect.

Discussion

Exactly the same system was used to gather data in the inner area and outer areas. The medical chip card, which has been in use for 10 years, enables the data to be processed easily. The four participating GPs examined the illness of 90% of Naila's inhabitants over the last 10 years. The basic data for this study were based on direct examination results of patients extracted from the medical chip cards, which record also the diagnosis and treatment. The study population is (in regards to age, sex and cancer risk) comparable, and therefore statistically neutral. The study deals only with people who have been living permanently at the same address for the entire study period and therefore

Type of tumour (organ)	no. of tumours found	total expected	incidence per 100,000	ratio inner: outer
breast	8	5.6	112	5:3
ovary	1	1.1	23	0:1
prostate	5	4.6	101	2:3
pancreas	m 3 f 2	0.6 0.9	14 18	2:1 1:1
bowel	m 4 f 0	3.7 4.0	81 81	2:2 0:0
skin melanoma	m 1 f 0	0.6 0.7	13 14	1:0 0:0
lung	m 3 f 0	3.6 1.2	79 24	2:1 0:0
kidney	m 2 f 1	1.0 0.7	22 15	1:1 1:0
stomach	m 1 f 1	1.2 1.1	27 23	0:1 0:1
bladder	m 1 f 0	2.0 0.8	44 16	0:1 0:0
blood	m 0 f 1	0.6 0.7	14 15	0:0 1:0

Table 7 : Summary of tumours occurring in Naila, compared with incidence expected from the Saarland cancer register

have the same duration of exposure regardless of whether they are in the inner area or outer area.

The result of the study shows that the proportion of newly developing cancer cases was significantly higher ($p<0.05$) among those patients who had lived during the past ten years within a distance of 400 metres from the cellular transmitter site, which has been in operation since 1993, in comparison to people who live further away. Compared to those patients living further away, the patients developed cancer on average 8.5 years earlier. This means the doubled risk of cancer in the inner area cannot be explained by an average age difference between the two groups. That the transmitter has the effect that speeds up the clinical manifestations of the illness and general development of the cancer cannot be ruled out.

In the years 1999-2004, *ie* after five years and more of transmitter operation, the relative risk of getting cancer had trebled for the residents of the area in the proximity of the mast compared to the inhabitants of Naila in the outer area ($p>0.01$). The division into inner area and outer area groups was clearly defined at the beginning of the study by the distance to the cell phone transmission mast. According to physical considerations people living close to cellular transmitter antennas were exposed to heightened transmitted radiation intensity.

Both calculated and empirical measurements revealed that the intensity of radiation is 100 times higher in the inner area compared to the outer area. According to the research StSch 4314 the horizontal and vertical position in regards to the transmitter antenna is the most important criterion in defining the radiation intensity area on inhabitants (16).

The layered epidemiological assessment method used in this study is also used in assessment of possible chemical environmental effects. In this case the layering is performed in regards to the distance from the cell phone transmitter station. Using this method it has been shown that there is a significant difference in probability of developing new cancers depending on the exposure intensity.

The number of patients examined was high enough according to statistical rules that the effects of other factors (such as use of DECT phones) should be normalised across the inner area and outer area groups. From experience the disruption caused by a statistical confounding factor is in the range between 20% and 30%. Such a factor could therefore in no way explain the 300% increase in new cancer cases. If structural factors such as smoking or excessive alcohol consumption are unevenly distributed between the different groups this should be visible from the specific type of cancers to have developed (*ie* lung, pharyngeal or oesophageal). In the study inner area there were two lung cancers (one smoker, one non-smoker), and one in the outer area (a smoker), but no oesophageal cancers. This rate of lung cancer is twice what is statistically to be expected and cannot be explained by a confounding factor alone. None of the patients who developed cancer was from a family with such a genetic propensity.

Through the many years experience of the GPs involved in this study, the social structures in Naila are well known. Through this experience we can say there was no significant social difference in the examined groups that might explain the increased risk of cancer.

The type and number of the diagnosed cancers are shown in Table 7. In the inner area the number of cancers associated with blood formation and tumour-controlling endocrine systems (pancreas), were more frequent than in the outer area (77% inner area and 69% outer area).

From Table 7, the relative risk of getting breast cancer is significantly increased to 3.4. The average age of patients that developed breast cancer in the inner area was 50.8 years. In comparison, in the outer area the average age was 69.9 years, approximately 20 years less. In Germany the average age for developing breast cancer is about 63 years. The incidence of breast cancer has increased from 80 per 100,000 in the year 1970 to 112 per 100,000 in the year 2000. A possible question for future research is whether breast cancer can be used as a ‘marker cancer’ for areas where there is high contamination from electromagnetic radiation. The report of Tynes *et al.* described an increased risk of breast cancer in Norwegian female radio and telegraph operators (20).

To further validate the results the data gathered were compared with the Saarland cancer register (21). In this register all newly developed cancers cases since 1970 are recorded for each Bundesland. These data are accessible via the Internet. Patents that suffer two separate tumours were registered twice, which increases the overall incidence up to 10%. In this

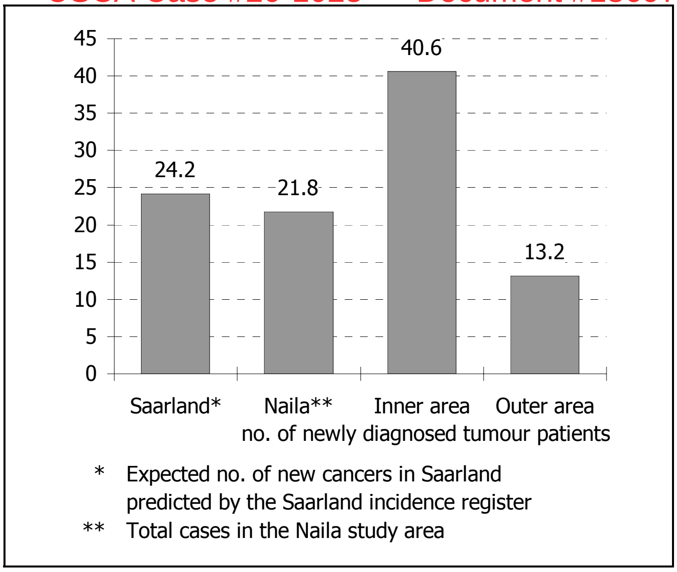

Fig. 3 : Number of new cancer cases 1999 to 2004, adjusted for age and gender, calculated for the 5,000 patient years

register there is no location-specific information, for instance proximity to cell phone transmission masts. The data in the cancer register therefore reflect no real control group but rather the effect of the average radiation on the total population.

From the Saarland cancer register for the year 2000 the incidence of new cancer cases was 498 per 100,000 for men and 462 per 100,000 for women. When adjusted for age and sex one would expect a rate of between 480 and 500 per 100,000 in Naila. For the years 1999 to 2004 there were 21 new cases of cancer among 967 patients. The expected number was 24 cases per 1,000 patients.

The results of the study are shown graphically in Fig. 3. The bars of the chart represent the number of new cancer cases per 1,000 patients in the separate areas, over the five years (bars 2 to 4). The first bar represents the expected number from the Saarland cancer register.

In spite of a possible underestimation, the number of newly developed cancer cases in the inner area is more than the expected number taken from the cancer register, which represents the total population being irradiated. The group who had lived during the past five years within a distance of 400 m from the cellular transmitter have a two times higher risk of developing cancer than that of the average population. The relative risk of getting cancer in the inner area compared with the Saarland cancer register is 1.7 (see to Table 7).

Conclusion

The result of this retrospective study in Naila shows that the risk of newly developing cancer was three times higher among those patients who had lived during past ten years (1994-2004), within a distance of 400m from the cellular transmitter, in comparison to those who had lived further away.

Cross-sectional studies can be used to provide the decisive empirical information to identify real problems. In the 1960s just three observations of birth deformities were enough to uncover what is today an academically indisputable Thalidomide problem.

This study, which was completed without any external financial support is a pilot project. Measurements of individual exposure as well as the focused search for further side effects would provide a useful extension to this work, however such research would need the appropriate financial support.

The concept of this study is simple and can be used everywhere, where there it a long-term electromagnetic radiation from a transmitting station.

The results presented are a first concrete epidemiological sign of a temporal and spatial connection between exposure to GSM base station radiation and cancer disease.

These results are, according to the literature relating to high frequency electromagnetic fields, not only plausible and possible, but also likely.

From both an ethical and legal standpoint it is necessary to immediately start to monitor the health of the residents living in areas of high radio frequency emissions from mobile telephone base stations with epidemiological studies. This is necessary because this study has shown that it is no longer safely possible to assume that there is no causal link between radio frequency transmissions and increased cancer rates.

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Footnotes

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INCREASED INCIDENCE OF CANCER NEAR A CELL-PHONE TRANSMITTER STATION.

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Increased Incidence of Cancer near a Cell-Phone Transmitter Station
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Abstract

Significant concern has been raised about possible health effects from exposure to radiofrequency (RF) electromagnetic fields, especially after the rapid introduction of mobile telecommunications systems. Parents are especially concerned with the possibility that children might develop cancer after exposure to the RF emissions from mobile telephone base stations erected in or near schools. The few epidemiologic studies that did report on cancer incidence in relation to RF radiation have generally presented negative or inconsistent results, and thus emphasize the need for more studies that should investigate cohorts with high RF exposure for changes in cancer incidence. The aim of this study is to investigate whether there is an increased cancer incidence in populations, living in a small area, and exposed to RF radiation from a cell-phone transmitter station.

This is an epidemiologic assessment, to determine whether the incidence of cancer cases among individuals exposed to a cell-phone transmitter station is different from that expected in Israel, in Netanya, or as compared to people who lived in a nearby area. Participants are people (n=622) living in the area near a cell-phone transmitter station for 3-7 years who were patients of one health clinic (of DW). The exposure began 1 year before the start of the study when the station first came into service. A second cohort of individuals (n=1222) who get their medical services in a clinic located nearby with very closely matched, environment, workplace and occupational characteristics was used for comparison.

In the area of exposure (area A) eight cases of different kinds of cancer were diagnosed in a period of only one year. This rate of cancers was compared both with the rate of 31 cases per 10,000 per year in the general population and the 2/1222 rate recorded in the nearby clinic (area B). Relative cancer rates for <u>females</u> were 10.5 for area A, 0.6 for area B and 1 for the whole town of Netanya. Cancer incidence of women in area A was thus significantly higher ($p<0.0001$) compared with that of area B and the whole city. A comparison of the relative risk revealed that there were 4.15 times more cases in area A than in the entire population.

The study indicates an association between increased incidence of cancer and living in proximity to a cell-phone transmitter station.

Key Words:

Radiofrequency radiation; Cell-phone transmitter station (cell-phone antenna); Cancer incidence study; Netanya.

Introduction

Much concern has been expressed about possible health effects from exposure to radiofrequency (RF) electromagnetic fields, particularly following publication of scientific reports suggesting that residence near high voltage power lines may be associated with an increased risk of developing childhood leukemia. While interest tended to focus on microwave ovens and radar equipment in the past, it is now mobile telecommunication that attracts the most attention. The rapid introduction of mobile telecommunications systems, the exponential increase in the use of such phones, and the many base stations needed for serving them have engendered renewed concerns about exposure to RF radiation.

The biological effects of low level electromagnetic fields and a possible potential relation to cancer causation are controversial. There have been several epidemiological studies of the possible adverse health effects associated with environmental exposure to extremely low frequency (0-300 Hz) non-ionizing radiation, such as that emitted by power cables and electric substations, linking such exposure to leukemia, brain cancer, male breast cancer and skin and eye melanoma (1-11).

Far less attention has been paid to health hazards from environmental exposure to radiation in the RF range (100 kHz to 300 GHz), including the radiation emitted from cell-phone equipment, in the frequencies of 850 MHz, at field strengths much below those required to produce thermal effects. The few epidemiologic studies that did report on cancer incidence in relation to RF radiation (mainly from occupational exposure including microwave and radar and from living in proximity to TV towers) have generally presented negative or inconsistent results, or were subject to possible confounding from other exposures (12-20).

Laboratory studies in this area have also been confusing and conflicting. While some animal studies suggested that RF fields accelerate the development of cancers, other studies found no carcinogenic effect (21).

Obviously, there is an urgent need for extensive, well-conducted epidemiological and laboratory studies (21-24).

An opportunity for studying the effect of RF radiation presented itself in South Netanya, where a cell-phone transmitter station was located in the middle of a small area. We took advantage of the fact, that most of the population in the investigated area belong to one outpatient clinic (of DW), and undertook an epidemiologic assessment, in which we compared the cancer incidence of this area to those of a nearby clinic, to the national incidence rates of the whole country and to the incidence rates in the whole town of Netanya.

Material and methods

Radio-frequency radiation

The cell-phone transmitter unit is located at the south of the city of Netanya in an area called Irus (area A). It first came into service in 7/96. The people in this area live in half a circle with a 350 meter radius centered on the transmitter.

The antenna is 10 meters high. The antenna bears total maximum transmission power at frequencies of 850 MHz of 1500 watt when working at full power.

Both measured and predicted power density (for the frequencies of 850 MHz) in the whole exposed area were far below 0.53 $\mu w/cm^2$ thus the power density is far below the current guidelines which are based on *the thermal effects of RF exposure.* Exact measured power density in each house are described in table 1.

The current Israeli standard uses 50 packets/sec with Time-Division-Multiple-Access (TDMA) quadrature modulation. The antenna produces 50 packets/sec, using a 3:1 multiplexed Time-Division-Multiple-Access (TDMA) modulation with a 33% duty cycle.

Statistical analysis:

We conducted a cancer incidence study to investigate the incidence of cancer cases of individuals exposed to a cell-phone transmitter station, in comparison to those of a nearby clinic, to the national incidence rates of the whole country and to the incidence rates in the whole town of Netanya.

The cohort included 622 people living in the Irus area (area A) for at least 3-7 years and were patients of one health clinic (of DW). The exposure began in 7/96 which was 1 year before the start of our study.

Statistical analysis was based on the comparison of observed and expected numbers of cancer cases.

In order to compare incidence rates, 95% confidence intervals were computed.

The observed number of cancer cases is the number of all the cancer cases in the exposed cohort in the period between 7/97 - 6/98.

In order to estimate relative risk, rate ratios were computed using the rate of 3 different cohorts as the base (the expected values):

The rate in a nearby clinic (which serves a population of 1222 people, all of them living in area B) during the same period of time, i.e. 7/97 - 6/98. In order to compare area A and area B populations we used:

χ^2 test to compare origin and sex division

t- test to compare age means

The national incidence rates of the whole country.

The incidence rates in the whole town of Netanya where the 2 clinics (of area A and B) are located. The data of 2 and 3 were given to us by the Israel cancer registry and are updated to the years 91-94.

We also examined the history of the exposed cohort (of the A area) for malignancies in the 5 years before the exposure began and found only 2 cases in comparison to 8 cases detected one year after the transmitter station came into service.

Results

Of the 622 people of area A, eight cases of different kinds of cancer were diagnosed in a period of only one year (from July 1997 to June 1998). Details on these cases are presented in Table 1. Briefly, we found 3 cases of breast carcinoma, and one case of ovary carcinoma, lung carcinoma, Hodgkin's disease, osteoid osteoma, and hypernephroma.

This rate of cancers in the population of area A was compared both with the rate of 31 cases per 10,000 per year in the general population and the 2/1222 rate recorded in a nearby clinic. To each one of the rates, a 95 percent confidence interval was calculated (Table 2): the rates in area A were significantly higher than both those in area B, and the population as a whole.

A comparison of the relative risk revealed that there were 4.15 times more cases in area A than in the entire population.

The population characteristics of areas A and B were very similar (Table 2-5). The χ^2 test for comparing gender and origin frequencies showed no significant differences in these parameters between the two areas. Age means, as compared by t-test and age distribution stratum also showed no significant difference between the two groups.

Table 2a lists the rates of cancer incidence of areas A and B compared to data of the whole town of Netanya. The comparison clearly indicated that the cancer incidence of women in area A is significantly higher ($p<0.0001$) compared with that of the whole city.

Discussion

Our study indicates an association between an increased incidence of cancer and living in proximity to a cell-phone transmitter station.

Studies of this type are prone to biases. Possible methodological artefacts to explain our alarming results were considered:

Differences in socioeconomic class and employment status, and demographic heterogeneity due to differences in age, sex and ethnicity were excluded. The two areas that were compared have very closely matched environment, workplace and occupational characteristics.

Confounding variables affecting individuals could not be absolutely adjusted for, however, there was no ionizing radiation that could affect the whole community except the previously mentioned mobile antenna station. There is no traffic density in this area, neither is there any industry or any other air pollution. The population of area A (on which adequate data could be gathered) did not suffer from uncommon genetic conditions, nor did they receive carcinogenic medications.

Differences in diagnosis and registration of cancer cases. Although we cannot altogether exclude the possibility that higher awareness of the physician responsible for area A led to an artificial increase in cancer cases in this area, this possibility seems to us very unlikely, since both are qualified family physicians.

Several findings are of particular interest:

The measured level of RF radiation (power density) in the area was low; far below the current guidelines based on the thermal effects of RF exposure. We suggest, therefore, that the current guidelines be re-evaluated.

The enormous short latency period; less than 2 years, indicates that if there is a real causal association between RF radiation emitted from the cell-phone base station and the cancer cases (which we strongly believe there is), then the RF radiation should have a very strong promoting effect on cancer at very low radiation!

Although the possibility remains that this clustering of cancer cases in one year was a chance event, the unusual sex pattern of these cases, the 6 different cancer kinds, and the fact that only one patient smoked make this possibility very improbable and remote. It should be noted that 7 out of 8 cancer cases were women, like in the work of Maskarinec (25) who found 6 out of 7 leukemia cases in proximity to radio towers to occur in girls. Such unusual appearances of cancer cases due to one accused factor on two completely different occasions is alarming.

We are aware of at least 2 areas in which a drastic increase in the incidence of cancer cases occurred near a cell-phone antenna, however, the setup was not suitable for a well design study of those cases. In one of them (which also got publication in the daily newspapers) there were 6 out of 7 cancer cases in women working in a store in close proximity to a cell-phone antenna.

In conclusion, the results of this study showed that there was a significantly greater incidence of cancers of all kinds within the vicinity of a cell-phone transmitter station.

It would be certainly too premature to draw any conclusions from our results before they are confirmed and repeated by other studies from other areas, particularly in view of the fact that a great majority of papers on this subject showed that RF fields and mobile telephone frequencies were not genotoxic, did not induce genetic effects in vitro and in vivo, and were not found to be teratogenic or to induce cancers (24). The results of this paper should, however, serve as an alarm and emphasize the need for further investigations.

Addendum

At one year following the close of the study, 8 new cases of cancer were diagnosed in area A and two cases in area B. Among the cases diagnosed in area A was one of osteoid osteoma, the second case from the beginning of the study.

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The opinions expressed herein are solely those of the writers and do not necessarily reflect the opinions of the institutions with which the writers are associated.

Table 1: Cancer cases in area A

NAME	AGE	SEX	ORIGIN[1]	SMOKING	CANCER TYPE	Measured power density in μw/cm²
Hemda	52	f	ash	No	Ovary ca stage 1	0.3μw/cm²
Edna	42	f	sph	No	Breast ca in situ	0.4μw/cm²
Tania	54	f	ash	No	Breast ca	0.5μw/cm²
Neli	67	f	ash	Yes	Breast ca	0.4μw/cm²
Galit	24	f	ash	No	Hodgkins	0.5μw/cm²
Miriam	61	f	sph	No	Lung ca	0.3μw/cm²
Masal	37	f	sph	No	Osteoid osteoma	0.4μw/cm²
Max	78	m	ash	No	Hypernephroma	0.3μw/cm²

1. Origin: ash - Ashkenazien Jews sph - Spharadic Jews

Table 2: Cancer rates in area A, B and the total population.

	No. of cancer cases	population size	Rate per year per 10,000	confidence interval lower limit	ce (95%) upper limit	relative risk
Area A	8	622	129	40.1	217.2	4.15
Area B	2	1222	16	-6.3	39.0	0.53
total populat	31	10,000	31	20.1	41.9	1.00

Table 2a: Cancer rates in area A, B and the whole town.

	Male		Female	
	rate	Relative rate	rate	relative rate
Area A	33	1.4	262	10.5
Area B	17	0.7	16	0.6
Whole town	24	1	25	1

Table 3: Comparing area A to area B by gender.

Gender	Area A		Area B	
	N	%	N	%
male	290	49	669	49
female	305	51	685	51

Table 4: Comparing area A to area B by origin.

Origin	Area		Area	
	N	%	N	%
Sfaradic	340	55	551	45
Ashkenaz	239	38	620	51
Russian	41	7	51	4

Table 5: Comparing age means in both areas.

	Area A		Area B	
	mean	Std	mean	std
age	26.5	17.9	25.5	12.4

Table 5: Age distribution by stratum.

	0-1	**1-10**	**10-20**	**20-30**	**30-40**	**40-50**	**50-60**	**60-70**	**>70**
IRUS	16	143	157	65	70	88	41	21	21
POLEG	31	285	257	139	180	158	83	55	34

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

TAKE PRIDE IN AMERICA

FEB - 7 2014

In Reply Refer To: (ER 14/0001) (ER 14/0004).

Mr. Eli Veenendaal
National Telecommunications and Information Administration
U.S. Department of Commerce
1401 Constitution Avenue, N.W.
Washington, D.C. 20230

Dear Mr. Veenendaal:

The Department of the Interior (Department) has reviewed the above referenced proposal and submits the following comments and attachment for consideration. Because the First Responder Network Authority (FirstNet) is a newly created entity, we commend the U.S. Department of Commerce for its timely proposals for NEPA implementing procedures.

The Department believes that some of the proposed procedures are not consistent with Executive Order 13186 Responsibilities of Federal Agencies to Protect Migratory Birds, which specifically requires federal agencies to develop and use principles, standards, and practices that will lessen the amount of unintentional take reasonably attributed to agency actions. The Department, through the Fish and Wildlife Service (FWS), finds that the proposals lack provisions necessary to conserve migratory bird resources, including eagles. The proposals also do not reflect current information regarding the effects of communication towers to birds. Our comments are intended to further clarify specific issues and address provisions in the proposals.

The Department recommends revisions to the proposed procedures to better reflect the impacts to resources under our jurisdiction from communication towers. The placement and operation of communication towers, including un-guyed, unlit, monopole or lattice-designed structures, impact protected migratory birds in two significant ways. The first is by injury, crippling loss, and death from collisions with towers and their supporting guy-wire infrastructure, where present. The second significant issue associated with communication towers involves impacts from non-ionizing electromagnetic radiation emitted by them (See Attachment).

In addition to the 147 Birds of Conservation Concern (BCC) species, the FWS has listed an additional 92 species as endangered or threatened under the Endangered Species Act. Together with the bald and golden eagle, this represents 241 species of birds whose populations are in trouble or otherwise merit special protection, according to the varying criteria of these lists. The Department suggests that FirstNet consider preparing a programmatic environmental impact statement (see attachment) to determine and address cumulative impacts from authorizing FirstNet projects on those 241 species for which the incremental impact of tower mortality, when added to other past, present, and reasonably foreseeable future actions, is most likely significant, given their overall imperiled status. Notwithstanding the proposed implementing procedures, a programmatic NEPA document might be the most effective and efficient method for establishing best management practices for individual projects, reducing the burden to individual applicants, and addressing cumulative impacts.

Categorical Exclusions
The Department has identified 13 of the proposed categorical exclusions (A-6, A-7, A-8, A-9, A-10, A-11, A-12, A-13, A-14 A-15, A-16, A-17, and A-19) as having the potential to significantly affect wildlife and the biological environment. Given this potential, we want to underscore the importance of our comments on FirstNet's procedural guidance under Environmental Review and Consultation Requirements for NEPA Reviews and its list of extraordinary circumstances in Appendix D.

Environmental Review and Consultation Requirements for NEPA Reviews
To ensure there are no potentially significant impacts on birds from projects that may otherwise be categorically excluded, the Department recommends including the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act to the list of requirements in this section.

Extraordinary Circumstances
To avoid potentially significant impacts on birds from projects that may otherwise be categorically excluded, the Department recommends including species covered under the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act to the list of environmentally sensitive resources. Additionally, adding important resources to migratory birds such as sites in the Western Hemisphere Shorebird Reserve Network and Audubon Important Bird Areas to the paragraph on areas having special designation or recognition would help ensure their consideration when contemplating use of a categorical exclusion.

Developing the Purpose and Need
The Department recommends inclusion of language that would ensure consideration of all other authorities to which NEPA is supplemental as opposed to simply the FirstNet mission. As currently written, the procedures are limited to ensuring the purpose and need considers the FirstNet mission. If strictly applied, this approach would severely limit the range of reasonable alternatives, and likely preclude consideration of more environmentally benign locations or construction practices.

Environmental Review Process, Apply NEPA Early in the Process, Where Action is by Non-Federal Entity
The Department recommends that FirstNet be required to coordinate with federal agencies having jurisdiction by law or special expertise on construction and lighting of its network of towers.

Thank you for the opportunity to comment on the draft document. If you have any questions concerning the comments, please contact Diana Whittington, NEPA Migratory Bird lead, at (703) 358-2010. If you have any questions regarding Departmental NEPA procedures, contact Lisa Treichel, Office of Environmental Policy and Compliance at (202) 208-7116.

Sincerely,

Willie R. Taylor

Willie R. Taylor
Director, Office of Environmental Policy
and Compliance

Enclosure

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Enclosure A

Background
The placement and operation of communication towers, including un-guyed, unlit, monopole or lattice-designed structures, impact protected migratory birds in two significant ways.

The first is by injury, crippling loss, and death from collisions with towers and their supporting guy-wire infrastructure, where present. Mass mortality events tend to occur during periods of peak spring and fall songbird bird migration when inclement weather events coincide with migration, and frequently where lights (either on the towers and/or on adjacent outbuildings) are also present. This situation has been well documented in the U.S. since 1948 in the published literature (Aronoff 1949, see Manville 2007a for a critique). The tallest communication towers tend to be the most problematic (Gehring *et al.* 2011). However, mid-range (~400-ft) towers as proposed by the First Responder Network Authority (FirstNet, a newly created entity under the Department of Commerce) can also significantly impact protected migratory birds, as can un-guyed and unlit lattice and monopole towers (Gehring *et al.* 2009, Manville 2007a, 2009, 2013a). Mass mortalities (more than several hundred birds per night) at unguyed, unlit monopole and lattice towers were documented in fall 2005 and 2011 in the Northeast and North Central U.S. (*e.g.*, Manville 2007a). It has been argued that communication towers including "short" towers do not impact migratory birds, including at the population level (*e.g.*, Arnold and Zink 2011), but recent findings have contradicted that assertion (Manville 2007a, 2013a, Longcore *et al.* 2012, 2013).

The second significant issue associated with communication towers involves impacts from non-ionizing electromagnetic radiation emitted by these structures. Radiation studies at cellular communication towers were begun circa 2000 in Europe and continue today on wild nesting birds. Study results have documented nest and site abandonment, plumage deterioration, locomotion problems, reduced survivorship, and death (*e.g.*, Balmori 2005, Balmori and Hallberg 2007, and Everaert and Bauwens 2007). Nesting migratory birds and their offspring have apparently been affected by the radiation from cellular phone towers in the 900 and 1800 MHz frequency ranges – 915 MHz is the standard cellular phone frequency used in the United States. However, the electromagnetic radiation standards used by the Federal Communications Commission (FCC) continue to be based on thermal heating, a criterion now nearly 30 years out of date and inapplicable today. This is primarily due to the lower levels of radiation output from microwave-powered communication devices such as cellular telephones and other sources of point-to-point communications; levels typically lower than from microwave ovens. The problem, however, appears to focus on very low levels of non-ionizing electromagnetic radiation. For example, in laboratory studies, T. Litovitz (personal communication) and DiCarlo *et al.* (2002) raised concerns about impacts of low-level, non-thermal electromagnetic radiation from the standard 915 MHz cell phone frequency on domestic chicken embryos – with some lethal results (Manville 2009, 2013a). Radiation at extremely low levels (0.0001 the level emitted by the average digital cellular telephone) caused heart attacks and the deaths of some chicken embryos subjected to hypoxic conditions in the laboratory while controls subjected to hypoxia were unaffected (DiCarlo *et al.* 2002). To date, no independent, third-party field studies have been conducted in North America on impacts of tower electromagnetic radiation on migratory birds. With the European field and U.S. laboratory evidence already available, independent, third-party peer-reviewed studies need to be conducted in the U.S. to begin examing the effects from radiation on migratory birds and other trust species.

Discussion

Collision Deaths and Categorical Exclusions

Attempts to estimate bird-collision mortality at communication towers in the U.S. resulted in figures of 4-5 million bird deaths per year (Manville 2005, 2009). A meta-review of the published literature now suggests, based on statistically determined parameters, that mortality may be 6.8 million birds per year in Canada and the U.S.; the vast majority in the United States (Longcore *et al.* 2012). Up to 350 species of birds have been killed at communication towers (Manville 2007a, 2009). The Service's Division of Migratory Bird Management has updated its voluntary, 2000 communication tower guidelines to reflect some of the more recent research findings (Manville 2013b). However, the level of estimated mortality alone suggests at a minimum that FirstNet prepare an environmental assessment to estimate and assess the cumulative effects of tower mortality to protected migratory birds.

A second meta-review of the published mortality data from scientific studies conducted in the U.S. and Canada (Longcore *et al.* 2013) strongly correlates population effects to at least 13 species of Birds of Conservation Concern (BCC, USFWS 2008). These are mortalities to BCC species based solely on documented collisions with communication towers in the U.S. and Canada, ranging from estimated annual levels of mortality of 1 to 9% of their estimated total population. Among these where mortality at communication towers was estimated at over 2% annually are the Yellow Rail, Swainson's Warbler, Pied-billed Grebe, Bay-breasted Warbler, Golden-winged Warbler, Prairie Warbler, and Ovenbird. Longcore *et al.* (2013) emphasized that avian mortality associated with anthropogenic sources is almost always reported in the aggregate, *i.e.*, "number of birds killed," which cannot detect species-level effects necessary to make effective and meaningful conservation assessments, including determining cumulative effects. These new findings strongly suggest the need for at least an environmental assessment by FirstNet, or more likely, an environmental impact statement.

Radiation Impacts and Categorical Exclusions

There is a growing level of anecdotal evidence linking effects of non-thermal, non-ionizing electromagnetic radiation from communication towers on nesting and roosting wild birds and other wildlife in the U.S. Independent, third-party studies have yet to be conducted in the U.S. or Canada, although a peer-reviewed research protocol developed for the U.S. Forest Service by the Service's Division of Migratory Bird Management is available to study both collision and radiation impacts (Manville 2002).

As previously mentioned, Balmori (2005) found strong negative correlations between levels of tower-emitted microwave radiation and bird breeding, nesting, and roosting in the vicinity of electromagnetic fields in Spain. He documented nest and site abandonment, plumage deterioration, locomotion problems, reduced survivorship, and death in House Sparrows, White Storks, Rock Doves, Magpies, Collared Doves, and other species. Though these species had historically been documented to roost and nest in these areas, Balmori (2005) did not observe these symptoms prior to construction and operation of the cellular phone towers. Balmori and Hallberg (2007) and Everaert and Bauwens (2007) found similar strong negative correlations among male House Sparrows. Under laboratory conditions, DiCarlo *et al.* (2002) raised troubling concerns about impacts of low-level, non-thermal electromagnetic radiation from the standard 915 MHz cell phone frequency on domestic chicken embryos – with some lethal results (Manville 2009). Given the findings of the studies mentioned above, field studies should be conducted in North America to validate potential impacts of communication tower radiation – both direct and indirect – to migratory birds and other trust wildlife species.

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Anthropogenic radiofrequency electromagnetic fields as an emerging threat to wildlife orientation

Alfonso Balmori. Anthropogenic radiofrequency electromagnetic fields as an emerging threat to wildlife orientation. Science of the Total Environment. Volumes 518–519, 15 June 2015, Pages 58-60.

Abstract

The rate of scientific activity regarding the effects of anthropogenic electromagnetic radiation in the radiofrequency (RF) range on animals and plants has been small despite the fact that this topic is relevant to the fields of experimental biology, ecology and conservation due to its remarkable expansion over the past 20 years. Current evidence indicates that exposure at levels that are found in the environment (in urban areas and near base stations) may particularly alter the receptor organs to orient in the magnetic field of the earth. These results could have important implications for migratory birds and insects, especially in urban areas, but could also apply to birds and insects in natural and protected areas where there are powerful base station emitters of radiofrequencies. Therefore, more research on the effects of electromagnetic radiation in nature is needed to investigate this emerging threat.

Highlights

- The growth of wireless telecommunication technologies causes increased electrosmog.
- Radio frequency fields in the MHz range disrupt insect and bird orientation.
- Radio frequency noise interferes with the primary process of magnetoreception.
- Existing guidelines do not adequately protect wildlife.
- Further research in this area is urgent.

Excerpts

Different animal groups are sensitive to low frequency electromagnetic fields, and many species with receptor organs are provided with important orientation cues from natural electric fields (Kalmijn, 1988). Animals can use the direction of the magnetic field as a compass and the intensity of the magnetic field as a component of the navigational map, with light-dependent reactions in specialised photo-pigments and reactions involving small crystals of magnetite, using one of these systems, or both simultaneously, depending on the animal groups (Kirschvink et al., 2001, Johnsen and Lohmann, 2005, Wiltschko et al., 2007, Hsu et al., 2007, Ritz et al., 2009 and Wajnberg et al., 2010).

Some insects, like bumblebees (Bombus terrestris), can interact with floral electric fields and electric field sensing constitutes a potentially important sensory modality. The perception of weak electric fields by bees in nature, which should be considered alongside vision and olfaction, may have an adaptive value (Clarke et al., 2013). An applied static magnetic field affects circadian rhythms, magnetosensitivity and orientation of insects through cryptochromes, and a prolonged weakening of the geomagnetic field affects the immune system of rats (Roman and Tombarkiewicz, 2009 and Yoshii et al., 2009).

In the radiofrequency range, the rapid development and increased use of wireless telecommunication technologies led to a substantial change in the radio-frequency electromagnetic field (RF-EMF) exposure (Levitt and Lai, 2010). This increased exposure was most consistently observed in outdoor areas due to emissions from radio and mobile phone base stations (Urbinello et al., 2014). Current evidence indicates that exposure at levels found in the environment (in urban areas and near base stations), may particularly alter the receptor organs to orient in the magnetic field of the earth, although the species conservation implications are unknown. Radio frequency fields in the MHz range disrupt birds' orientation interfering directly with the primary processes of magnetoreception and therefore disable the avian compass as long as they are present (Wiltschko et al., 2014). Ritz et al. (2004 & 2009) reported the sensitivity for orientation of European robins (Erithacus rubecula) to radiofrequency magnetic fields. The orientation of migratory birds is disrupted when very weak high-frequency fields (broad-band field of 0.1–10 MHz of 85 nT or a 1.315 MHz field of 480 nT) are added to the static geomagnetic field of 46.000 nT (Thalau et al., 2006). It was convincingly demonstrated that robins are unable to use their magnetic compass in the presence of urban electromagnetic radiofrequency noise in the frequency range of 2 kHz–5 MHz (Engels et al., 2014). Therefore, electrosmog scrambles birds' magnetic sense and this finding could inform policies written to protect the habitats of endangered species.

As with birds, radio frequency magnetic fields disrupt magnetoreception in insects. The geomagnetic field reception in American cockroach is sensitive to weak radio frequency field causing a disruptive effect (Vacha et al., 2009), so these authors suggest that electromagnetic smog will have to be taken more seriously in animal magnetoreception experiments. In an experimentally-generated electromagnetic field of about 1 V/m with a realistic (and even lower) power intensity similar to those surrounding communication masts, the results and observations suggest that GSM (Global System for Mobile communications) 900 MHz radiation might have a severe impact on the nerve cells of exposed ants, especially affecting the visual and olfactory memory, causing the loss of their ability to use visual cues and suggesting that electromagnetic radiation may have an impact on the orientation behaviour and navigation of animals that use magnetic fields to find their way (Cammaerts et al., 2012 and Cammaerts et al., 2014). Honeybees are sensitive to pulsed electromagnetic fields generated by mobile phones and observable changes in the bee behaviour could be one explanation for the loss of colonies (Favre, 2011). Magnetoreception system in Monarch butterfly orientation (Guerra et al., 2014) may be also suffering interference with anthropogenic radio frequency magnetic fields and this, together with other factors (Brower et al., 2012), may be a cause of their population decline.

Electromagnetic fields act via activation of voltage-gated calcium channels (Pall, 2013). Changes in the size of the magnetic granules upon applying additional magnetic field to the cells of Apis mellifera were observed, and this size fluctuation triggered the increase of calcium intracellular (Hsu et al., 2007). Therefore, we may hypothesise that some of the disruptive effects of radio frequency fields on the orientation of animals may be related to the interference with calcium channels.

An aversive effect on bats has been found in habitats exposed to radiofrequency radiation (1–4 GHz) when compared with matched sites where no such radiation can be detected (Nicholls and Racey, 2009). Cattle exposed to radiofrequency emissions (900 MHz) from nearby base stations may suffer changes in the redox proteins and enzyme activities. It was also found that some are sensitive to radiation, while others are not (Hässig et al., 2014).

Exposure to low intensity radiation can have a profound effect on biological processes (Bolen, 1994). Although there is a good degree of evidence on the injurious effects of radiofrequency electromagnetic fields on the immune system, pineal gland, circadian rhythm, oxidative stress and teratogenicity, these topics remain controversial (Lerchl et al., 2008, Takahashi et al., 2009, Jin et al., 2012, Qin et al., 2012, Bilgici et al., 2013, Tsybulin et al., 2013, Yakymenko et al., 2014 and Cao et al., 2015). Conversely, there is a scientific agreement regarding harmful effects of radio frequency radiation on human reproduction (Adams et al., 2014). Low-voltage electricity current-generated electromagnetic field can produce a significantly negative effect on the breeding success of birds (Ciconia ciconia) nesting directly on electricity lines (Vaitkuvienė and Dagys, 2014) and these same results have been found in nests exposed to radiofrequency radiation near phone masts (Balmori, 2005).

The health risk of electromagnetic fields to aquatic organisms needs to be addressed (Lee and Yang, 2014). The potential interactions between diadromous fishes of conservation importance and the electromagnetic fields and subsea noise from marine renewable energy developments are being studied (Gill et al., 2012).

In a systematic review of published scientific studies on the potential ecological effects of radiofrequency electromagnetic fields (RF-EMF) in the range of 10 MHz–3.6 GHz, about two thirds of the reviewed studies show ecological effects of RF-EMF at high, as well as at low, dosages (Cucurachi et al., 2013). The low dosages are compatible with real field situations, and could be found under environmental conditions (Cucurachi et al., 2013 and Balmori, 2014). However, studies conducted in real field situations must be made with a sufficient experimental exposure time, since results with a short period of exposure are likely to be ambiguous (e.g. 48 h in Vijver et al., 2013).

A limited number of studies have addressed the effects of radiofrequency radiation on plants indicating that these effects depend on the plant family, growth stage, exposure duration, frequency, and power density, among other factors (Senavirathna and Takashi, 2013 and Halgamuge et al., 2015). There are two papers warning on negative effects of radio frequencies from mobile phone masts on trees (Balmori, 2004 and Waldmann-Selsam and Eger, 2013) and researchers have found very worrying effects in laboratory studies (Pesnya and Romanovsky, 2013). The results of these preliminary findings indicate that further research on this topic is extremely urgent.

These results could have important implications for wildlife, especially in urban and suburban areas, but also in rural, natural and protected areas where there are powerful base station emitters of radiofrequencies (Bürgi et al., 2014). Such effects have not yet been examined, but the consequences continue due to the fact that the existing guidelines of public health protection only consider the effects of short-term thermal exposure (Hyland, 2000) and do not adequately protect wildlife. EMF safety standard should be based on the more sensitive, natural biological response (Blank, 2014). Therefore, more research on the effects of electromagnetic radiation in nature is needed to investigate this emerging threat (Balmori, 2014).

Survey (Medical/biological Study)

Anthropogenic radiofrequency electromagnetic fields as an emerging threat to wildlife orientation. review

By: Balmori A
Published in: Sci Total Environ 2015; 518 : 58 - 60

Endpoint

- wildlife orientation

(Study character: medical/biological study, survey)

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House Sparrows, White Storks, Rock Doves, Magpies, Collared Doves, and other species. Though these species had historically been documented to roost and nest in these areas, Balmori (2005) did not observe these symptoms prior to construction and operation of the cellular phone towers. Balmori and Hallberg (2007) and Everaert and Bauwens (2007) found similar strong negative correlations among male House Sparrows. Under laboratory 'conditions, DiCarlo et al. (2002) raised troubling concerns about impacts of low-level, non-thermal electromagnetic radiation from the standard 915 MHz cell phone frequency on domestic chicken embryos- with some lethal results (Manville 2009). **Given the findings of the studies mentioned above, field studies should be conducted in North America to validate potential impacts of communication tower radiation both direct and indirect - to migratory birds and other trust wildlife species."**

The full text of the letter, the addendum and citations are available at:
http://1.usa.gov/1jn3CZg

Dept. of Interior attacks FCC regarding Adverse Impact of Cell Tower Radiation on Wildlife

The Department of Interior charges that the FCC standards for cell phone radiation are outmoded and no longer applicable as they do not adequately protect wildlife.

FOR IMMEDIATE RELEASE

PRLog (Press Release) - ***Mar. 24, 2014 - BERKELEY, Calif. --*** The Director of the Office of Environmental Policy and Compliance of the United States Department of the Interior sent a letter to the National Telecommunications and Information Administration in the Department of Commerce that addresses the Interior Department's concern that cell tower radiation has had negative impacts on the health of migratory birds and other wildlife.

The Interior Department accused the Federal government of employing outdated radiation standards set by the Federal Communications Commission (FCC), a Federal agency with no expertise in health. The standards are no longer applicable because they control only for overheating and do not protect organisms from the adverse effects of exposure to the low-intensity radiation produced by cell phones and cell towers:

"the electromagnetic radiation standards used by the Federal Communications Commission (FCC) continue to be based on thermal heating, a criterion now nearly 30 years out of date and inapplicable today."

The Department criticized the Federal government's proposed procedures for placement and operation of communication towers, and called for "independent, third-party peer-reviewed studies" in the U.S. to examine the effects of cell tower radiation on "migratory birds and other trust species."

More information is available at:
http://www.saferemr.com/2014/03/dept-of-interior-attacks-...

Dependence of non-thermal biological effects of microwaves on physical and biological variables: implications for reproducibility and safety standards

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Abstract

Diverse biological responses, including adverse health effects, to non-thermal (NT) microwaves (MW) have been described by many research groups all over the world. The aim of this paper is to provide an overview of the complex dependence of these effects on various physical and biological parameters, which must be controlled in replication studies.
Besides well-known dependencies on carrier frequency and modulation, emerging data suggest dependencies of NT MW effects on polarization, intermittence and coherence time of exposure, static magnetic field, electromagnetic stray fields, genotype, gender, physiological and individual traits, cell density during exposure. Data also indicate that duration of exposure may be as important as power density (PD) and specific absorption rate (SAR). Further evaluation of these dependencies are needed for understanding the mechanisms by which NT MW affect biological systems, planning *in vivo* and epidemiological studies, developing medical treatments, setting safety standards, and minimizing the adverse effects of MW from mobile communication.

***Key words*: non-thermal effects of microwaves, mobile (cellular) phones, safety standards.**

List of abbreviations:
Anomalous viscosity time dependence (AVTD); blood-brain barrier (BBB); catalase (CAT); Digital Enhanced (former European) Cordless Telecommunications (DECT); circularly polarized (CP); continuous wave (CW); Digital Advanced Mobile Phone System (DAMPS); discontinuous transmission (DTX); electroencephalographic (EEG); electromagnetic field (EMF); embryonic stem (ES) cells; ethidium bromide (EtBr); extremely low frequency (ELF); Gaussian Minimum Shift Keying (GMSK); Ginkgo biloba (Gb); Global System for Mobile Communication (GSM); glutathione peroxidase (GSH-Px); International Commission for Non-Ionizing Radiation Protection (ICNIRP); linearly polarized (LP); malondialdehyde (MDA); micronucleus (MN) assay; microwaves (MWs); N-acetyl-beta-d-glucosaminidase (NAG); nitric oxide (NO); non-thermal (NT); ornithine decarboxylase (ODC); phorbol ester 12-myristate 13-acetate (PMA); phosphorylated H2AX histone (γ-H2AX); power density (PD);

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regional cerebral blood flow (rCBF); Russian National Committee on Non-Ionizing Radiation Protection (RNCNIRP); specific absorption rate (SAR); static magnetic field (SMF); superoxide dismutase (SOD); Time Division Multiple Access (TDMA); tumor suppressor p53 binding protein 1 (53BP1); ultraviolet (UV); Universal Mobile Telecommunications System (UMTS).

Introduction

Exposures to non-ionizing electromagnetic fields vary in many parameters: power (specific absorption rate, incident power density), wavelength/frequency, near field/far field, polarization (linear, circular), continues wave (CW) and pulsed fields (that include variables such as pulse repetition rate, pulse width or duty cycle, pulse shape, pulse to average power, etc.), modulation (amplitude, frequency, phase, complex), static magnetic field (SMF) and electromagnetic stray fields at the place of exposure, overall duration and intermittence of exposure (continuous, interrupted), acute and chronic exposures. With increased absorption of energy, so-called thermal effects of microwaves (MW) are usually observed that deal with MW-induced heating. Specific absorption rate (SAR) or power density (PD) is a main determinate for thermal MW effects. Several other physical parameters of exposure have been reported to be of importance for so-called non-thermal (NT) biological effects, which are induced by MW at intensities well below any measureable heating[1-11]. An important question is how these physical parameters could be taken into account in setting safety standards.

Most often, current safety standards are based on thermal MW effects observed in short-term (acute) exposures. On the other hand, NT MW effects, especially those induced during prolonged (chronic) exposures, are accepted and taken into account for setting the national safety standards in some countries such as Russia[10-12]. It should be noted that, in contrast to the ICNIRP (International Commission for Non-Ionizing Radiation Protection) safety standards[13] which are based on the acute thermal effects of MW, the standards adopted by the Russian National Committee on Non-Ionizing Radiation Protection (RNCNIRP) are based on experimental data from chronic (up to 4 month) exposures of animals to MW at various physical parameters including intensity, frequency and modulation, obtained from research performed in the former Soviet Union[10-12].

Since setting the current safety standards, the situation with exposure of the general population to MW has changed significantly. Nowadays, most of the human population is chronically exposed to MW signals from various sources including mobile phones and base stations. These exposures are characterized by low intensities, varieties and complexities of signals, and long-term durations of exposure that are comparable with a lifespan. So far, the “dose” (accumulated absorbed energy that is measured in radiobiology as the dose rate multiplied by exposure time) is not adopted for the MW exposures and SAR or PD is usually used for guidelines. To what degree SAR/PD can be applied to the nowadays NT MW chronic exposures is not known and the current state of research demands reevaluation of the safety standards[12].

There are two main approaches to treat numerous data regarding NT MW effects. The first one is based on the consideration of these effects in dependence on various physical parameters and biological variables as has consistently been described in many experimental studies and will be reviewed in this paper. The second approach is based on neglecting or minimizing the experimentally observed NT MW effects based on the current state of theoretical physical science that is insufficient for comprehensive explanation of the NT MW effects. As a result of such various treatments of the experimental data, the safety standards significantly vary, up to 1000 times, among countries.

The literature on the NT MW effects is very broad. There are four lines of evidence for the NT MW effects: (1) altered cellular responses in laboratory *in vitro* studies and results of chronic exposures *in vivo* studies[3, 11, 14]; (2) results of medical application of NT MW in the former Soviet Union countries[4, 7, 15, 16]; (3) hypersensitivity to electromagnetic fields (EMF); (4) epidemiological studies suggesting increased cancer risks for mobile phone users[17-19].

This paper is not intended to be a comprehensive review of this literature. In this review, we will focus on the studies which evaluate dependence of the NT MW effects on physical parameters and biological variables.

Experimental studies

The first data on the NT effects of MW in so-called millimeter range (wavelength 1-10 mm in vacuum) was obtained by Vilenskaya and co-authors[20] and Devyatkov[21]. Highly resonant effects of ultra-weak MW (near 70 GHz) on the induction of λ-phage were first established by Webb[22], and subsequently corroborated[23]. In these and subsequent studies the observed spectra of MW action were found to have the following common properties: (1) the MW effects were strongly dependent on the frequency (frequency windows), (2) there was an associated power (intensity) threshold below which no effect was observed, and above which the effects of exposure depended only weakly on power over several orders of magnitude (so-called S-shaped or sigmoid dependence), (3) the occurrence of MW effects depended on the duration of exposure, a certain minimum duration of exposure was necessary for an effect to manifest itself. These important regularities of the NT MW effects have previously been reviewed[2, 7-9, 24-27].

The first investigations of the NT MW effects at lower frequency ranges were performed by Blackman and colleagues[28-30] and Adey and colleagues[31, 32]. These groups found dependence of the NT MW effects on modulation.

Since that time, other groups have confirmed and extended the main findings of these pioneering studies as will be reviewed below.

Frequency dependence and frequency windows

The effects of NT MW on DNA repair in *E. coli* K12 AB1157 were studied by the method of anomalous viscosity time dependence (AVTD)[33, 34]. The AVTD method is a sensitive technique to detect changes in conformation of nucleoids/chromatin induced by either genotoxic or stress factors[35-40]. Significant inhibition of DNA repair was found when X-ray-irradiated cells were exposed to MW within the frequency ranges of 51.62-51.84 GHz and 41.25-41.50 GHz. The effects were observed within two "frequency windows", both displaying a pronounced resonance character with the resonance frequencies of 51.755 GHz and 41.32 GHz, respectively[33, 34]. Of note, these MW effects were observed at PD well below any thermal effects and could not be accounted for by heating. The frequency windows of resonance type have often been termed "resonances" as also will be used below.

The resonance frequency of 51.755 GHz was stable within the error of measurements, ±1 MHz with decreasing the PD from $3 \cdot 10^{-3}$ to 10^{-19} W/cm^2 [34, 35]. At the same time, the half-width of the resonance decreased from 100 MHz to 3 MHz revealing an extremely sharp dependence on frequency (Q ~ 10^4). This sharp narrowing of the 51.755 GHz resonance with decreasing the PD from $3 \cdot 10^{-3}$ to 10^{-7} W/cm^2 followed by an emergence of new resonances, 51.675±0.001, 51.805±0.002, and 51.835±0.005 GHz[35, 41]. The half-widths of all these resonances including the main one, 51.755±0.001 GHz, were about 10 MHz at the PD of 10^{-10} W/cm^2. These data were interpreted in the framework of the model of electron-conformational interactions as a splitting of the main resonance 51.755 GHz by the MW field[35].

The MW effects were studied at different PD and several frequencies around the resonance frequency of 51.675 GHz[41]. This resonance frequency was found to be stable, ±1 MHz, within the PD range of 10^{-18} - 10^{-8} W/cm^2. Along with disappearance of the 51.675 GHz resonance response at the sub-thermal PD of 10^{-6} - 10^{-3} W/cm^2, a new resonance effect arose at 51.688±0.002 GHz[41]. This resonance frequency was also stable within the PD range studied.

Taken together, these data[34, 35, 41] suggested a sharp rearrangement of the frequency spectra of MW action, which was induced by the sub-thermal MW. The half-widths of all three resonances depended on PD, changing either from 2-3 MHz to 16-17 MHz (51.675 GHz and 51.668 GHz resonances) or from 2-3 MHz to 100 MHz (51.755 GHz resonance)[35, 41]. The data indicated also that dependencies of half-width on PD might vary for different resonance frequencies.

Significant narrowing in resonance response with decreasing PD has been found when studying the growth rate in yeast cells[42] and chromatin conformation in thymocytes of rats[43]. In the Gründler's study, the half-width of the resonance (near 41 GHz) decreased from 16 MHz to 4 MHz as PD decreased from 10^{-2} W/cm^2 to 5 pW/cm^2[42].

Thus, the results of studies with different cell types indicate that narrowing of the resonance window upon decrease in PD is one of the general regularities in cell response to NT MW. This regularity suggests that many coupled oscillators are involved non-linearly in the response of living cells to NT MW as has previously been predicted by Fröhlich[44].

Gapeev *et al.* studied effects of MW exposure (frequency range 41.75-42.1 GHz, frequency increment 50 MHz, PD 240 μW/cm^2) on the respiratory burst induced by calcium ionophore A23187 and phorbol ester 12-myristate 13-acetate (PMA) in the peritoneal neutrophils of mice[45, 46]. MW inhibited the respiratory burst. MW effect displayed resonance-like dependence on frequency, the resonance frequency and half-width of the resonance being 41.95 GHz and 160 MHz, respectively (Q= 260)[45, 46]. In other studies, Gapeev *et al.* analyzed acute zymosan-induced paw edema in mice[47, 48]. MW exposure of animals at the PD of 0.1 mW/cm^2 resulted in decrease of the paw edema that was frequency-dependent in the range of 42-43 GHz.

Based on the extrapolation from the data obtained in the extremely high frequency range (30-300 GHz), the values for half-width of resonances at the frequency range of mobile phones (0.9–2 GHz) were estimated to be 1-10 MHz[40]. Effects of GSM (Global System for Mobile Communication) MW on chromatin conformation and 53BP1 (tumor suppressor p53 binding protein 1)/γ-H2AX (phosphorylated H2AX histone) DNA repair foci in human lymphocytes were studied in this frequency range[38-40, 49]. Dependence of these MW effects on carrier frequency was observed[38, 40, 49]. This dependence was replicated in independent experiments with lymphocytes from twenty six healthy and hypersensitive persons[38, 39, 49].

Tkalec and colleagues exposed duckweed (*Lemna minor L.*) to MW at the frequencies of 400, 900, and 1900 MHz[50]. The growth of plants exposed for 2 h to a 23 V/m electric field of 900 MHz significantly decreased in comparison with the control, while an electric field of the same strength but at 400 MHz did not have such effect. A modulated field at 900 MHz strongly inhibited the growth, while at 400 MHz modulation did not influence the growth significantly. At both frequencies, a longer exposure mostly decreased the growth and the highest electric field (390 V/m) strongly inhibited the growth. Exposure of plants to lower field strength (10 V/m) for 14 h caused a significant decrease at 400 and 1900 MHz while 900 MHz did not influence the growth. Peroxidase activity in exposed plants varied, depending on the exposure characteristics. Observed changes were mostly small, except in plants exposed for 2 h to 41 V/m at 900 MHz where a significant increase (41%) was found. The authors concluded that MW might influence plant growth and, to some extent, peroxidase activity. However, the effects of MW strongly depended on the characteristics of the field exposure such as frequency and modulation. These dependences were confirmed in further study of the same group[51, 52].

Remondini *et al.* analyzed changes in gene expression in human EA.hy926 endothelial cells using gene microarrays[53]. Cells were exposed to MW (SAR 1.8-2.5 W/kg, 1 h exposure) either at 900-MHz GSM Basic mode or 1800-MHz GSM Basic mode. Exposure to 900 MHz resulted in up-regulation in 22 genes and down-regulation in 10 genes. No significant change in gene expression was observed after exposure to 1800 MHz.

Sigmoid intensity dependences and power windows

It was found by Devyatkov et al. that NT MW effects display sigmoid dependence on intensity above certain intensity thresholds[21]. This type of PD dependence for the MW effects was observed in other studies as previously reviewed[7-9, 24, 25].

The data obtained in experiments with *E coli* cells and rat thymocytes provided new evidence for sigmoid type of PD dependence and suggested that similar to ELF effects, MW effects may be observed within specific "intensity windows"[35, 41, 43, 54]. The most striking example of the sigmoid PD dependence was found at the resonance frequency of 51.755 GHz[35]. When exposing *E. coli* cells at the cell density of $4 \cdot 10^8$ cell/ml, the effect reached saturation at the PD of 10^{-18}-10^{-17} W/cm^2 and did not change up to PD of 10^{-3} W/cm^2. In these experiments, the direct measurements of PD below 10^{-7} W/cm^2 were not available and lower PD was obtained using calibrated attenuators. Therefore, some uncertainty in the evaluation of the lowest PD was possible. The background MW radiation in this frequency range has been estimated to be 10^{-21}-10^{-19} W/m^2/Hz[55]. Based on the experimentally determined half-width of the 51.755 GHz resonance, 1 MHz[35], the background PD was estimated as 10^{-19}-10^{-17} W/cm^2 within the 51.755 GHz resonance. The resonance MW effects on *E. coli* cells were observed at the PD very close to the estimated background value[35, 41, 56-58]. These data suggested that the PD dependence of MW effect at the specific resonance frequencies might have a threshold comparable with the background level. Dependence of the MW effect on PD at one of the resonance frequencies, 51.675 GHz, had the shape of "intensity window" in the PD range from 10^{-18} to 10^{-8} W/cm^2 [41]. It is interesting, that no MW effect at this resonance frequency was observed at sub-thermal and thermal PD. This type of PD dependence has supported hypothesis about possible rearrangement of the frequency MW spectra action by the MW field[35]. The position of the PD window varied between different resonance frequencies and depended on cell density during exposure of cells[41]. Despite some uncertainty in the evaluation of PD at the levels below 10^{-7} W/cm^2 in the referred studies the data indicated that NT MW at the resonance frequencies may result in biological effects at very low intensities comparable with intensities from base stations and other MW sources used in mobile communication.

Gapeev *et al.* have studied dependence of the MW effects at the resonance frequency of 41.95 GHz on the respiratory burst induced by calcium ionophore A23187 and PMA in the peritoneal neutrophils of mice[45, 46]. Inhibitory effects of MW exposure has been observed at the PD of 0.001 mW/cm^2 and displayed sigmoid dependence on PD at higher power densities[45, 46].

In other study, Gapeev *et al.* analyzed acute zymosan-induced paw edema in mice[48]. MW exposure of animals at the frequency of 42.2GHz and exposure duration of 20 min decreased the paw edema. Sigmoid dependence of this effect on PD has been obtained with a maximum reached at the PD of 0.1 mW/cm^2.

In their pioneering study on blood-brain barrier (BBB) permeability, Oscar and Hawkins exposed rats to MW at 1.3 GHz and analyzed BBB permeability by measuring uptake of several neutral polar substances in certain areas of the brain[59]. A single, 20 min exposure, to continuous wave (CW) MW increased the uptake of D-mannitol at average power densities of less than 3 mW/cm^2. Increased permeability was observed both immediately and 4 h after exposure, but not 24 h after exposure. After an initial rise at 0.01 mW/cm^2, the permeability of cerebral vessels to saccharides decreased with increasing microwave power at 1 mW/cm^2. Thus, the effects of MW were observed within the power window of 0.01-0.4 mW/cm^2. Differences in the level of uptake occurred between effects of CW MW and pulsed MW of the same average power. Microwaves of the same average power but different pulse characteristics also produced different uptake levels.

These findings on "power windows" for BBB permeability have been subsequently corroborated by the group of Persson and Salford[60, 61]. In their recent study, the effects of GSM MW on the permeability of the BBB and signs of neuronal damage in rats were investigated using a real GSM programmable mobile phone in the 900 MHz band[62]. The rats were exposed for 2 h at an SAR of 0.12, 1.2, 12, or 120 mW/kg. Albumin extravasation and also its uptake into neurons increased after 14 d. The occurrence of dark neurons in the rat brains increased later, after 28 d. Both effects were seen already at 0.12 mW/kg with only slight increase, if any, at higher SAR values.

Duration of exposure and time after exposure

Bozhanova with co-authors reported that the effect of cellular synchronization induced by NT MW depended on duration of exposure and PD[63]. The dependence on duration of exposure fitted to exponential function. The important observation was that in order to achieve the same synchronization of cells, the decrease in PD could be compensated by the increase in the duration of exposure.

Kwee and Raskmark analyzed effects of MW at 960 MHz and various SARs, 0.021, 0.21, and 2.1 mW/kg on proliferation of human epithelial amnion cells[64]. These authors reported linear correlations between exposure time to MW at 0.021 and 2.1 mW/kg and the MW-induced changes in cell proliferation albeit no such clear correlation was seen at 0.21 mW/kg.

MW exposure of *E. coli* cells and rat thymocytes at PDs of 10^{-5}-10^{-3} W/cm^2 resulted in significant changes in chromatin conformation if exposure was performed at resonance frequencies during 5-10 min[33, 43, 65]. Decrease in the MW effects due to lowering the PD by orders of magnitude down to 10^{-14}-10^{-17} W/cm^2 was compensated by several-fold increase of exposure time to 20-40 min[57]. At the relatively longer duration of exposure, more than 1 h, the same effect at the lowest PD of 10^{-19} W/cm^2 was observed[57].

Gapeyev *et al.* found the frequency and power dependence of anti-inflammatory effect of low-intensity MW exposure (0.1 mW/cm^2) using the model of acute zymosan-induced footpad edema in mice[47]. Single whole-body MW exposure of mice at the frequencies of 42.2, 51.8, and 65 GHz after zymosan injection reduced both the footpad edema and local hyperthermia. Some other frequencies from the frequency range of 37.5-70 GHz were less effective or not effective at all. At the frequency of 42.2 GHz the effect had sigmoid dependence on exposure duration with a maximum at 20-80 min. A linear dependence with significantly lower increment was observed at a 10-fold less intensity (0.01 mW/cm^2). However, this decrease in the effect was compensated by a slight increase in duration of exposure from 80 min to 120 min.

The MW effects on *E. coli* cells depended on the post-exposure time[56-58]. This dependence had an initial phase of increase about 100 min post-exposure followed by a phase, which was close to a plateau, around 100 min. A trend to decrease in effect was observed at longer times up to 300 min[56, 58].

Significant MW-induced changes in chromatin conformation were observed when rat thymocytes were analyzed in-between 30-60 min after exposure to MW[43]. This effect nearly disappeared if the cells were incubated more than 80 min between exposure and analysis.

Gapeev *et al.* have studied dependence of the MW effect on the function of the mouse peritoneal neutrophils in dependence on duration of exposure at the frequency of 41.95 GHz and the PD of 240 μW/cm^2 [45, 46]. This dependence had a bell-shaped form with the maximal effects at 20 - 40 min of exposure.

In recent studies, human lymphocytes from peripheral blood of healthy and hypersensitive to EMF persons were exposed to MW from the GSM mobile phones[38, 39]. MW induced changes in chromatin conformation similar to those induced by heat shock, which remained up to 24 h after exposure. It was found in the same and following studies that GSM MW at the carrier frequency of 915 MHz and UMTS (Universal Mobile Telecommunications System) MW at 1947.4 MHz inhibited formation of 53BP1/γ-H2AX DNA repair foci and these adverse effects remained at 72 h after an 1-h exposure[38, 39, 49].

Of note is that prolonged MW exposures were associated with less prominent effects than shorter exposures in some studies[51, 66, 67]. This type of dependence on exposure duration was explained by adaptation of the exposed systems to the MW exposure[67].

The data indicate that there is a time window for observation of the NT MW effects, which may be dependent on endpoint measured, cell type, duration and PD of exposure. The data from different groups suggest also that duration of exposure may have a larger role for some NT MW effects than PD/SAR.

Coherence time

MW exposure of L929 fibroblasts was performed by the group of Litovitz[68]. MW at 915 MHz modulated at 55, 60, or 65 Hz approximately doubled ornithine decarboxylase

(ODC) activity after 8 h. Switching the modulation frequency from 55 to 65 Hz at coherence times of 1.0 s or less abolished enhancement, while times of 10 s or longer provided full enhancement. These results suggested that the microwave coherence effects are remarkably similar to those observed previously with extremely low frequency (ELF) magnetic fields by the same authors.

Intermittence

Diem and colleagues exposed cultured human diploid fibroblasts and cultured rat granulosa cells to intermittent and continuous MW (1800 MHz; SAR 1.2 or 2 W/kg; different modulations; during 4, 16 and 24 h; intermittent 5 min on/10 min off or continuous exposure)[69]. Comet assay was applied to analyze DNA single- and double-strand breaks. MW-induced effects occurred after 16 h exposure in both cell types and after different mobile-phone modulations. The intermittent exposure showed a stronger effect than continuous exposure.

Remondini *et al.* analyzed changes in gene expression in human HL-60 leukemia cells using gene microarrays[53]. Cells were exposed to MW (SAR 1.0-1.3 W/kg, 1800 MHz DTX mode, 24 h exposure) either continuously or intermittently, 5 min ON/5 min OFF. Gene expression was affected by intermittent exposure but not continuous exposure.

Modulation

There is strong experimental evidence for the role of modulation in the diverse biological effects of NT MW both *in vitro* and *in vivo*[32, 60, 70-79]. Examples include different types of modulation such as amplitude-, speech and phase modulations: (i) Amplitude modulation at 16 Hz, but not 60 Hz or 100 Hz, of a 450-MHz MW increased activity of ODC[74]. (ii) Speech-modulated 835-MHz MW produced no effect on ODC as compared to the typical signal from a TDMA (Time Division Multiple Access) digital cellular phone[71]. (iii) Phase-modulated GSM-1800 MW (Gaussian Minimum Shift Keying, GMSK) at 1.748 GHz induced micronuclei in human lymphocytes while CW MW did not[75].

Gapeev and co-authors studied production of reactive oxygen species (ROS) in isolated peritoneal neutrophils of mice using a model of synergistic reaction of calcium ionophore A23187 and phorbol ester PMA[79, 80]. MW exposure at 41.95 GHz, continuous wave mode and 50 μW/cm^2, inhibited ROS production. MW modulated with the frequency of 1 Hz resulted in stimulation of the synergistic reaction. Modulation frequencies of 0.5, 2, 4, and 8 Hz did not cause significant effects, and modulation frequencies of 0.1, 16, and 50 Hz inhibited the synergistic reaction.

In other study, Gapeev *et al.* analyzed acute zymosan-induced paw edema in mice[48]. MW exposure of animals at the PD of 0.1- 0.7 mW/cm^2 and some "effective" frequencies in the range of 42-43 GHz decreased the paw edema. Application of different modulation frequencies from the range of 0.03–100 Hz to MW exposure at the effective carrier frequency of 42.2 GHz did not lead to considerable changes in the effect. In contrast, modulation of MW at the ''ineffective'' carrier frequencies of 43.0 and 61.22 GHz by frequencies from the ranges of 0.07–0.1 and 20–30 Hz resulted in a maximal anti-inflammatory effects. The results suggested a complex dependence of the anti-inflammatory action of low-intensity MW on carrier and modulation frequencies.

Huber with co-authors investigated effects of MW similar to those used in mobile communication, a "base-station-like" and a "handset-like" signal (10 g tissue-averaged spatial peak-SAR of 1 W/kg for both conditions), on waking regional cerebral blood flow (rCBF) in 12 healthy young men[76]. The effect depended on the spectral power in the amplitude modulation of the carrier frequency such that only "handset-like" MW exposure with its stronger low-frequency components but not the "base-station-like" MW exposure affected rCBF. This finding supported previous observations of these authors[77] that pulse modulation of MW is of importance for changes in the waking and sleep EEG, and substantiated the notion that pulse modulation is crucial for MW-induced alterations in brain physiology.

Markkanen *et al.* exposed cdc48-mutated *Saccharomyces cerevisiae* yeast cells to 900 or 872 MHz MW, with or without exposure to ultraviolet (UV) radiation, and analyzed apoptosis[78]. Amplitude modulated (217 pulses per second) MW significantly enhanced UV induced apoptosis in cells, but no effect was observed in cells exposed to unmodulated fields at the identical time-average SAR of 0.4 W/kg that was lower than the ICNIRP safety standards.

Persson and colleagues studied effects of MW of 915 MHz as CW and pulse-modulated with different pulse power and at various time intervals on permeability of the blood-brain barrier (BBB) in Fischer 344 rats[60]. Albumin and fibrinogen were demonstrated immunochemically and classified as normal versus pathological leakage. The CW-pulse power varied from 0.001 W to 10 W and the exposure time from 2 min to 960 min. The frequency of pathological rats significantly increased in all exposed rats. Grouping the exposed animals according to the level or specific absorption energy (J/kg) gave significant difference in all levels above 1.5 J/kg. The exposure was 915 MHz MW either pulse modulated at 217 Hz with 0.57 ms pulse width, at 50 Hz with 6.6 ms pulse width, or CW. The frequency of pathological rats was significantly higher in MW-exposed groups than in controls and the frequency of pathological rats after exposure to pulsed radiation was significantly less than after exposure to CW.

In a study by Lopez-Martin *et al.*[81], GSM-exposed picrotoxin-pretreated rats showed differences in clinical and EEG signs, and in c-Fos expression in the brain, in comparison to picrotoxin-treated rats exposed to an equivalent dose of unmodulated radiation. Neither MW exposure caused tissue heating, so thermal effects could be ruled out. The most marked effects of GSM MW on c-Fos expression in picrotoxin-treated rats were observed in limbic structures, olfactory cortex areas and subcortical areas, the dentate gyrus, and the central lateral nucleus of the thalamic intralaminar nucleus group. Nonpicrotoxin-treated animals exposed to unmodulated radiation showed the highest levels of neuronal c-Fos expression in cortical areas. These results suggested a specific effect of the pulse GSM modulation on brain activity of a picrotoxin-induced seizure-proneness rat model.

Luukkonen *et al.*[82] investigated effects of MW at 872 MHz and relatively high SAR value (5 W/kg) on intracellular reactive oxygen species (ROS) production and DNA damage in human SH-SY5Y neuroblastoma cells. The experiments also involved combined exposure to MW and menadione, a chemical inducing intracellular ROS production and DNA damage. Both CW and a pulsed signal similar to that used in GSM mobile phones were used. Exposure to the CW radiation increased DNA breakage in comparison to the cells exposed only to menadione. Comparison of the same groups also showed that ROS level was higher in cells exposed to CW RF radiation at 30 and 60 min after the end of exposure. No effects of the GSM-like modulated signal were seen on either ROS production or DNA damage.

Hinrikus *et al.*[83] evaluated the effects of MW (450 MHz) pulse-modulated at the frequencies of 7, 14 and 21 Hz on human electroencephalographic (EEG) rhythms. The field power density at the scalp was 0.16 m W/cm^2. Modulated microwaves caused an increase in the average EEG alpha (17%) and beta (7%) power but the theta rhythm remained unaffected. Increases in the EEG alpha and beta power were statistically significant during the first half-period of the exposure interval (30 s) at the modulation frequencies of 14 and 21 Hz. The authors concluded that the effect of the 450-MHz MW modulated at 7, 14 and 21 Hz varies depending on the modulation frequency.

Hoyto *et al.*[84] exposed human SH-SY5Y neuroblastoma and mouse L929 fibroblast cells to MW (SAR of 5 W/kg) at 872 MHz using continuous-waves (CW) or a modulated GSM-like signal under isothermal conditions[83]. Menadione was used to induce reactive oxygen species, and tert-butylhydroperoxide (t-BOOH) was used to induce lipid peroxidation. Two statistically significant differences related to MW exposure were observed: Lipid peroxidation induced by t-BOOH was increased in SH-SY5Y (but not in L929) cells, and menadione-induced caspase 3 activity was increased in L929 (but not in SH-SY5Y) cells. Both differences were statistically significant only for the GSM-modulated signal.

Franzellitti *et al.*[85] exposed human trophoblast HTR-8/SVneo cells to MW at 1.8 GHz CW and differently modulated GSM signals (GSM-217Hz and GSM-Talk) during 4 - 24 h[84]. The inducible HSP70C transcript was significantly enhanced after 24 h exposure to GSM-217 Hz signals while being reduced after 4 and 16 h exposure to GSM-Talk signal.

Significant amount of *in vivo* studies under varying parameters of exposure (intensity, frequency, exposure time, modulation, intermittence) have been performed in Russia/Soviet Union and published in Russian. Retrospective analysis of 52 Russian/Soviet *in vivo* studies with animals (mice, rats, rabbits, guinea pigs) on chronic exposure to MW has recently been published[11]. In these studies, various endpoints were measured up to 4 month of chronic exposure including analysis of: weight of animal body, histological analysis and weight of tissues, central nervous system, arterial pressure, blood and hormonal status, immune system, metabolism and enzymatic activity, reproductive system, teratogenic and genetic effects. Based on their analysis, the authors concluded that: "exposure to modulated MW resulted in bioeffects, which can be different from the bioeffects induced by CW MW; exposure to modulated MW at low intensities (non-thermal levels) could result in development of unfavorable effects; direction and amplitude of the biological response to non-thermal MW, both *in vitro* and *in vivo*, depended on type of modulation; often, but not always, modulated MW resulted in more pronounced bioeffects than CW MW; the role of modulation was more pronounced at lower intensity levels".

One review of the Russian/Soviet studies on the role of modulation on MW effects is available in English[15]. The authors conclude that "a number of good-quality studies have convincingly demonstrated significant bioeffects of pulsed MW. Modulation often was the factor that determined the biological response to irradiation, and reactions to pulsed and CW emissions at equal time-averaged intensities in many cases were substantially different".

In conclusion, significant amount of in vitro and in vivo studies from different research groups, although not universally reported, clearly indicated dependence of the MW effects on modulation.

Polarization

It is believed that circular polarization might have been important in inducing chiral asymmetry in interstellar organic molecules that could be subsequently delivered to the early Earth and could explain the origin of the chirality of biological molecules[86].

The effects of circularly polarized (CP) MW were studied in *E. coli* cells at the frequencies from two frequency windows (resonances) that were identified using linearly polarized (LP) MW, within the frequency ranges of 51.62-51.84 GHz and 41.25-41.50 GHz[34, 65]. At the resonance frequency of 51.76 GHz, right-handed CP MW inhibited repair of X-ray-induced DNA damages[34, 65]. In contrast to right-handed polarization, left-handed CP MW had virtually no effect on the DNA repair, while the efficiency of LP MW was in-between of two circular polarizations. Inversion in effectiveness of circular polarizations was observed at another resonance frequency, 41.32 GHz. In contrast to the frequency of 51.76 GHz, left-handed CP MW at 41.32 GHz significantly inhibited DNA repair, while right polarization was almost ineffective. MW of the same CP affected cells at several frequencies tested within each resonance, alternative CP being almost ineffective[34, 54, 65]. Therefore, specific sign of effective CP, either left- or right-, was the attribute of each resonance. Two different types of installations, based on either spiral waveguides[65] or quarter-wave mica plates[34, 41, 54, 87, 88], were used to produce CP MW. Similar results were observed regardless the way of producing the MW of different polarizations.

Pre-irradiation of *E. coli* cells to X-rays inverted the sign of effective polarization[34, 54]. This inversion was observed for two different resonances, 41.32 and 51.76 GHz. Neither resonance frequencies, nor half-widths of the resonance changed during the inversions in effective CPs. The effects of left- and right-handed CP MW become the same at 50 cGy[34]. At this dose, about one single stranded DNA break per haploid genome was induced. X-ray-induced DNA breaks result in relaxation of the supercoiled DNA-domains. It is known that the majority of DNA in living cells has a right-handed helicity (B-form) but a minor part, in order of 1 %, may alternate from the B-form with the form of left-handed helix (Z-form). Supercoiling is connected with transitions between right B-form to left Z-form in these DNA sequences. Therefore, the data suggested that difference in biological effects of polarized MW might be connected with DNA helicity and supercoiling of DNA-domains.

Supercoiling of DNA-domains is changed during cell cycle because of transcription, replication, repair, and recombination. It can also be changed by means of DNA-specific intercalators such as ethidium bromide (EtBr). EtBr changes supercoiling and facilitates the transition of DNA sequences from Z-form to B-form. Preincubation of *E. coli* AB1157 cells with EtBr inverted the effective polarization at the resonance frequency of 51.755 GHz and right-handed MW became more effective than left polarization[87]. EtBr changed the supercoiling of DNA-domains starting at a concentration of 1 μg/ml as measured with the AVTD in different cell types including *E. coli*[35, 37, 89]. These data provided further evidence that DNA may be a target for the NT MW effects.

The effects of MW on conformation of nucleoids in *E. coli* cells have recently been studied at the power flux density of 100 μW/cm^2 [90]. Linearly polarized MW resulted in significant effects within specific frequency windows of resonance type in the range of 51-52 GHz. The distances between frequency windows were about 55-180 MHz. Only one of the two possible circular polarizations, left-handed or right-handed, was effective at each frequency window. The sign of effective circular polarization alternated between frequency windows.

While most data on polarization have been obtained by the same research group[34, 41, 43, 54, 56, 65, 87, 88, 90-92], recent data of others corroborated our findings at least partially[93]. These authors analyzed the condensation of chromatin in human buccal epithelium cells by the method of vital indigo carmine staining. MW induced chromatin condensation in dependence on polarization[93].

Obviously, the difference in effects of right- and left polarizations could not be explained by the heating or by the mechanism dealing with "hot-spots" due to unequal SAR distribution. The data about the difference in effects of differently polarized MW, the inversion of effective circular polarization between resonances and after irradiation of cells with X-rays and incubation with EtBr provided strong evidence for the non-thermal mechanisms of MW effects. These data suggested chiral asymmetry in the target for the NT MW effects, one of which is presumably chromosomal DNA[34], and selection rules on helicity if quantum-mechanical approach is applied[54].

Electromagnetic environment

Hypothetically, background EMF might be of importance for the MW effects. This hypothesis is based on the experimental observations that SMF, ELF magnetic fields, and MW at low intensities induced similar effects in cells under specific conditions of exposure[1, 39, 94-96]. Despite very little has been achieved for mechanistic explanation of such effects, there are attempts to consider the effects of EMF in a wide frequency range in the frames of the same physical models[97-103].

Litovitz and colleagues found that the ELF magnetic noise inhibited the effects of MW on ODC in L929 cells[72]. The ODC enhancement was found to decrease exponentially as a function of the noise root mean square amplitude. With 60 Hz amplitude-modulated MW, complete inhibition was obtained with noise levels at or above 2 μT. With the DAMPS (Digital Advanced Mobile Phone System) cellular phone MW, complete inhibition occurred with noise levels at or above 5 μT. Further studies by the same group revealed that the superposition of ELF noise inhibited hypoxia de-protection caused by long term repeated exposures of chick embryos to MW[104].

The effect of a magnetic noise on microwave-induced spatial learning deficit in the rat was investigated by Lai[105]. Rats were exposed to MW (2450 MHz CW, PD 2 mW/cm^2, average whole-body SAR 1.2 W/kg) alone or in combination with noise exposure (60 mG). Microwave-exposed rats had significant deficit in learning. Exposure to noise alone did not significantly affect the performance of the animals. However, simultaneous exposure to noise significantly attenuated the microwave-induced spatial learning deficit. The author concluded that simultaneous exposure to a temporally incoherent magnetic field blocks MW-induced spatial learning and memory deficits in the rat[105].

Lai and Singh studied combined effects of a temporally incoherent magnetic noise (45 mG) and MW (CW 2450 MHz, PD 1 mW/cm^2, average whole-body SAR of 0.6

W/kg) in rat brain cells[106]. MW exposure induced significant DNA breakages as measured with both neutral and alkaline comet assays. Exposure to noise alone did not significantly affect cells. However, simultaneous noise exposure blocked the MW-induced effects.

Yao and colleagues investigated the influence of the GSM-like MW at 1.8 GHz on DNA damage and intracellular reactive oxygen species (ROS) formation in human lens epithelial cells (hLECs)[107]. DNA damage examined by alkaline comet assay was significantly increased after 3 W/kg and 4 W/kg radiation, whereas the double-strand breaks (DSB) evaluated by γ-H2AX foci were significantly increased only after 4 W/kg radiation. Significantly elevated intracellular ROS levels were detected in the 3-W/kg and 4-W/kg groups. After exposure to 4 W/kg for 24 hours, hLECs exhibited significant G_0/G_1 arrest. All the effects were blocked when the MW exposure was superposed with a 2 μT electromagnetic noise. The authors concluded that superposed electromagnetic noise blocks MW-induced DNA damage, ROS formation, and cell cycle arrest.

We have previously reported that resonance effects of MW on *E. coli* cell depend on the magnitude of static magnetic field at the place of MW exposure[57]. This dependence was explained by the model of electron-conformational interactions that also predicted possible shift of resonance frequencies in dependence on SMF[35]. More recently, Ushakov with co-authors exposed *E. coli* cells to MW at the PD of 10^{-10} W/cm^2 and the frequencies of 51.675, 51.755 and 51.835 GHz[88]. In this study, cells were exposed to MW at various values of SMF: 22, 49, 61, or 90 μT. The authors observed that the effects of MW exposure on the conformation of nucleoids depended on the SMF during exposure.

Gapeev *et al.* analyzed effects of MW (41.85-42.1 GHz, frequency increment 50 MHz, PD 50 μBт/cm^2, 20 min exposure) on synergistic reaction of calcium ionophore A23187 and phorbol ester PMA in activation of the respiratory burst of the peritoneal neutrophils of mice[79]. The MW exposure was performed at various SMF. At a SMF of 50 μT, the authors observed frequency-dependent inhibition of the synergetic reaction with maximal effect at the frequency of 41.95 GHz. In the same frequency range, frequency-dependent activation of the synergetic reaction with a maximal effect at the frequency of 42.0 GHz was found at a SMF of 95 μT. The authors concluded that increasing the SMF from 50 to 95 μT resulted in the inversion of ten MW effects and the shift of the resonance frequency by 50 MHz[79, 108]. Moreover, these effects of MW at the 41.95 GHz and 42.0 GHz were not found at the SMF of ±1, 28.3, 75.5 or 117.3 μT suggesting that the NT MMW effects may appear only at specific values of SMF[79, 108].

The observations on dependence of the NT MW effects on SMF and ELF stray field may be of significant interest for further development of physical theory for the NT MW effects and development of safe mobile communication.

Cell-to-cell interaction in response to NT MW

The effects of NT MW at the resonance frequency of 51.755 GHz on conformation of nucleoids in *E. coli* cells were analyzed with respect to cell density during exposure[57]. The per-cell-normalized effect of MW increased by a factor of 4.7±0.5 on average as cell density increased by one order of magnitude, from $4{\cdot}10^7$ to $4{\cdot}10^8$ cell/ml. These data suggested a co-operative nature of cell response to MW, which is based on cell-to-cell

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interaction during exposure. This suggestion was in line with the observed partial synchronization of cells after exposure to MW.

The co-operative nature of cell response to MW at the resonance frequency of 51.755 GHz was confirmed in further studies with *E. coli* cells[35, 41, 58]. In addition, dependence of the per-cell-normalized effect on cell density was found for two other resonances, 51.675 GHz and 51.688 GHz. These data suggested that dependence on cell density during exposure is a general attribute of the resonance response of *E. coli* cells to NT MW. At the cell density of $4{\cdot}10^8$ cells/ml, the average intercellular distance was approximately 13 μm that is 10 times larger than the linear dimensions of *E. coli* cells[57, 58]. Therefore, no direct physical contact seemed to be involved in the cell-to-cell interaction. Two mechanisms, biochemical and electromagnetic, were considered to account for the co-operative nature in the resonance response to weak EMF in wide frequency range including ELF, MW and ionizing radiation[57, 109, 110]. The first one, biochemical, is based on release of secondary chemical messengers (ions, radicals, or molecules) by those cells, which were directly targeted. Via diffusion, these messengers can induce response in other cells. The second mechanism, electromagnetic, is based on reemission of secondary photons. According to this mechanism, reemitted photons can induce response in other cells if the intercellular distance is shorter than the length of photon absorption. Our experimental data on MW effects fitted better to the electromagnetic mechanism but a combination of two mechanisms was also possible[57, 58]. In particular, free radicals with prolonged lifetimes might be involved in the observed cell-to-cell communication during response to EMF[111].

The absorption length of photons with the frequencies of 10^{12}-10^{13} Hz corresponds to the intracellular distance at the cell density of $5{\cdot}10^8$ cell/ml, at which saturation in the dependences of EMF effects on cell density was observed[57, 58, 111, 112]. Such photons may be involved in cell-to-cell communication according to the electromagnetic mechanism and in agreement with the prediction of Fröhlich that biosystems support coherent excitations within frequency range of 10^{11}-10^{12} Hz[44]. From this point of view, cell suspension may respond to NT MW as a whole. In this case, the number of the exposed cells should be large enough to facilitate cell-to-cell communication during the responses to MW at specific parameters of exposure such as frequency, modulation, and polarization. Interestingly, the cell density for saturation of both MW and ELF effects was about $5{\cdot}10^8$ cell/ml that is close to cell densities in soft tissues of eukaryotes[58, 111]. Such density of cells in the tissues may be important for regulation of living systems by electromagnetic cell-to-cell communication. Cellular membranes and DNA have been considered as possible sources of coherent excitations and photons, which may be involved in electromagnetic cell-to-cell communication[35, 44, 111].

PD dependences of the MW effect at the 51.755 GHz resonance frequency were considerably different between two cell densities, $4{\cdot}10^7$ cells/ml and $4{\cdot}10^8$ cells/ml[35]. However, the resonance frequency of 51.755 GHz did not shift with the changes in cell density. The half-width of the 51.755 GHz resonance did not depend on cell density either. Contrary to the 51.755 GHz resonance response, the half-width of the 51.675 GHz resonance depended on cell density[41]. The data suggested that intracellular interaction during the NT MW exposures at some specific frequencies might affect sub-cellular targets for NT MW. This target is presumably chromosomal DNA that is organized in the DNA-domains[34, 92, 97].

In all studies concerning dependence of the MW effects on cell density, the cells occupied a negligible part of the exposed volume and could not change the absorption of MW even at the highest cell densities[35, 41, 57, 58]. Striking difference in the cell responses at various cell densities provided further evidence for non-thermal mechanism of the observed MW effects.

Significant MW effect on synchronization of *Saccharomyces carlsbergensis* yeast cells were observed by Golant and co-authors[113]. Exposure to MW at 30 μW/cm^2 and 46 GHz induced synchronization as measured by cell density and bud formation. The authors assumed that MW induced cell-to-cell interaction resulting in the observed synchronization.

Genetic background and cell type

We studied effects of MW on *E. coli* cells of three isogenic strains with different length of chromosomal DNA[92]. Bacterial chromosomal DNA in N99 wild type cells was lengthened by inserting DNA from λ and λ*imm*^{434}*bio*^{10} phages. Lysogenic strains N99(λ) and N99(λ,λ*imm*^{434}*bio*^{10}) obtained were used for MW exposure along with the wild type N99 strain. The response of each strain was studied at 10-17 frequencies within the ranges of 41.24-41.37 GHz and 51.69-51.795 GHz. Clear resonance responses to MW at 10^{-10} W/cm^2 were observed for each strain in both frequency ranges. Significant shifts of both resonance frequencies were found between strains. The shifted resonances had the same amplitude and half-width as for N99 cells[92]. Upon shifting, no changes in effective circular polarization within each shifted resonance were observed. The shifts in resonance frequencies could not be explained by activity of additional genes inserted with the phage DNA. On the other hand, the theoretical consideration based on oscillations of the DNA-domains regarding a whole nucleoid provided a good correlation between the increasing in the DNA length and the shifts in resonances[92].

A detailed analysis of MW effects on *E. coli* AB1157 cells at 10^{-10} W/cm^2 and various frequencies revealed the resonance frequency of 51.755±0.001 GHz[35]. This value was statistically significantly different from the resonance frequency of 51.765±0.002 in response of *E. coli* N99 cells to MW in the same frequency range[35]. It should be noted that both strains, AB1157 and N99, are considered as wild type strains. Nevertheless, these strains are different in their genotypes by several specific gene markers[23, 33]. These data suggested that strains of different origin, even being considered as wild type strains, might have different resonance responses to NT MW.

Stagg with colleagues exposed tissue cultures of transformed and normal rat glial cells to packet-modulated MW (TDMA that conforms to the North American digital cellular telephone standard) at 836.55 MHz[114]. Results from DNA synthesis assays differed for these two cell types. Sham-exposed and MW-exposed cultures of primary rat glial cells showed no significant differences for either log-phase or serum-starved condition. C6 glioma cells exposed to MW at 5.9 μW/g SAR (0.9 mW/cm^2) exhibited small (20-40%) but significant increases in 38 % of [^{3}H]-thymidine incorporation experiments.

Repacholi with co-authors chronically exposed wild-type mice and E mu-Pim1 transgenic mice, which are moderately predisposed to develop lymphoma spontaneously, to plane-wave pulse-modulated MW at 900 MHz with a pulse repetition frequency of 217 Hz and a pulse width of 0.6 ms[115]. Incident power densities were 2.6-13 W/m^2 and SARs were 0.008-4.2 W/kg, averaging 0.13-1.4 W/kg. The lymphoma risk was found to be significantly higher in the exposed transgenic mice. No effects were seen in the wild type mice.

Markkanen with colleagues found that MW affected the UV-induced apoptosis in *Saccharomyces cerevisiae* yeast cells KFy437 (cdc48-mutant) but did not modify apoptosis in KFy417 (wild-type) cells[78].

Czyz with colleagues exposed pluripotent embryonic stem (ES) cells of wild-type and deficient for the tumor suppressor p53 to pulse modulated GSM MW at 1.71 GHz[116]. Two dominant GSM modulation schemes (GSM-217 and GSM-Talk), which generate temporal changes between GSM-Basic (active during talking phases) and GSM-DTX (discontinuous transmission, which is active during listening phases thus simulating a typical conversation), were applied to the cells at and below the ICNIRP safety standards. GSM-217 MW induced a significant upregulation of mRNA levels of the heat shock protein hsp70 of p53-deficient ES cells differentiating in vitro, paralleled by a low and transient increase of c-jun, c-myc, and p21 levels in p53-deficient, but not in wild-type cells. Theses data substantiated the notion that the genetic background determines cellular responses to GSM MW.

Human cultured fibroblasts of three different donors and three different short-term human lymphocyte cultures were exposed to UMTS-like MW at 1950 MHz and the SAR below safety limit of 2 W/kg by Schwarz *et al.*[117]. The alkaline comet assay and the micronucleus assay were used to analyze genotoxic effects. UMTS exposure increased the comet tail factor (CTF) and induced centromere-negative micronuclei in human cultured fibroblasts in a dose and time-dependent way. No UMTS effect was obtained with lymphocytes, either unstimulated or stimulated with phytohemagglutinin. The authors concluded that UMTS exposure may cause genetic alterations in some but not in all human cells in vitro.

Hoyto *et al.*[118], analyzed the effects of MW exposure on cellular ornithine decarboxylase (ODC) activity in fibroblasts, two neural cell lines and primary astrocytes. Several exposure times and exposure levels were used, and the fields were either unmodulated or GSM-like-modulated. Murine L929 fibroblasts, rat C6 glioblastoma cells, human SH-SY5Y neuroblastoma cells, and rat primary astrocytes were exposed to RF radiation at 872 MHz in a waveguide exposure chamber equipped with water cooling. Cells were exposed for 2, 8, or 24 hours to CW MW or to a GSM type signal pulse modulated at 217 Hz. ODC activity in rat primary astrocytes was decreased statistically significantly and consistently in all experiments performed at two exposure levels (1.5 and 6.0 W/kg) and using GSM modulated or CW radiation. In the secondary cell lines, ODC activity was generally not affected. The authors concluded that ODC activity was affected by MW exposure in rat primary neural cells, but the secondary cells used in this study showed essentially no response. In further studies by the same group, the difference in response of human SH-SY5Y neuroblastoma and mouse L929 fibroblast cells to a GSM-modulated MW at 872 MHz was documented[84].

Nylund and Leszczynski have examined cell response to MW (900 MHz GSM-like signal, average SAR of 2.8 W/kg) using two human endothelial cell lines: EA.hy926 and EA.hy926v1[119]. Gene expression changes were examined using cDNA Expression Arrays and protein expression changes were examined using 2-DE and PDQuest software. The same genes and proteins were differently affected by exposure in each of the cell lines.

Remondini *et al.* analyzed changes in gene expression in six human cell lines by gene microarrays[53]. Cells were exposed to MW at 900 MHz GSM Basic mode, SAR 1.8-2.5

W/kg, 1 h exposure. Most cell lines responded to GSM-900 MHz, except for the CHME5 human microglial cells.

Zhao *et al.* studied whether expression of genes related to cell death pathways are dysregulated in primary cultured neurons and astrocytes by exposure to MW from GSM cell phone at the frequency of 1900 MHz for 2 h[120]. Microarray analysis and real-time RT-PCR have shown up-regulation of caspase-2, caspase-6 and Asc (apoptosis associated speck-like protein containing a card) gene expression in neurons and astrocytes. Up-regulation occurred in both "on" and "stand-by" modes in neurons, but only in "on" mode in astrocytes. Additionally, astrocytes showed up-regulation of the Bax gene. The authors concluded that even relatively short-term exposure to the cell phone can up-regulate elements of apoptotic pathways in cells derived from the brain, and that neurons appear to be more sensitive to this effect than astrocytes.

Finally, it follows from the emerging data that MW effects are defined by the genotype and may be cell-type and cell-line dependent. These dependences may explain, at least partly, the discrepancies among replication studies from different laboratories.

Gender- and age-related differences

There are studies indicating that MW may exert a gender-related influence on brain activity[121-123]. Papageorgiou and co-authors investigated the gender-related influence of MW similar to that emitted by GSM900 mobile phones on brain activity[121]. Baseline EEG energy of males was greater than that of females, and exposure to MW decreased EEG energy of males and increased that of females. Memory performance was invariant to MW exposure and gender influences. Smythe and Costall reported the effects of mobile phone exposure on short- and long-term memory in male and female subjects[122]. The results showed that males exposed to an active phone made fewer spatial errors than those exposed to an inactive phone condition, while females were largely unaffected. These results further indicated that mobile phone exposure has functional consequences for human subjects, and these effects appear to be gender-dependent. Nam and colleagues exposed volunteers of both gender to MW emitted by a CDMA cellular phone for half an hour[123]. Physiological parameters such as systolic and diastolic blood pressures, heart rate, respiration rate, and skin resistance were simultaneously measured. All the parameters for both groups were unaffected during the exposure except for decreased skin resistance of the male subjects[123].

Prevalence of women (usually around 70%) among subjects, which report hypersensitivity to electromagnetic fields of wide frequency range including MW, may also be considered as an indirect evidence for the gender-dependent effects of MW.

In his pioneering study concerning age in cancer risk from MW exposure, Hardell and colleagues found that the highest risks were associated with >5-year latency period in the 20-29-year age group for analog phones (OR = 8.17, 95% CI = 0.94-71), and cordless phones (OR = 4.30, 95% CI = 1.22-15)[124]. Of note, no participants of age less 20 years were involved on this study. In further studies from the Hardell's group, highest risk was found in the age group <20 years at time of first use of wireless phones[125, 126].

Nam with co-authors reported that skin resistance in teenagers decreased by exposure to CDMA MW from cellular phones whereas no effects were seen in adults[123].

Individual differences

We observed significant individual variations in effects of GSM and UMTS MW on chromatin conformation and 53BP1/γ-H2AX DNA repair foci in studies with lymphocytes from hypersensitive to EMF subjects and healthy persons[38-40, 49].

Shckorbatov with colleagues investigated electrokinetic properties of cell nuclei and condensation of heterochromatin in human buccal epithelium cells in response to MW at 42.2 GHz[127]. MW exposure decreased electric charge of cell nuclei and an increased chromatin condensation in dependence on individual traits of donors[127].

Hinrikus *et al.*[83] evaluated the effects of pulse-modulated MW (450 MHz) on human EEG rhythms. Thirteen healthy volunteers were exposed to MW; the field power density at the scalp was 0.16 m W/cm^2. Differences were found in individual sensitivity to exposure. Increases in the EEG beta power appeared statistically significant in the case of four subjects. In other study, the same authors confirmed and extended their observations on individual sensitivity to exposure with pulse-modulated MW[128]. The experiments were carried out on four different groups of healthy volunteers. A 450-MHz MW modulated at 7 Hz (first group), 14 and 21 Hz (second group), 40 and 70 Hz (third group), 217 and 1000 Hz (fourth group) frequencies was applied. MW exposure, SAR 0.303 W/kg, increased the EEG energy. The proportion of subjects significantly affected was similar in all groups except for the 1000 Hz group: in the first group 16% at 7 Hz modulation; in the second group 31% at 14 Hz modulation and 23% at 21 Hz modulation; in the third group 20% at 40 Hz and 13% at 70 Hz modulation; in the fourth group 16% at 217 Hz and 0% at 1000 Hz modulation frequency.

Zotti-Martelli with colleagues exposed peripheral blood lymphocytes from nine different healthy donors for 60, 120 and 180 min to CW MW with a frequency of 1800 MHz and PD of 5, 10, and 20 mW/cm^2 and analyzed DNA damage using micronucleus (MN) assay[129]. Both spontaneous and induced MN frequencies varied in a highly significant way among donors, and a statistically significant increase of MN, although rather low, was observed dependent on exposure time and PD. The data analysis highlighted a wide inter-individual and reproducible variability in the response.

Sannino *et al.* evaluated the induction of micronuclei in response to MW (900 MHz, average SAR of 1.25 W/kg) exposure and subsequent treatment with mitomycin C in peripheral blood lymphocytes from five human volunteers[130]. MW exposure reduced the level of mitomycin C –induced micronuclei in cells collected from four donors (i.e., responders). However, the effect of MW was not observed in the remaining donor (i.e., non-responder). The overall data indicated the existence of heterogeneity in the MW response among individuals.

Physiological variables

The importance of physiological variables, which may include all conditions of cell culture growth such as aeration, the composition of the growth and exposure media, on NT MW effects has previously been reviewed[8].

In our investigations, *E. coli* cells were exposed to CP or LP MW (100 μW/cm^2) at the resonance frequencies of 41.32 GHz and 51.76 GHz[56, 57]. Both value and direction of the MW effects strongly depended on the phase of culture growth. At logarithmic phase of growth, MW resulted in condensation of nucleoids. In contrast, MW exposure decondensed nucleoids in cells if exposure was performed at the stationary phase of growth. It is known, that the state of nucleoid condensation depends on cell activity. In stationary cells nucleoids are more condensed compared to logarithmic cells that divide actively. We concluded that MW are able to either stimulate or inhibit activity of the cells in dependence on stage of growth, stationary or logarithmic, respectively. Higher variability in effects was observed for logarithmic phase and effects were more stable for the stationary phase that is characterized by partial synchronization of cells[56, 57]. There was no effect at all if cells were exposed at the end of the logarithmic phase where the MW effects changed their direction from inhibition to stimulation[57]. Another peculiarity was observed at the very beginning of the logarithmic stage, where the condensation of chromatin induced by MW was very weak. The AVTD data were confirmed by the electrophoretic analysis of proteins bound to DNA[56]. The main feature of the effect in the stationary phase was a decrease in the quantity of several unidentified DNA-bound proteins with molecular weights of 61, 59, 56, 26, and 15 kDa. In contrast, the main trend was an increase in some proteins, 61, 56, 51 and 43 kDa after exposure at the logarithmic phase. The decrease or increase in the level of proteins bound to DNA correlated with the observed changes in the state of nucleoids, decondensation or condensation, respectively.

The MW effects was studied both at stationary and logarithmic phase of growth during exposure to MW in the PD range of 10^{-18} to $3 \cdot 10^{-3}$ W/cm^2 at various cell densities[58]. Relatively weak response to MW was observed in exponentially growing cells. Partially synchronized stationary cells were more sensitive, especially at the cell densities above 10^8 cell/ml. The data suggested that the co-operative responses of cells to MW vary in dependence on phase of growth.

Recent data by Ushakov and colleagues indicated that the MW effects on *E. coli* cells depended on concentration of oxygen in the cell suspension during exposure[88]. This dependence might suggest that oxygen concentration should be indicated in order to improve reproducibility in replication studies.

Similar to the effects of ELF[95], the MW effects were reported to depend on concentration of divalent ions[79].

Antioxidants and radical scavengers inhibit effects of MW

Lai and Singh described effects of MW on the rat brain cells as measured using a microgel electrophoresis assay[131]. These effects were significantly blocked by treatment of rats either with the spin-trap compound N-tert-butyl-α-phenylnitrone or with melatonin that is a potent free radical scavenger and antioxidant[132]. These data suggested that free radicals might be involved in the effects of MW.

Oktem and colleagues exposed rats to MW from GSM900 mobile phone with and without melatonin treatment[133]. Malondialdehyde (MDA), an index of lipid peroxidation, and urine N-acetyl-beta-d-glucosaminidase (NAG), a marker of renal tubular damage, were used as markers of oxidative stress-induced renal impairment. Superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GSH-Px) activities were studied to evaluate changes in antioxidant status. In the MW-exposed group, while tissue MDA and urine NAG levels increased, SOD, CAT, and GSH-Px activities were reduced. Melatonin treatment inhibited these effects. The authors concluded that melatonin might exhibit a protective effect on mobile phone-induced renal impairment in rats.

Ozguner and colleagues exposed Wistar-Albino rats to MW from GSM900 mobile phone with and without melatonin and analyzed histopathologic changes in skin[134]. MW induced increase in thickness of stratum corneum, atrophy of epidermis, papillamatosis, basal cell proliferation, granular cell layer (hypergranulosis) in epidermis and capillary proliferation. Impairment in collagen tissue distribution and separation of collagen bundles in dermis were all observed in exposed animals as compared to the control group. Most of these changes, except hypergranulosis, were prevented with melatonin treatment. The authors concluded that exposure to GSM900 MW caused mild skin changes and melatonin treatment could reduce these changes. In other studies of the same group, the ability of melatonin to reduce various MW-induced effects was confirmed and inhibitory potential of the antioxidant caffeic acid phenethyl ester (CAPE) was reported[135-138].

Ayata *et al.* analyzed the effects of 900 MHz MW with and without melatonin on fibrosis, lipid peroxidation, and anti-oxidant enzymes in rat skin[139]. The levels of MDA and hydroxypyroline and the activities of SOD, GSH-Px, and CAT were studied. MDA and hydroxyproline levels and activities of CAT and GSH-Px were increased significantly in the exposed group without melatonin and decreased significantly in the exposed group with melatonin. SOD activity was decreased significantly in the exposed group and this decrease was not prevented by the melatonin treatment. The authors assumed that the rats irradiated with MW suffer from increased fibrosis and lipid peroxidation and that melatonin can reduce the fibrosis and lipid peroxidation caused by MW.

Ilhan with co-authors investigated oxidative damage in brain tissue of rats exposed to GSM900 MW with and without pretreatment with Ginkgo biloba (Gb)[140]. MW induced oxidative damage measured as: (i) increase in MDA and nitric oxide (NO) levels in brain tissue, (ii) decrease in brain SOD and GSH-Px activities, and (iii) increase in brain xanthine oxidase and adenosine deaminase activities. These MW effects were prevented by the Gb treatment. Furthermore, Gb prevented the MW-induced cellular injury in brain tissue revealed histopathologically. The authors concluded that reactive oxygen species may play a role in the adverse effects of GSM900 MW and Gb prevents the MW-induced oxidative stress by affecting antioxidant enzymes activity in brain tissue.

Koylu *et al.* studied the effects of MW on the brain lipid peroxidation in rats, and the possible protective effects of melatonin on brain degeneration induced by MW[141]. The levels of lipid peroxidation in the brain cortex and hippocampus increased in the MW group compared with the control group, although the levels in the hippocampus were decreased by combined administration of MW and melatonin. Brain cortex lipid peroxidation levels were unaffected by melatonin treatment. The authors concluded that melatonin may prevent MW-induced oxidative stress in the hippocampus by strengthening the antioxidant defense system.

Sokolovic *et al.* [142] evaluated the intensity of oxidative stress in the brain of Wistar rats chronically exposed to MW from mobile phones (SAR = 0.043-0.135 W/kg) during 20, 40 and 60 days. A significant increase in brain tissue malondialdehyde (MDA) and carbonyl group concentration was found. Decreased activity of catalase (CAT) and increased activity of xanthine oxidase (XO) remained after 40 and 60 days of MW exposure. Melatonin treatment significantly prevented the increases in MDA content and XO activity in the brain tissue after 40 days of exposure while it was unable to prevent the decrease of CAT activity and increase of carbonyl group contents. The authors concluded that exposure to the mobile phone MW caused oxidative damage in the brain and that treatment with melatonin significantly prevented this oxidative damage.

To conclude this section, several studies suggest that supplementation with antioxidants and radical scavengers can reduce MW effects.

Summary of experimental studies

Numerous experimental data have provided strong evidence for NT MW effects and have also indicated several regularities in appearance of these effects: dependence on frequency within specific frequency windows of "resonance-type"; narrowing of the frequency windows with decreasing intensity; dependence on modulation and polarization; sigmoid dependence on intensity within specific intensity windows including super-low PD comparable to intensities from base stations; thresholds in intensity and exposure time (coherence time); dependence on duration of exposure and post-exposure time; dependence on cell density that suggests cell-to-cell interaction during response to NT MW; dependence on physiological conditions during exposure, such as stage of cell growth, concentration of oxygen and divalent ions, activity of radicals; dependence on genotype; cell-type and cell-line dependence; gender-, age- and individual differences; and SMF and EMF stray field during exposure may be of importance for the effects of NT MW.

Replication studies

Obviously, not taking into account the dependences of NT MW effects on a number of physical parameters and biological variables may result in misleading conclusions regarding the reproducibility of these effects. Especially important might be the observations that NT MW could inhibit or stimulate the same functions dependent on conditions of exposure[2]. Under different conditions of exposure, MW either increased or decreased the growth rate of yeast cells[8], the radiation-induced damages in mice[141], the respiratory burst in neutrophils of mice[79], the condensation of nucleoids in *E coli* cells[56, 57] and human lymphocytes[40]. Potentially bi-directional effects of MW should be taken into account in replication studies.

Despite of considerable body of studies with NT MW in biology, only a few studies were performed to replicate the original data on the NT MW effects. It should be noted, that these replications are usually not completely comparable with the original studies because of either missing description of important parameters of exposure or significant differences in these parameters between original study and replication.

One well-known attempt to replicate the results of Gründler was the study by Gos and co-authors[144]. No MW effects were observed in this replication study. However, the deviations from the Gründler's protocol might be a simple reason for poor reproducibility. For example, synchronized cells were used in studies of Gründler. Contrary to the Gründler's original protocol, Gos used exponentially growing cells. If the MW effects in yeast cells are dependent on stage of growth, cell density and intercellular interactions as it has been described for *E. coli* cells[35, 41, 56, 57], no response should be expected in the logarithmic phase of growth. Gos and colleagues used *S. cerevisiae* strain with the auxotrophy mutations for leucine and uracil. Gründler used the wild type strain. It might suggest another cause for the deviations between the data of Gründler and Gos. Despite orientation of SMF in respect to electric and magnetic components of MW was the same, the values of SMF were different. The stray ELF field was 120 nT in the study by Gos, that is higher than usually observed background fields, < 50 nT. The spectral characteristics of the background fields, which were described only in the study by Gos, might be also different. In addition, the conditions of cell cultivation might vary between studies; for example, the data on oxygen concentration in media used in both studies are not available.

Amount of already known physical and biological variables that are important for reproducibility of NT MW effects seem to be far beyond the limits of usually controlled parameters in biological experiments. The knowledge of some of these variables is based on consistent findings following from experimental studies of different research groups. Further evaluation of variables that are important for the NT MW effects would benefit from the developing of the physical and molecular biological models for the MW effects.

Most reviews of the experimental studies do not include analysis of various biological variables and physical parameters when comparing the data on NT MW effects from different studies. As result, misleading conclusion is often made that MW at NT levels produce no "reproducible" effects.

Possible mechanisms

Analyzing theoretically our experimental data on the MW effects at super-low intensities we concluded that these effects should be considered using quantum-mechanical approach[57]. Reanalysis of our data by Binhi resulted to the same conclusion[97]. This is in line with the fundamental quantum-mechanical mechanism that has been suggested by Fröhlich[145]. Most probably, the physical mechanisms of the NT MW effects must be based on quantum-mechanical approach and physics of non-equilibrium and nonlinear systems[44, 98, 146-148].

Our data indicated also that chromosomal DNA is a target for interaction with MW[34, 87, 92]. The length of genomic DNA is much longer than the dimension of surrounding compartment. For example, there is about 1.8 m of DNA in a human genome that is compacted in interaction with other compounds such as proteins, RNA and ions to fit into a nucleus with a characteristic diameter of 5-10 μm. Importantly, concentration of DNA in the nuclei is higher than in crystallization solutions for DNA, 50-100 mM versus 10-30 mM, respectively. Whether DNA is organized in nuclei as a liquid crystal remains to be investigated. However, it is clear that DNA in a living cell cannot be considered as an aqueous solution of DNA molecules in a thermodynamic equilibrium.

The quantum-mechanical physical model for primary interaction of MW with DNA has been proposed[149]. We hypothesized that genomic DNA contain two different codes[109]. The first one is the well-known genetic triplet code for coding the genes. The second one is a "physical code" that determine the spectrum of natural oscillations in chromosomal DNA including electromagnetic, mechanical and acoustic oscillations, which are hypothetically responsible for regulation of gene expression at different stages of ontogenesis and for genomic rearrangements in evolution[109]. The physical model describing these coupled oscillations in chromosomal DNA has been proposed[92]. This model helps to resolve the so-called C-paradox that addresses the issue of a genome size, so-called C-value. Only few percent of DNA encodes genes in almost all eukaryotic genomes. The same amount of DNA is involved in regulation of gene expression by known biochemical mechanisms. The function of the rest of DNA, which does not depend on complexity of eukaryotic species and is represented by noncoding repetitive DNA sequences, is not understood in molecular biology providing a basement for hypotheses such as "junk DNA". The function of this major part of genomic DNA became clear given that the whole genomic DNA is responsible for the creation of the natural spectrum of oscillations that is hypothetically a main characteristic of each biological species[109].

The understanding of mechanisms for the NT MW effects is far from comprehensive. Many questions remain to be addressed such as whether resonance effects of MW depend on electromagnetic noise and SMF during exposure.

Urgent needs and further perspectives

At present, new situation arose when a significant part of the general population is exposed chronically (much longer than previously investigated durations of exposures) to NT MW from different types of mobile communication including GSM and UMTS/3G phones and base stations, WLAN (Wireless Local Area Networks), WPAN (Wireless Personal Area Networks such as Bluetooth), DECT (Digital Enhanced (former European) Cordless Telecommunications) wireless phones. It should be anticipated that some part of the human population, such as children, pregnant women and groups of hypersensitive persons could be especially sensitive to the NT MW exposures.

Multiple sources of mobile communication result in chronic exposure of significant part of general population to MW at the non-thermal levels. Therefore, the ICNIRP safety standards, which are based on thermal effects in acute exposures, cannot protect the general population from the chronic exposures to NT MW from mobile communication[13].

Most of the real signals that are in use in mobile communication have not been tested so far. Very little research has been done with real signals and for durations and intermittences of exposure that are relevant to chronic exposures from mobile communication. In some studies, the so-called "mobile communication-like" signals were investigated that in fact were different from the real exposures in such important aspects as intensity, carrier frequency, modulation, polarization, duration and intermittence. How relevant such studies to evaluation of adverse health effects from MW of mobile communication is not known.

Emerging evidence suggests that the SAR concept, which has been widely adopted for safety standards, may not be useful alone for the evaluation of health risks from MW of mobile communication. How the role of other exposure parameters such as frequency, modulation, polarization, duration, and intermittence of exposure should be taken into account is an urgent question to solve. Solving this question would greatly benefit from the knowledge of the physical mechanisms of the NT MW effects.

So far, most laboratory and epidemiological studies did not control important features of the NT MW effects as described above and therefore, only limited conclusion regarding health effects of MW from mobile communication can be drawn from these studies. It should be noted that one group of epidemiologists with a long-lasting experience in studying relationship between mobile phone usage and cancer risk have consistently been concerned regarding importance of various MW signals and exposure durations[19, 150-152]. The group of Hardell was the first epidemiologic group in attempting to study separately the MW signals from cordless phones, analogue phones and digital phones. As a rule, analogue phones had the highest association with the cancer risk. Cordless phones were associated with the risk for brain tumors, acoustic neuroma, and

T-cell lymphoma stronger or in the same degree as digital and analogue phones despite significantly lower SAR values were produced by cordless phones[17, 19, 151, 152]. It should be also noted that epidemiological data are controversial and methodological differences are a subject of debates between various research groups[17, 153]. However, the approach of Hardell's group is more valid from the mechanistic point of view and this should be taken into account when comparing with results of other groups that ignore or minimize the complex dependencies of the NT MW effects on several parameters/variables.

The data about the effects of MW at super low intensities and significant role of duration of exposure in these effects along with the data showing that adverse effects of NT MW from GSM/UMTS mobile phones depend on carrier frequency and type of the MW signal suggest that MW from base-stations/masts can also produce adverse effects at prolonged durations of exposure and encourage the mechanistic *in vitro* studies using real signals from base stations/masts. Further investigations with human primary cells under well controlled conditions of exposure, including all important parameters as described above, are urgently needed to elucidate possible adverse effects of MW signals that are currently being used in wireless communication, especially in new technologies such as UMTS mobile telephony.

The dependence of adverse effects of NT MW from GSM/UMTS mobile phones on carrier frequency and type of signal should be taken into account in settings of safety standards and in planning of *in vivo* and epidemiological studies. Of note, the data from epidemiological studies should be treated with care. Indeed, it is almost impossible to select control unexposed groups because the whole population in many countries is exposed to wide range of MW signals from various sources such as mobile phones and base stations/masts of various kinds, WLAN, WPAN, DECT wireless phones and given that duration of exposure (must be at least 10 years for cancer latency period) may be more important for the adverse health effects of NT MW than PD/SAR. From this point of view, current epidemiological studies may be either inconclusive, if results are negative, or may underestimate the hazard of MW exposure, if results are positive.

The joined efforts of scientific groups within national or international programs are needed for mechanistic studies of the NT MW effects. In order to take unto account all necessary physical parameters and biological variables, these programs should involve scientists with long-lasting experience in studying NT MW effects.

Because NT MW affect not only brain cells, but also blood cells[38-40, 75], skin and fibroblasts[68, 69, 134, 154], stem cells[67, 116, 155], reproductive organs and sperm quality[156-159] the using of hands-free cannot minimize all adverse health effects. Possibilities to minimize the adverse effects of NT MW using various biophysical and biochemical approaches should be studied.

Identification of those signals and frequency channels/bands for mobile communication, which do not affect human cells, is needed as a high priority task for the development of safe mobile communication.

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Is cognitive function affected by mobile phone radiation exposure?

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Abstract

Behavioral tasks, including the Morris water maze (MWM), radial arm maze and object recognition task, have been extensively used to test cognitive impairment following exposure of rodents to mobile phone (MP) radiation on various frequencies and specific absorption rate (SAR) values. Exposed animals in most of the cases revealed defects in their working memory possibly due to cholinergic pathway distraction. The only experiment on mice at very low SAR did not show statistically significant deficits by 8-arm maze, but our own data in mice exposed to GSM 900 MHz radiation, revealed memory lesions on MWM task; exposed mice had difficulties in memory consolidation and/or retrieval of the stored information. Lastly, a number of studies have been applied to volunteers showing variable results depending on the experimental setup, revealing memory improvement or deficits following MP exposure.
The recorded data from the literature are generally favouring the conclusion that EMF is affecting memory function although a more rigorous and reproducible exposure system has to be adopted in relation to the recently criticized importance of SAR.

Key words: **electromagnetic fields, Morris water maze, spatial memory, cognition**

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Note added in proofs:
A number of studies have appeared after the submission of the manuscript, dealing with EMFs and cognitive memory function. It is worth mentioning that a positive effect was found on transgenic mice for Alzheimer's disease following chronic exposure to MP radiation as reported by Arendash GW, Sanchez-Ramos J, Mori T, et al. Journal of Alzheimer's Disease 2010; 19: 191–210.

Introduction

The extended use of mobile phone technology throughout all social levels and all ages, starting from as low as 4 years old, has forced a large number of scientists to get involved in the investigation of the effects. The major issue is that unlike other forms of everyday radiation exposure, the use of the mobile phone and the wireless DECT phone takes place near the user's head and therefore direct or indirect effect on the brain function is highly possible. Thus, the elucidation of the cellular, molecular and behavioural effects has to be explored in depth, especially since the majority of life-time users will be the current teenagers.

The aim of this kind of research is to determine a specific absorption rate (SAR) value threshold below which no obvious effects are detected in any organism, any cell, in order to propose biologically based levels for exposing humans on a daily basis either through cell phones, or base stations or DECT wireless phones or even wi-fi routers and baby monitors.

To approach these questions, extensive research is being performed in various laboratories. Due to the still unknown mode of primary action at the molecular level, many approaches studying the effects of microwaves (MW) have been applied[1].

At the population level, studies deal with the effects by statistically correlating exposure conditions to health symptoms, as severe as brain tumors[2, 3], or mild well being discomforts, such as headaches or fatigue[4]. There is also a report on children exposed prenatally to mobile phone radiation showing defects on behavior[5]. In humans, the studies involve mainly volunteers and have investigated possible effects on sleeping conditions and memory function[6].

Studies on animal models involve every possible aspect of experimental approach (behavioral, molecular, biochemical, biophysical, ultrastructural, physiological). Such models used are mainly rodents and to a less degree insects. Our group has shown DNA fragmentation and induced cell death during oogenesis, along with a decrease in the offspring number in insects and a defect on osteogenesis following prenatal exposure in mice[7-9].

Due to the fact that mobile phone use affects mainly the brain tissues, special attention has been given to the study of hippocampus, cerebellum and frontal brain function and structure on rodents (mostly rats). In general there are numerous reports on the effects of electromagnetic fields (EMF) on cognitive functions. Animal learning and memory function have been tracked using mazes, such as the Morris water maze (MWM), the radial arm maze (RAM), as well as the object recognition task (ORT) and the object location task (OLT). It is well documented that these mazes are related to the spatial environment and recognition learning and memory. Extra maze spatial cues are widely applied to facilitate learning and testing any deficits following exposure to MW. Especially RAM is being used to explain hippocampal formation and function[10].

The MWM task is widely used since spatial navigation is a complex cognitive function that depends on several neural and cognitive systems for successful completion[6, 11]. Unlike the T-maze in which the animals have to make a binary decision (i.e. going left or right), in the MWM successful performance requires continuous monitoring of the animal's position in relation to extra-maze cues: a process that involves "cognitive mapping". Many reports have controversially showed impairment[12, 13], or improvement[14, 15].

At the cell culture level, a number of studies have been performed in order to clarify under controllable and reproducible conditions, the actual primary damage induced by

EMFs. Thus, in cultured hippocampus neurons a decrease of excitatory synaptic activity and a reduced number of excitatory synapses was detected after exposure to GSM 1800 radiation (15 min/day for 7 days) at a SAR value of 2.4 W/kg[16].

In addition, a recent report has found that EMFs affect the endocytotic activity of murine melanoma cells[17].

Besides MW radiation effects, a limited number of studies has used extremely low frequency (ELF) EMF (50 or 60 Hz depending on the power line) revealing memory deficits on rats[18-20], which, interestingly, become less prominent upon exposure of the animals to MW[21]. A similar study but on mice showed reversible effects on cognitive functions as revealed by 8-arm RAM[22].

Given the controversial evidence existing on the occurrence or not of any effects following MW exposure, we present herein a comparative analysis of reports on cognitive effects including some of our own recently published experimental data.

Results and discussion

Several pioneer studies concerning the effects of MW on cognitive functions, that examined the short term memory of rats, are published using a 2450-MHz circular waveguide exposure system and a SAR value of 0.6 W/kg[23]. These investigators demonstrated significant deficits when exposed rats were performing at the RAM and the MWM and suggested that the reported defects in the working memory of rats are possibly due to cholinergic pathway distraction. On a later report it was shown that rats exposed to the same conditions, pulsed 2450-MHz MW (500 pulses/s, average power density 2 mW/cm^2, average whole body SAR 1.2 W/kg), for 1 hour just before each training session in a water maze, showed a deficit in their spatial "reference" memory[24].

On the other hand, Cobb and collaborators[25], replicating the experiments by Lai[23], under the same conditions of exposure, i.e. 2450-MHz, circular polarized waveguide system (CWG), SAR value 0.6 W/kg, but with minor methodological differences, did not find any effects on memory and learning in rats. Additionally, another report that appeared at the same year by exposing rats at similar conditions, did not observe any effects with RAM (Table 1)[26]. However, it had been reported earlier that MW affect specific cognitive aspects of behavior such as, attention, memory, learning, discrimination, time perception, which may occur even at very low SAR levels[27].

Also, using RAM and ORT, no evidence was found at even higher SAR values of 1-3.5 W/kg, by applying head only and not whole body exposure of rats for 45 minutes and at another frequency of 900-MHz[28]. Cosquer and collaborators on 2005 using a 12-arm maze apparatus, bordered by 30 cm high opaque walls, observed that exposed rats behaved normally. Therefore they concluded that MW exposure under those conditions (2450-MHz, circularly polarized field – Table 1) does not alter spatial working memory, when access to spatial cues was reduced[29].

In a recent report, the MWM performance of male Wistar rats was affected following exposure to 50 missed calls/day for 4 weeks by a GSM (900/1800 MHz) mobile phone in vibratory mode[30]. The phone-exposed animals had significantly (~3 times) higher mean latency to reach the target quadrant in the MWM and spent significantly (~2 times) less time in the target quadrant. Trying to understand the cellular basis of the observed behavioural deficits, Leif Salford and collaborators have reported that a 2-hr exposure of rats at GSM 915-MHz resulted in neuronal damage, 28 and 50 days later[31]. In addition,

Table 1 - Comparative studies of EMF on cognitive performance
(ND=not determined, MWM=Morris Water Maze, RAM=Radial Arm Maze)

Study	Experimental Animal	Exposure source	Frequency	SAR or density	Duration of exposure	Task	Findings
Lai *et al.*, 1994	Rats	Circular polarized generator	2450 MHz	0.6 W/kg	45' before each trial	12-arm RAM	Deficit in working memory
Wang B, Lai H, 2000	Rats	Circular polarized generator	2450 MHz	1.2 W/kg	1 h before each training	MWM	Deficit in spatial reference memory
Cobb *et al.*, 2004	Rats	Circular polarized generator	2450 MHz	0.6 W/kg	45' before each trial	12-arm RAM	No effect
Dubreuil *et al.*, 2003	Rats	RF generator Head only	GSM 900 MHz	1 W/kg 3.5 W/kg	45' before each trial	12-arm RAM ORT	No effect
Cassel *et al.*, 2004	Rats	Circular polarized generator	2450 MHz	0.6 W/kg	45' before each trial	RAM	No effect
Cosquer *et al.*, 2005	Rats	Circular polarized generator	2450 MHz	0.6 W/kg	45' before each trial	RAM reduced access to cues	No effect
Nittby *et al.*, 2008	Rats	TEM cells	GSM 900 MHz	0.6 mW/kg 60 mW/kg	2 hr/week for a year	ORT episodic-like memory test 3 weeks after exposure	Effect
Narayanan *et al.*, 2009	Rats	Mobile phone	GSM 900/1800 MHz	ND	~ 50'/day (50 missed calls/day for 4 weeks)	MWM	Spatial memory impairment
Lai, 1996 Lai *et al.*, 1998	Rats	Sinusoidal magnetic fields	60Hz	1 mT	1 hr	12-arm RAM	Effect
Jadidi *et al.*, 2007	Rats	Sinusoidal magnetic fields	50 Hz	8 mT	20'	MWM	Spatial memory impairment
Sienkiewicz *et al.*, 2000	Mice	GTEM cells far field	GSM 900 MHz	0.05 W/kg	45'/day for 10 days	8-arm RAM	No effect
Fragopoulou *et al.*, 2010	Mice	Mobile phone	GSM 900 MHz	0.41-0.98 W/kg	1 hr before each trial and between the trials	MWM	Spatial memory impairment, learning lesions

(continued)

Table 1 - *continued*
(ND=not determined, MWM=Morris Water Maze, RAM=Radial Arm Maze)

Study	Experimental Animal	Exposure source	Frequency	SAR or density	Duration of exposure	Task	Findings
Sienkiewicz *et al.*, 1998	Mice	Sinusoidal magnetic fields	50 Hz	7.5 µT to 7.5 mT	45' before each trial	8-arm RAM	Reversible effects
Preece *et al.*, 1999	Humans	Local brain exposure analog phone	915 MHz	1 W power	ND	Working memory	Improved performance
Koivisto *et al.*, 2000	Humans	Local brain exposure by mobile phone	GSM 902 MHz	0.25 W mean power	On and off	Working memory	Improved performance
Edelstyn and Oldershaw, 2002	Humans 20-22 years old	Local brain exposure by mobile phone	GSM 900 MHz	1.19 W/kg	30'	Cognitive neuropsycho-logical tests subtraction and verbal fluency	Improvement
Maier *et al.*, 2004	Humans	Local brain exposure by mobile phone	GSM 915 MHz	1.0 mW/m^2	50'	Auditory discrimination	Impairment
Besset *et al.*, 2005	Humans	Local brain exposure by mobile phone	GSM 900	ND	2 hr/day, 5 days/week for 45 days	Cognitive tasks	No effect
Russo *et al.*, 2006	Humans	Local brain exposure by mobile phone	GSM 888 MHz Modulated CW-un-modulated	1.4 W/kg	40' prior to test	Cognitive tasks	No effect
Krause *et al.*, 2006	Children	Local brain exposure by mobile phone	GSM 902 MHz	1.4 W/kg	On and off	Auditory memory task	Effects on brain oscillatory responses
Regel *et al.*, 2007	Humans	Local brain exposure by mobile phone	GSM 900 MHz	1.0 W/kg	30' prior to test	Cognitive tasks	Increased accuracy in a working memory test
Haarala *et al.*, 2007	Humans	Signal generator and dummy phone	GSM 902 MHz	1.1 W/kg	On and off	Cognitive tasks	No effects
Luria *et al.*, 2009	Humans	Local brain exposure by mobile phone	GSM Nokia 5110	0.54-1.09 W/kg	On and off	Spatial working memory	Delay on reaction time

(continua)

Table 1 - *continued*
(ND=not determined, MWM=Morris Water Maze, RAM=Radial Arm Maze)

Study	Experimental Animal	Exposure source	Frequency	SAR or density	Duration of exposure	Task	Findings
Wiholm *et al.,* 2009	Humans	Headset with a fixed antenna placed on the left side of the head	884 MHz	1.4 W/kg	150' prior to test at 10 p.m.	Spatial memory and learning	Symptomatic group improved their performance

Reports have been ordered according to date published, species exposed and type of radiation

the same group has reported that the blood brain barrier (BBB) has been disrupted in irradiated rats[32].

Concerning the long term effects, Salford's group has shown in rats that whole body SAR values, as low as 0.6 and 60 mW/kg, significantly alter the performance during an episodic-like memory test after 55 weeks of 2-hr exposure once a week[33].

Studies on the effects of MW radiation on mice' cognitive functions are very limited. In one of them the animals were exposed within GTEM (Gigahertz Transverse Electromagnetic) cells at GSM 900-MHz frequency but at very low SAR of just 0.05 W/kg. No statistically significant deficits were resolved by 8-arm maze[34]. Expanding the exploration on the effects of radiation on mice, our group has performed a series of experiments to test spatial memory and learning in mice *Mus musculus* Balb/c using primarily the MWM task. The exposure setup consisted of a commercially available mobile phone, as firstly introduced by our group in insects[7, 8] and applied recently as well in mice[9, 35]. In these experiments free moving mice were irradiated within their home plastic cages, as also reported by other studies in rats[30, 36]. The animals were exposed to a 2-hr daily dose of pulsed GSM 900-MHz voice modulated at a SAR level of 0.41 to 0.98 W/kg, for four consecutive days during the MWM task protocol. Extended analysis of the data revealed that the animals exposed to the near field of a commercially available mobile phone could not transfer the learned information across the training days. Moreover, the data of the memory probe trial showed that the exposed animals had difficulties in memory consolidation and/or retrieval of the stored information of the position of the hidden platform, since they showed no preference for the target quadrant. Before each set of experiments the mean power density of the radiation emitted by the mobile phone handset in the RF range at 900-MHz was measured with the field meter's probe placed inside the cage with the animals. The measured exposure values were in general within the established exposure limits by ICNIRP on 1998[37]. We used commercially available digital mobile phone handsets, in order to analyse effects of real mobile telephony exposure conditions. Thus, instead of using simulations of digital mobile telephony signals with constant parameters (frequency, intensity, etc.), or even "test mobile phones" programmed to emit mobile telephony signals with controllable power or frequency, we used real GSM signals which are never constant since there are continuous changes in their intensity[35].

The SAR was approximately calculated according to the formula[37, 38]:

$$SAR = \sigma E^2/\rho$$

where **E** is the root mean square value of the electrical field, **σ** is the mean electrical conductivity of the tissues and **ρ** is the mass density. The SAR is a parameter widely used by many authors to compare the absorbed energy in different biological tissues. Thus, the parameters used for mice and rats were calculated according to Peyman *et al.*[39].

Another very promising and significant set of approaches involves experimental studies on volunteers and have focused on human cognitive function following exposure to mobile phone radiation (Table 1). One category of reports has shown memory improvement, i.e. facilitation in attention following exposure to mobile phone[14]. In another case, 915-MHz mobile phone exposure improved performance in a working memory task[13], and in the same direction another study found improvement in cognitive tasks, i.e. verbal memory capacity, sustained attention and visuospatial working memory[40].

Also, DeSeze' group has studied on 2005 the outcomes from the daily use of mobile phones GSM 900 on cognitive function[41]. Fifty-five subjects (27 males and 28 females) were divided into two groups: a group with mobile phone switched on and a group with mobile phone switched off. The two groups were matched according to age, gender, and IQ. This double blind study lasted for 45 days and the neuropsychological test battery composed of 22 tasks, screened four neuropsychological categories: information processing, attention capacity, memory function, and executive function. This neuropsychological battery was performed four times, on day 2, day 15, day 29, and day 43. The results indicated that daily mobile phone use had no effect on cognitive function after a 13-hr rest period.

In a very interesting study Krause and collaborators assessed the effects of EMF emitted by mobile phones on the 1-20 Hz range by event-related brain oscillatory electroencephalogram (EEG) responses in children performing an auditory memory task (encoding and recognition)[42]. What they found was that EMF emitted by mobile phones has effects on brain oscillatory responses during cognitive processing at least in teenagers. Also in an attempt to test MW effects on human attention Russo and collaborators studied on 2006 a large sample of volunteers (168) using a series of cognitive tasks apparently sensitive to RF exposure (a simple reaction task, a vigilance task, and a subtraction task)[43]. Participants performed those tasks twice, in two different sessions. In one session they were exposed to RF, with half of subjects exposed to GSM signals and the other half exposed to continuous waves (CW) signals, while in the other session they were exposed to sham signals. No significant effects of RF exposure on performance for either GSM or CW were found. On the other hand, it has been shown that in humans, exposure at 1 W/kg, to pulse-modulated radio frequency electromagnetic field 900 MHz, reduced reaction speed and increased accuracy in a working-memory task[44]. The same study showed that exposure prior to sleep alters brain activity. For a summary of the available literature see Table 1.

The possible effects of CW and pulse modulated (PM) EMF on human cognition in 36 healthy male subjects were studied by Haarala and collaborators on 2007. They performed cognitive tasks while the volunteers were exposed to CW, PM, and sham EMF. They found no differences between the different EMF conditions[45].

In a just recent report, Bengt Arnetz' group investigated the effects of a 2 hr and 30 min RF exposure (884-MHz) on spatial memory and learning, using a double-blind repeated measures design[6]. The exposure was designed to mimic a real-life mobile phone conversation, at a SAR value of 1.4 W/kg. The primary outcome measure was a ''virtual'' spatial navigation task modelled after the commonly used and validated MWM. The distance travelled on each trial and the amount of improvement across trials (i.e., learning) were used as dependent variables. The participants were daily mobile phone users, with and without symptoms attributed to regular mobile phone use. The symptomatic group improved their performance during RF exposure while there was no such effect in the non-symptomatic group (Table 1).

Conclusions

In the presented studies the effects of MW radiation deriving either from RF generator providing continuous or modulated mobile phone-like signal, or from conventional mobile phone either computer controlled or under normal communication, were investigated at various carrier frequencies, 900, 1800 and 2450 MHz on the spatial learning and memory of rodents and humans. Several investigators have demonstrated the commonality between the performance of humans on real time spatial navigation tasks as compared to rats, mice and most other mammals studied so far[46]. The role of hippocampus, in particular, in navigation is concordant with neuronal response in rats and we assume in mice as well.

In our experiments using the MWM, Balb/c mice were required to find a submerged platform in the circular pool after 4 days of training by creating a “reference map” (reference memory)[47]. Exposed mice to the near field of a conventional mobile phone showed difficulty in finding the position of the hidden platform during training and could not transfer the learned information across the days. The recorded data from the probe trial indicated that exposed mice had difficulty in memory consolidation and/or retrieval of the stored information[35].

A number of studies have used a range of SAR values, from 0.02 mW/kg up to 4 W/kg in order to induce and detect memory deficits in rodents and especially in rats. In the vast majority of the studies the Transversal Electromagnetic Mode (TEM) cells were used, exposing the animals at a given power density from an RF generator. Similar learning and memory deficits revealed with the MWM following exposure to pulsed circularly polarized 2450-MHz MW at 2 mW/cm^2 power density, have been also reported in rats[25]. Some studies failed to reveal any effects whereas others have demonstrated that according to the radiation set up used (frequency, power density and duration of exposure) the animals’ memory function is somehow affected by EMF (Table 1). In a very recent study Narayanan and collaborators using similar to ours exposure setup protocol irradiated male Wistar rats, 10-12 weeks old, which are developmentally comparable to human teenagers[30]. The rats were exposed to 50 missed calls/day for 4 weeks from a GSM (900/1800-MHz) mobile phone in vibratory mode (no ring tone). After the experimental period, the animals were tested for spatial memory performance using the MWM test. Both phone exposed and sham exposed animals showed a significant decrease in escape time with training. In the probe trial phone exposed animals had significantly (~3 times) higher mean latency to reach the target quadrant and spent significantly (~2 times) less time in the target quadrant than age- and sex-matched controls. It is crucial to note that this work has used similar to ours experimental protocol having the mobile phone within the cage, but with longer exposure. It seems therefore that mice and rats respond similarly to the radiation stress by exhibiting deficits in their spatial memory operation. Some investigators (including our group) have chosen to perform experiments in animals allowed to move freely in their home cages during exposure to radiation[9, 30, 35, 36]. Doing so, any possible confounding effects of restraint stress are minimized, since it is well known that stress affects learning and memory[48]. Exposure conditions were carefully selected in order to simulate as close as possible ordinary mobile phone use (duration and signal strength). EMF with changing parameters are found to be more bioactive than fields with constant parameters[44, 49, 50]. That is probably because it is more difficult for living organisms to get adapted to them. Experiments with constant GSM or DCS signals can be performed, but they do not simulate actual conditions. International guidelines limit the local SAR to a maximum of 2 W/kg[37], or 1.6 W/kg[38]. Since the maximum SAR value as calculated in our experiments was at most 0.98 W/kg and since this SAR value does not affect the mice's body temperature[37], the exposure conditions used in our experiments can be considered nonthermal.

Furthermore, some investigators (including us) selected the age of the experimental animals (50-day-old) to correspond approximately to that of late adolescence in humans, a population in which mobile phone use is particularly prevalent. Similar to our exposure conditions have been used by other investigators[51]; they have irradiated rats with conventional mobile phone operating at a maximum power of 0.607 W. They found by mRNA analysis an effect on injury associated proteins leading to cellular damage to the rat brain.

Since it is well known that performance in the MWM is dependent on the hippocampus, it is plausible to assume that MW radiation exposure affected this brain area. Such a notion may be supported by the observation that apoptotic cells have been detected in the hippocampus of rats after a 2 hr for 50 days GSM radiation[31, 32]. Furthermore, the function of the hippocampus could be affected by the GSM irradiation possibly due to disruption of the blood-brain barrier, which has been reported to occur as a result of GSM irradiation[52, 53]. However, other investigators using 915-MHz at power levels resulting in whole-body specific absorption rates of 0.0018-20 W/kg failed to reveal such a relationship[54].

Considering that memory functions are similar in mice and humans with respect to the involvement of the hippocampus[55], we may assume that upon using the mobile phone in contact with the head, a person may experience cognitive deficits. Interestingly, it has been reported that exposure to GSM 890-MHz radiation results in deficits of human cognitive function[56]. The same research group reported recently using a spatial working memory task that the average reaction time (RT) of the right-hand responses under left-side exposure condition was significantly longer than those of the right-side and sham-exposure groups[57]. These results confirmed the existence of an effect of exposure on RT, as well as the fact that exposure duration (together with the responding hand and the side of exposure) may play an important role in producing detectable radiofrequency radiation (RFR) effects on performance. It is notable that right and left hemispheres did not show similar patterns of activation. Differences in these parameters might be the reason for the failure of certain studies to detect or replicate RFR effects. The question whether the memory impairment is reversible is open for exploration by further experiments which are in progress. Finally the actual molecular impact of the EMF is being studied at the proteomics level in our lab, in an attempt to explain the molecular events underlying the brain cells' malfunction after irradiation.

It has been suggested that behavioral alterations induced by EMF are thermally mediated[58]. That is because in most studies these effects derive from SAR values beyond the reference standard of 2 W/kg. The effects reported at very low SAR values may be explained by free radical formation as suggested[59]. It could also be due to protein conformation changes[60]. It might be possible that these changes cause alterations in cognitive function-related proteins, such as androgen receptors and apolipoprotein A[61].

Finally, as questioned in a recent study by Philips and collaborators[59]: "Are studies unable to replicate the work of others more credible than the original studies? In other words, can negative studies cancel positive studies or may studies showing effects be less valid because no explanation is provided?" The answer is that given the different frequency and modulation and in general the exposure set up conditions used in different studies, the issue remains open as to which of the parameters used in the "exposure cocktail", is crucial to alter brain cells' function. Is it the RF itself or the modulation? Or may be the ELF component of the battery switching mode of the cell phone. This issue is more complex than it seems when trying to compare animal studies with human clinical or experimental findings, possibly due to the differences in exposure conditions. Till the final elucidation of the effects, this research task is open for investigation requiring probably more sophisticated approaches and experimentation procedures.

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Provocation study using heart rate variability shows microwave radiation from 2.4 GHz cordless phone affects autonomic nervous system

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Abstract

Aim: **The effect of pulsed (100 Hz) microwave (MW) radiation on heart rate variability (HRV) was tested in a double blind study.** ***Materials and Methods:*** **Twenty-five subjects in Colorado between the ages of 37 to 79 completed an electrohypersensitivity (EHS) questionnaire. After recording their orthostatic HRV, we did continuous real-time monitoring of HRV in a provocation study, where supine subjects were exposed for 3-minute intervals to radiation generated by a cordless phone at 2.4 GHz or to sham exposure.** ***Results:*** **Questionnaire: Based on self-assessments, participants classified themselves as extremely electrically sensitive (24%), moderately (16%), slightly (16%), not sensitive (8%) or with no opinion (36%) about their sensitivity. The top 10 symptoms experienced by those claiming to be sensitive include memory problems, difficulty concentrating, eye problems, sleep disorder, feeling unwell, headache, dizziness, tinnitus, chronic fatigue, and heart palpitations. The five most common objects allegedly causing sensitivity were fluorescent lights, antennas, cell phones, Wi-Fi, and cordless phones. Provocation Experiment: Forty percent of the subjects experienced some changes in their HRV attributable to digitally pulsed (100 Hz) MW radiation. For some the response was extreme (tachycardia), for others moderate to mild (changes in sympathetic nervous system and/or parasympathetic nervous system). and for some there was no observable reaction either because of high adaptive capacity or because of systemic neurovegetative exhaustion.** ***Conclusions:*** **Orthostatic HRV combined with provocation testing may provide a diagnostic test for some EHS sufferers when they are exposed to electromagnetic emitting devices. This is the first study that documents immediate and dramatic changes in both Hearth Rate (HR) and HR variability (HRV) associated with MW exposure at levels**

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well below (0.5%) federal guidelines in Canada and the United States (1000 microW/cm²).

***Key Words*: heart rate variability, microwave radiation, DECT phone, autonomic nervous system, provocation study, sympathetic, parasympathetic, cordless phone, 2.4 GHz, electrohypersensitivity**

Introduction

A growing population claims to be sensitive to devices emitting electromagnetic energy. Hallberg and Oberfeld[1] report a prevalence of electrohypersensitivity (EHS) that has increased from less than 2% prior to 1997 to approximately 10% by 2004 and is expected to affect 50% of the population by 2017. Whether this is due to a real increase in EHS or to greater media attention, is not known. However, to label EHS as a psychological disorder or to attribute the symptoms to aging and/or stress does not resolve the issue that a growing population, especially those under the age of 60, are suffering from some combination of fatigue, sleep disturbance, chronic pain, skin, eye, hearing, cardiovascular and balance problems, mood disorders as well as cognitive dysfunction and that these symptoms appear to worsen when people are exposed to electromagnetic emitting devices[2-7].

The World Health Organization (WHO) organized an international seminar and working group meeting in Prague on EMF Hypersensitivity in 2004, and at that meeting they defined EHS as follows[8]:

". . . a phenomenon where individuals experience adverse health effects while using or being in the vicinity of devices emanating electric, magnetic, or electromagnetic fields (EMFs) . . . Whatever its cause, EHS is a real and sometimes a debilitating problem for the affected persons . . . Their exposures are generally several orders of magnitude under the limits in internationally accepted standards."

The WHO goes on to state that:

"EHS is characterized by a variety of non-specific symptoms, which afflicted individuals attribute to exposure to EMF. The symptoms most commonly experienced include dermatological symptoms (redness, tingling, and burning sensations) as well as neurasthenic and vegetative symptoms (fatigue, tiredness, concentration difficulties, dizziness, nausea, heart palpitation and digestive disturbances). The collection of symptoms is not part of any recognized syndrome."

Both provocation studies (where individuals are exposed to some form of electromagnetic energy and their symptoms are documented) and amelioration studies (where exposure is reduced) can shed light on the offending energy source and the type and rate of reaction.

Several amelioration studies have documented improvements in the behavior of students and the health and wellbeing of teachers[9], among asthmatics[10], and in both diabetics and those with multiple sclerosis[11,12] when their exposure to dirty electricity is reduced. Dirty electricity refers to microsurges flowing along electrical wires in the kHz range that can damage sensitive electronic equipment and, it appears, affect the health of those exposed.

In contrast to amelioration studies, provocation studies, examining the response of people with self-diagnosed EHS, have generated mixed results.

Rea *et al.*[13] were one of the first to show that sensitive individuals responded repeatedly to several frequencies between 0.1 Hz and 5 MHz but not to blank challenges. Reactions were mostly neurological and included tingling, sleepiness, headache, dizziness, and - in severe cases - unconsciousness, although other symptoms were also observed including pain of various sorts, muscle tightness particularly in the chest, spasm, palpitation, flushing, tachycardia, etc. In addition to the clinical symptoms, instrument recordings of pupil dilation, respiration, and heart activity were also included in the study using a double-blind approach. Results showed a 20% decrease in pulmonary function and a 40% increase in heart rate. These objective instrumental recordings, in combination with the clinical symptoms, demonstrate that EMF sensitive individuals respond physiologically to certain EMF frequencies although responses were robust for only 16 of the 100 potentially sensitive individuals tested.

In a more recent review, Rubin *et al.*[14] concluded that there was no robust evidence to support the existence of a biophysical hypersensitivity to EMF. This was based on 31 double-blind experiments that tested 725 EHS subjects. Twenty-four studies found no difference between exposure and sham conditions and of the seven studies that did find some evidence that exposure affected EHS participants, the research group failed to replicate the results (two studies) or the results appeared to be statistical artifacts (three studies).

Those who live near antennas and those who suffer from EHS often complain of cardiovascular problems such as rapid heart rate, arrhythmia, chest pain, and/or changes in blood pressure[3,7,15,16].

Indeed, the doctors who signed the Freiburger Appeal[17] stated the following:

> *"We have observed, in recent years, a dramatic rise in severe and chronic disease among our patients especially . . . extreme fluctuations in blood pressure, ever harder to influence with medications; heart rhythm disorders; heart attacks and strokes among an increasingly younger population . . ."*

Based on these findings we decided to study the affect of microwave (MW) radiation generated by a digital cordless phone on the cardiovascular system by monitoring heart rate variability (HRV). Unlike cell phones that radiate microwaves only when they are either transmitting or receiving information, the cordless phone we used radiates constantly as long as the base of the phone is plugged into an electrical outlet. The phone we used was an AT&T digitalally pulsed (100 Hz) cordless telephone that operates at 2.4 GHz or frequencies commonly used for microwave ovens and Wi-Fi. It resembles its European version know as a Digital Enhanced Cordless Telecommunications (DECT) phone that operates at 1.9 GHz[18].

HRV is increasingly used for screening cardiovascular and neurological disorders[19-24]. We wanted to determine whether HRV could be used as a tool to diagnose EHS and whether it could be used to predict probability and/or intensity of the reaction to a MW provocation. The HRV analysis, using NervExpress software[25, 26], provides information about the functioning of the sympathetic and parasympathetic nervous system with real time monitoring and provides additional information including a pre-exposure fitness score based on the orthostatic test.

Materials and methods

Background electromagnetic environment

Testing was done in two locations, one in Golden and the other in Boulder, Colorado, on three separate weekdays during a 6-day period (Table 1). Background levels of low frequency magnetic fields, intermediate frequency radiation on electrical wires, and radio frequency radiation were monitored at each location and the values are provided in Table 1. All testing of the electromagnetic environment was done in the area where volunteers were tested for their heart rate variability during the provocation study.

The extremely low frequency **magnetic field** was measured with an omni-directional Trifield meter. This meter is calibrated at 60 Hz with a frequency-weighted response from 30 to 500 Hz and a flat response from 500 to 1000 Hz. Accuracy is ± 20%.

Power quality was measured with a Microsurge Meter that measures high frequency transients and harmonics between 4 and 150 kHz (intermediate frequency range). This meter provides a digital reading from 1 to 1999 of dv/dt expressed as GS units with a +/- 5% accuracy[27]. Since we were trying to ensure low background exposure, we installed GS filters to improve power quality. The results recorded are with GS filters installed.

Within at least 100 m of the testing area, all wireless devices (cell phones, cordless phones, wireless routers) were turned off. **Radio frequency radiation** from outside the testing area was measured with an Electrosmog Meter, which has an accuracy of ±2.4 dB within the frequency range of 50 MHz to 3.5 GHz. Measurements were conducted using the omni-directional mode and were repeated during the testing. This meter was also used to determine the exposure of test subjects during provocation with a digital cordless phone. This **cordless phone** emits radio frequency radiation when the base station is plugged into an electrical outlet. This happens even when the phone is not in use. We used the base station of an AT&T 2.4 GHz phone (digitally pulsed at 100 Hz) to expose subjects to MW radiation[18]. The emission of MWs at different distances from the front of the base station is provided in fig. 1.

Testing of subjects

Subjects were **recruited** by word-of–mouth based on their availability during a short period of testing. Of the 27 people who volunteered to be tested, two were excluded, one based on age (less than 16 years old) and another based on a serious heart condition.

Subjects were asked to complete a wellness and EHS **questionnaire**. They were then asked questions about their age, height, weight, blood type, time of last meal, and occupation (in the event of occupational exposure to electromagnetic fields/radiation).

Table 1 - Measurements of the electromagnetic environment at each testing location

Location Colorado	Date	Magnetic Field 30 - 1000 Hz mG	Power Quality 4 - 150 kHz GS units	Radio Frequency Radiation 50 MHz – 3.5 GHz microW/cm^2
Golden	10/16/08	3 – 15	140	0.8
Boulder	10/20/08	0.4	37	<0.01
Boulder	10/21/08	0.4	80	<0.01

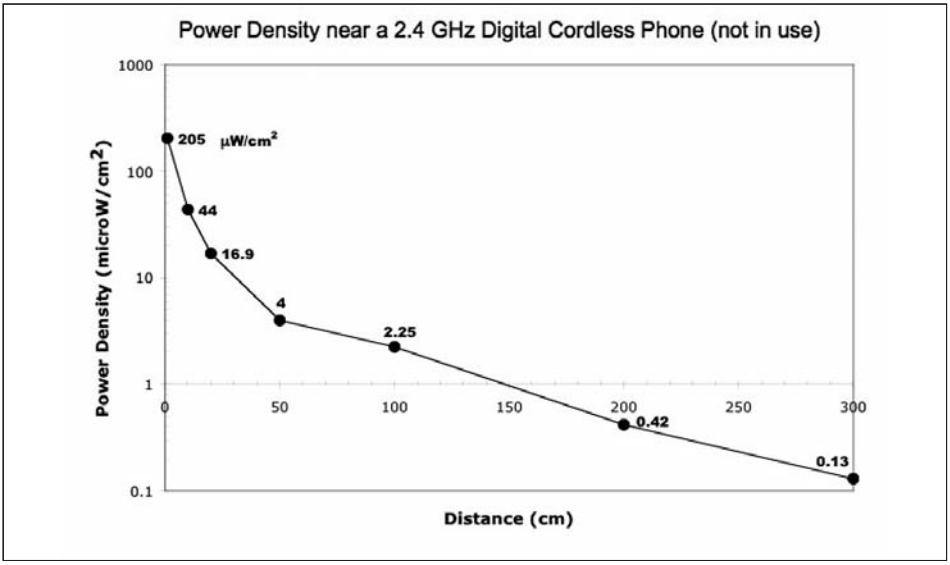

Fig. 1. Radiation near a 2.4 GHz AT&T digital cordless phone when the base station of the phone is plugged into an electrical outlet and the phone is not in use

We measured resting heart rate and blood pressure using a Life Source UA-767 Plus digital blood pressure monitor; saliva pH with pH ion test strips designed for urine and saliva (pH range 4.5-9.0), and blood sugar with ACCU-CHEK Compact Plus.

In an attempt to address the question: "Is there a simple test that relates EHS with the electrical environment of the human body?", we measured galvanic skin response (GSR), body voltage, and the high and low frequency electric and magnetic field of each subject.

Wrist-to-wrist galvanic skin response was measured as an indicator of stress using a Nexxtech voltmeter (Cat. No. 2200810) set at 20 volts DC and attached to the inner wrist with a Medi Trace 535 ECG Conducive Adhesive Electrodes Foam used for ECG monitoring. Capacitively coupled "body voltage" was measured with a MSI Multimeter connected to a BV-1 body voltage adaptor. The subject's thumb was placed on one connector and the other connector was plugged into the electrical ground, which served as the reference electrode. High frequency (HF) and low frequency (LF) electric and magnetic fields were measured with a Multidetektor II Profi Meter held at approximately 30 cm from the subject's body, while the subject was seated.

HRV testing

Two types of HRV testing were conducted. The first was an *orthostatic* test and the second was *continuous monitoring* of heart rate variability with and without provocation (exposure to MW frequencies from a digital cordless phone). NervExpress software was used for HRV testing[25]. NervExpress has both CE and EU approval and is a Class Two Medical Device in Canada and in the European Union. An electrode belt with transmitter was placed on the person's chest near the heart, against the skin. A wired HRV cable with receiver was clipped to the clothing near the transmitter and connected to the COM port of the computer for acoustical-wired transmission (not wireless). This provided continuous monitoring of the interval between heartbeats (R-R interval).

For the *orthostatic* testing subject laid down on his/her back and remained in this position for 192 R-R intervals or heartbeats (approximately 3 minutes), at which time a beep from the computer indicated that the person stand up and remain standing until the end of the testing period, which was 448 intervals (approximately 7 minutes depending on heart rate).

For the *provocation* testing, subject remained in a lying down position for the duration of the testing. A digital cordless phone base station, placed approximately 30 to 50 cm from subject's head, was then connected randomly to either a live (real exposure) or dead (sham exposure) extension cord. It was not possible for the subject to know if the cordless phone was on or off at any one time. Continuous real-time monitoring recorded the interval between each heartbeat. Data were analyzed by timed stages consisting of 192 R-R intervals (heartbeats).

The sham exposures are referred to as either pre-MW exposure or post-MW exposure to differentiate the order of testing. Since type of exposure was done randomly in some instances either the pre-MW or the post-MW is missing. Subjects who reacted immediately to the cordless phone were retested with more real/sham exposures. When subject was exposed multiple times, only the first exposure was used for comparison. Provocation testing took between 9 to 30 minutes per subject.

After the initial testing, treatments (deep breathing, laser acupuncture, Clean Sweep) that might alleviate symptoms were tried on a few subjects but these results will be reported elsewhere.

Interpretation of HRV results

The results for the orthostatic testing and provocation testing were sent to one of the authors (JM) for interpretation. An example of the type of information send is provided in fig. 2 (orthostatic) and fig. 3 (provocation). No information was provided about the subject's self-proclaimed EHS and the information about exposure was blinded. JM did not examine the provocation results until he reviewed the orthostatic results. No attempt was made to relate the two during this initial stage of interpretation.

Predicting response and health based on orthostatic test

For the orthostatic testing JM provided a ranking for cardiovascular tone (CVT), which is based on the blood pressure and heart rate (sum of systolic and diastolic blood pressure times heart rate) and provides information on whether the cardiovascular system is hypotonic (<12,500) or hypertonic (>16,500). We used a 5-point ranking scale as follows: Rank 1: < 12,500, hypotonic; Rank 2: 12,500 to 14,000; Rank 3: 14,000 to 15,500; Rank 4: 15,500 to 16,500; Rank 5: > 16,500, hypertonic.

Non-Adaptive Capacity (NAC)[a] was ranked on a 5-point scale with 1 indicating highly adaptive and 5 indicating highly non-adaptive. This was based on a balanced sympathetic (SNS) and parasympathetic (PSNS) nervous system (average orthostatic response within ±1 standard deviation from center on graph) and on the overall fitness

[a] Later Adaptive Capacity (AC) was used, which is the inverse of NAC.

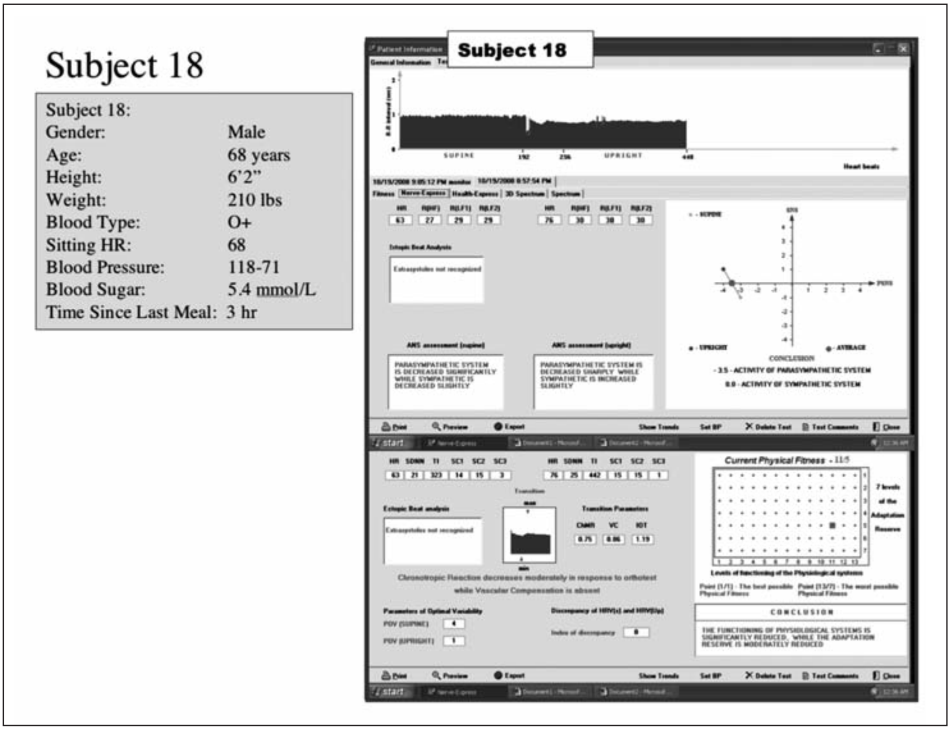

Fig. 2. Orthostatic HRV information provided for blinded analysis of Subject 18

score. The closer to normal value of the autonomic nervous system (ANS) in a given subject, the less likely they are to react, since their adaptive capacity is high. "Normal" refers to the balanced SNS/PSNS and the appropriate direction of movement under stress, in this case when person stood up. Direction of movement is shown in the NervExpress graph (fig. 2). Appropriate direction of movement would be either up 1 standard deviation (small increase in SNS and no change in PSNS); up and to the left 1 standard deviation each (small increase in SNS and small decrease in PSNS); or to left (no change in SNS and slight decrease in PSNS). For those who move further to the left (greater down regulation of PSNS) or further up and to the left (greater up regulation of SNS combined with a greater down regulation of PSNS), the less likely they are to adapt and the more likely they are to react. Likewise, if the fitness score is high or adequate, the individual would be capable of resisting the stressor. An adequate physical fitness score is between 1:1 and 10:6. The first number refers to the functioning of the physiological system and the second is the adaptation reserve. The lower the numbers the greater the level of fitness in each category. Note, if a subject with good or adequate fitness was to be a reactor to MW stress, his/her reaction would be both rapid and strong.

Probability of Reaction (POR) was ranked on a 5-point scale with "1" indicating low probability of a reaction and "5" indicating high probability of a reaction to stress of any kind. Criteria were similar to the NAC. However, greater consideration was given to the Chronotropic Myocardial Reaction Index (ChMR) value and the dysautonomic

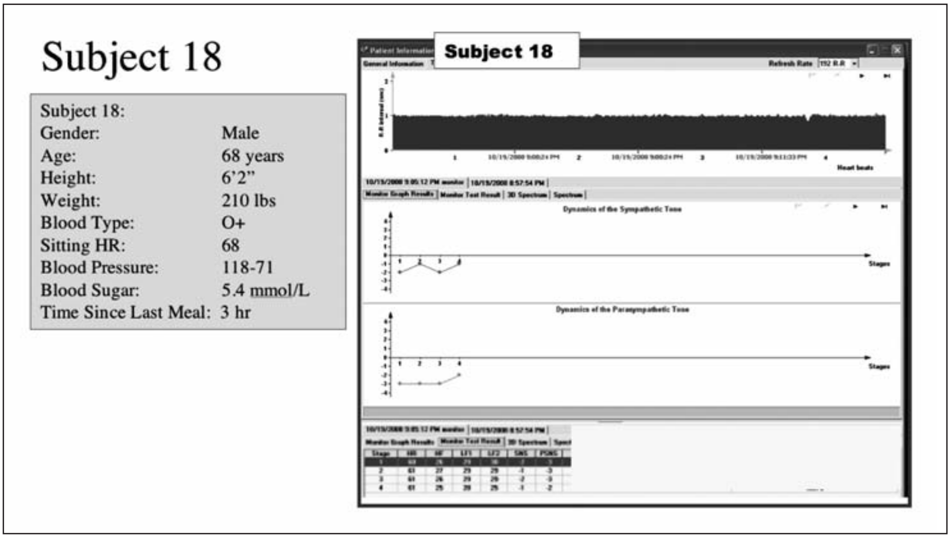

Fig. 3. Continuous monitoring of HRV with real and sham exposure to MW radiation from a digital cordless phone. Information provided for blinded analysis of Subject 18

status (average of orthostatic test is more than two standard deviations from center or up to the right) of the subject, whereby individuals with compromised ANS and a poor ChMR ranking (outside the range of 0.53 to 0.69) would be most likely to react and *vice versa*.

A potential non-responding reactor is someone with low energy, average orthostatic response in lower left quadrate, and a physical fitness score between 10:6 and 13:7. Subject 18 in fig. 2 is a borderline non-responding reactor. Note, this does not necessarily imply that this person is hypersensitive, only that he probably does not have enough energy to mount a reaction even if he was EHS.

JM also provided his comments on the health status of the subject based on the rhythmogram, autonomic nervous system assessment (changes in the SNS and PSNS), Fitness Score, Vascular Compensation Reaction (VC), ChMR, Compensation Response (CR), Ortho Test Ratio (OTR), Parameters of Optimal Variability (POV), Index of Discrepancy (ID); and Tension Index (TI). The interpretation of the HRV parameters is dependant to a certain degree on the integration of all the data provided as a whole with value being given to the total ANS picture presented. Those skilled in the art and science of HRV analysis should reach similar interpretive assessment of the data presented here[26].

Blinded analysis of provocation results

The blinded data for the continuous monitoring of heart rate variability with real and sham exposure were sent to JM for analysis (fig. 3). JM attempted to identify the stage during which exposure took place, stage during which the subject reacted, and then ranked symptom probability (5-point scale) and intensity (non-reactive, mild, moderate, intense). The assessment is provided in Appendix A.

Wellness and EHS Questionnaire

Prior to any testing, each subject was asked to complete a wellness and EHS questionnaire. This was designed on surveymonkey (www.surveymonkey.com) and was administered in paper format. This questionnaire was analyzed separately from the HRV data.

Results

Background electromagnetic environment

The two environments, where we conducted the testing, differed in their background levels of EMF and electromagnetic radiation (EMR). The Golden site had high magnetic fields (3-15 mG), high levels of dirty electricity (140 GS units) despite the GS filters being installed, and elevated levels of radio frequency (RF) radiation (0.8 microW/cm^2) coming from 27 TV transmitters on Lookout Mountain within 4 km of our testing environment. Despite RF reflecting film on windows the RF levels inside the home were elevated. The Boulder environment was relatively pristine and differed only with respect to power quality on the two days of testing (Table 1).

The cordless phone, used for provocation, produced radiation that was maximal at the subject's head (3 to 5 microW/cm^2) and minimal at the subject's feet (0.2 to 0.8 microW/cm^2) depending on height of subject and the environment. The cordless phone did not alter magnetic field or power quality.

Participants

A total of 25 subjects were included in this pilot study, ranging in age from 37 to 79 with most (40%) of the subjects in their 50s (Table 2). Eighty percent were females. Approximately half of the participants had normal body mass index and the other half were either overweight (28%) or obese (16%)[28]. Mean resting heart rate for this group was 70 (beats per minute) and ranged from 53 to 81. Blood pressure fell within a normal range for 40% of participants and fell within stage 1 of high blood pressure for 16% of the subjects[29]. None of the subjects had pacemakers, a prerequisite for the study. Forty percent had mercury amalgam fillings and 28% had metal (artificial joints, braces, etc.) in their body. This is relevant as metal implants and mercury fillings may relate to EHS[30].

Questionnaire

Self-perceived Electrosensitivity

One third of participants did not know if they were or were not electrically sensitive, 40% believed they were moderately to extremely sensitive, 16% stated that they had a little sensitivity, and 8% claimed they were not at all sensitive. Their sensitivity was slightly debilitating for 24% and moderately debilitating for 20% of participants (fig. 4).

Reaction time for symptoms to appear after exposure ranged from immediately (12%) to within 2 hours (4%) and was within 10 minutes for the majority of those who believe they react (28%) (fig. 5). Recovery time ranged from immediately to within 1 day with

Table 2 - Information about participants

		#	%
Gender	Male	5	20%
	Female	20	80%
Age	Mean and Range	60 years	37-79 years
Age Class	20s	1	4%
	30s	1	4%
	40s	2	8%
	50s	10	40%
	60s	5	20%
	70s	7	28%
BMI[a]	obese	4	16%
	overweight	7	28%
	normal	13	52%
	underweight	1	4%
Resting Heart Rate	Mean and Range	70 bpm	53-81 bpm
Blood Pressure[b]	Normal	10	40%
	Pre-hypertension	11	44%
	High Blood Pressure	4	16%
Metal in Body	Pace maker	0	0%
	Mercury fillings	10	40%
	Other metal	7	28%

[a] BMI = Body Mass Index based on height and weight[28]
[b] Blood Pressure (BP) according to National Heart Lung and Blood Institute (nd)[29]

only 4% claiming to recover immediately. Several participants noted that the rate of reaction and recovery is a function of the severity of their exposure and their state of health. The more intense the exposure the more rapid their response and the slower their rate of recovery. These results may have a bearing on the provocation study as we are testing an immediate reaction/recovery response (~3 minutes) to a moderate intensity exposure (3 to 5 $\mu W/cm^2$) and the percent that claims to respond quickly is low among this group.

Symptoms

The most common symptoms of exposure to electrosmog, as identified by this group of participants, included poor short-term memory, difficulty concentrating, eye problems, sleep disorder, feeling unwell, headache, dizziness, tinnitus, chronic fatigue and heart palpitations (fig. 6, upper graph). Of the symptoms commonly associated with EHS, heart palpitations (10th), rapid heartbeat (18th), arrhythmia (21st), and slower heartbeat (23rd) are the only ones we would be able to identify with HRV testing. For most participants who claim to react, reactions are mild to moderate.

All of the symptoms, except high blood pressure, arrhythmia, and slower heartbeat, were experienced several times per day (daily) or several times per week (weekly) by at least one or more participants. The patterns for symptom severity and frequency are similar (fig. 6, upper *vs* lower graph). Some of the symptoms (feeling unwell, pain, chronic fatigue, gas/bloat, skin problems) were experienced several times each month (monthly) may relate to menses in pre-menopausal or peri-menopausal women (16 women).

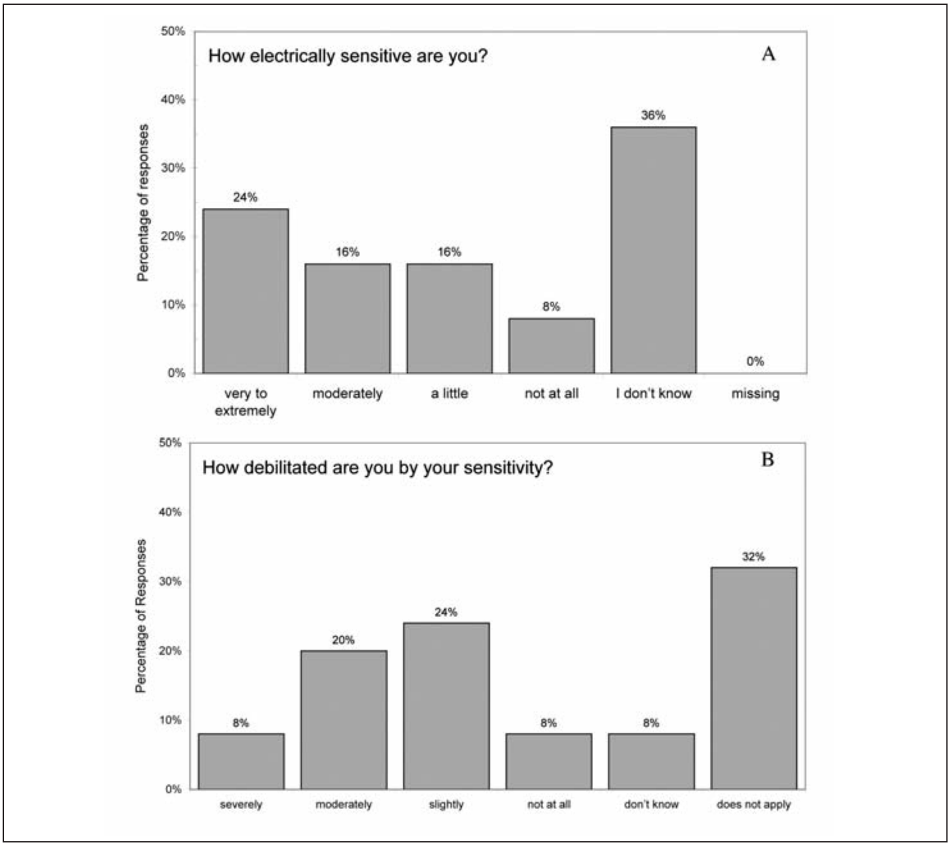

Fig. 4. Self-proclaimed electrosensitivity of participants (n=25)

A large percentage of participants had food allergies (64%), mold/pollen/dust allergies (48%), pet allergies (20%), and were chemically sensitive (36%) (fig. 7).

Some also had pre-existing health/medical conditions (fig. 8). The top five were anxiety (28%); hypo-thyroidism (24%); autoimmune disorder (20%), depression (16%) and high blood pressure (16%). Note these may be self-diagnosed rather than medically diagnosed conditions.

Objects contributing or associated with adverse health symptoms

Among the objects identified as contributing to adverse health symptoms, tube fluorescent lights were at the top of the list with more than 40% of participants reacting *often* or *always* (fig. 9). The next 4 items on the list (antennas, cell phones, Wi-Fi, cordless phones) all emit microwave radiation. According to this figure 16% of subjects respond to cordless phones *often* or *always* and their responses may include headaches, dizziness, depression, which we are unable to monitor with HRV.

Fifty-two percent stated they are debilitated by their sensitivity, 24% slightly, 20% moderately, and 8% severely. Some have difficult shopping, which may relate to

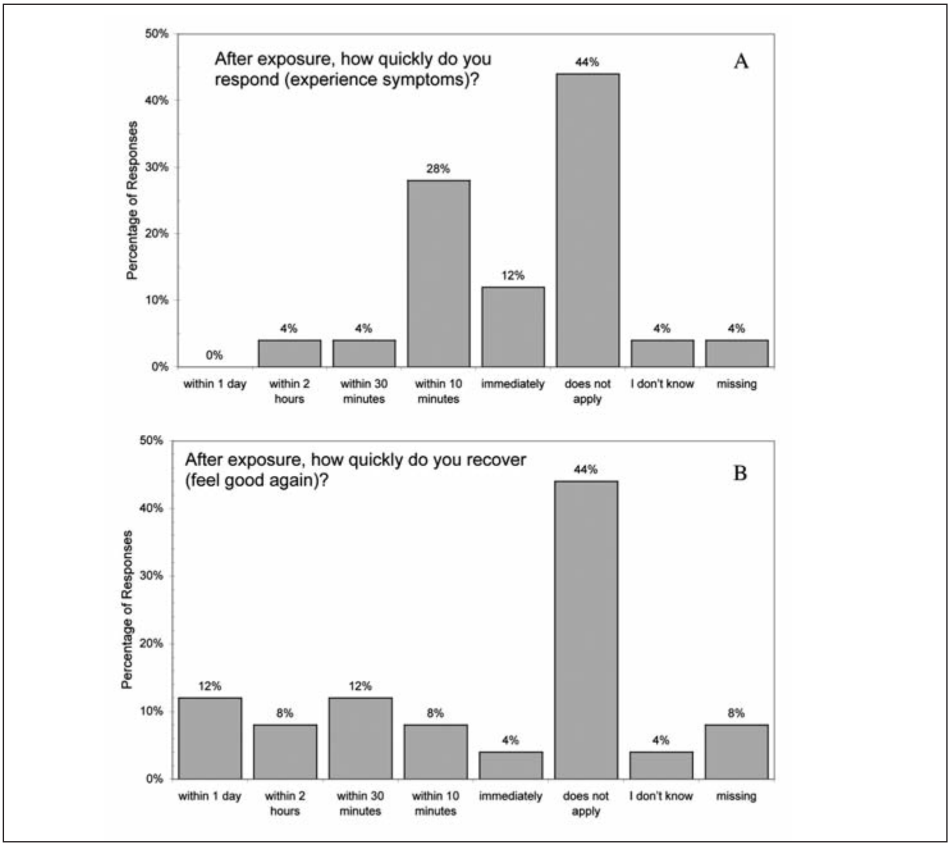

Fig. 5. Self-proclaimed response time of participants to electro-stress and recovery (n=25)

lighting in stores. Others have difficulty flying or traveling by car, perhaps due to microwave exposure on highways and in airplanes. A few subjects are unable to use mobile phones and computers and are unable to watch television. Some are unable to wear jewelry because it irritates the skin and/or watches because they often malfunction (fig. 7).

EHS and person's EMF

The body voltage, as measured by the potential difference between the subject and the electrical ground, differed at the two sites. Subjects at Golden had much higher values than those at Boulder. This was also the case for the high and low frequency electric field and for the HF and LF magnetic field (Table 3). Galvanic skin response was highly variable among subjects prior to testing and did not relate to either sensitivity or the environment. There was no association between any of the EMF measurements (body voltage, GSR, electric field or magnetic field) that we conducted prior to testing and EHS of the subjects tested. In a follow-up study it would be useful to monitor each person's EMF before, during, and after exposure.

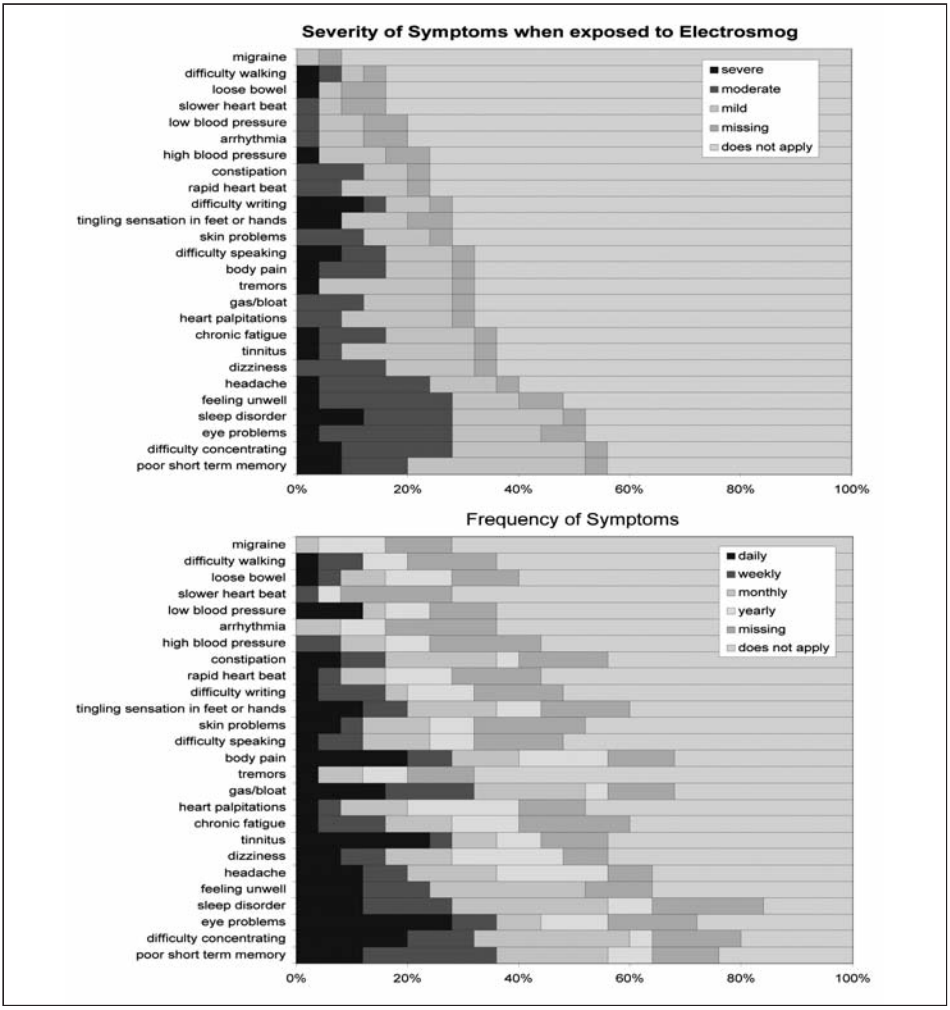

Fig. 6. Severity and frequency of symptoms associated with electrosmog exposure (n=25)

Blind assessment of responses: orthostatic HRV provocation HRV

The Orthostatic HRV provided us with the state of the ANS and the relative fitness score of the individual prior to exposure, which is important for predicting the intensity outcome of exposure.

A summary of the orthostatic HRV (blinded analysis) along with the self-assessment and the provocation HRV (blinded and unblinded) are provide in Appendix A for each subject. For those individuals who had either a moderate or intense response, the blinded predictions show good agreement for stage of exposure and for intensity of exposure.

Based on the orthostatic test, those with high adaptive capacity had a lower probability of reacting to stress, but if they did react, their reaction would be moderate to

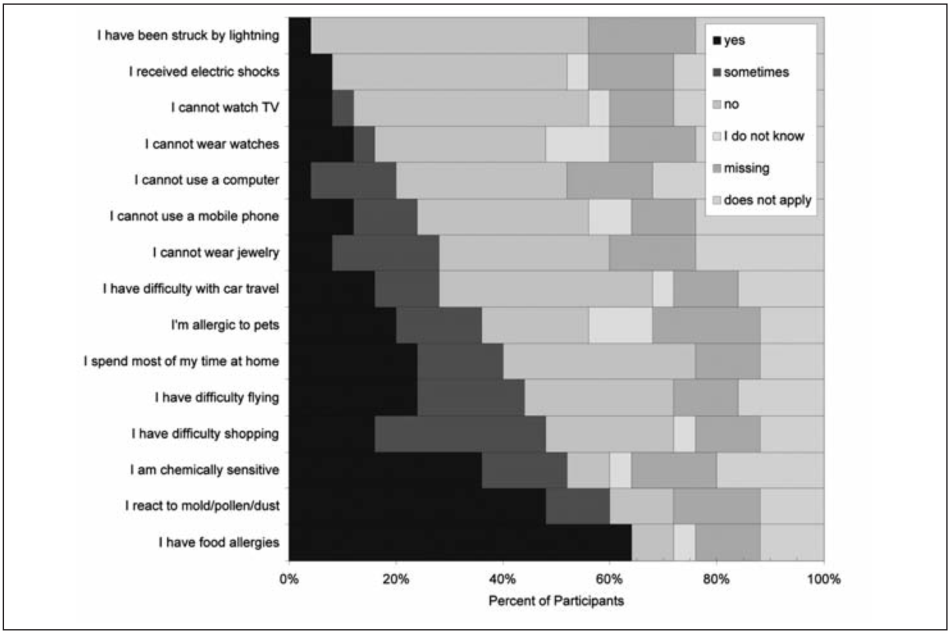

Fig. 7. Response to specific questions that may contribute to or be associated with electrical sensitivity (n=25)

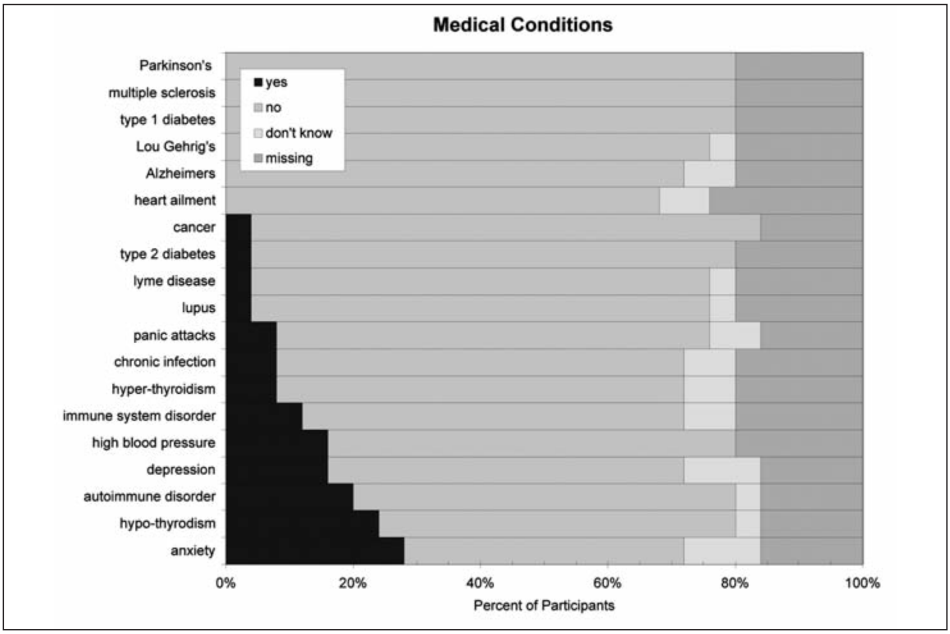

Fig. 8. Existing medical conditions of participants (n=25)

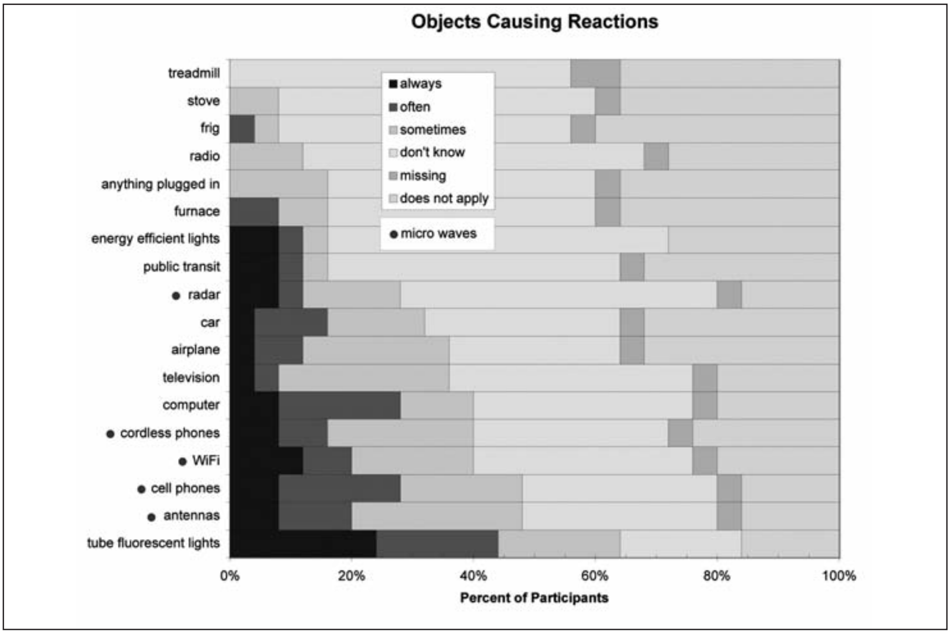

Fig. 9. Objects contributing to adverse health symptoms. Those marked with a dot generate microwave frequencies (n=25)

Table 3 - Personal electromagnetic environment (mean ± standard deviation) of subjects tested including galvanic skin response (GSR), body voltage, electric (E-field) and magnetic fields (M-field) at both high and low frequency (HF and LF) [* P ≤0.05].

Location	Date	GSR mV	Body Voltage mV	E-field HF mV	E-field LF mV	M-field HF mG	M-field LF mG
Golden	10/16/08	3.5 ± 1.8	3.4 ± 0.5*	88 ± 85*	333 ± 71*	4.6 ± 5.7*	17 ± 14*
Boulder	10/20/08	3.2 ± 2.5	0.5 ± 0.5	13 ± 33	63 ± 94	0.2 ± 0.6	2.7 ± 0.7*
Boulder	10/21/08	4.1 ± 1.3	0.2 ± 0.1	2 ± 0.8	57 ± 50	0.1 ± 0.4	1.7 ± 0.6*

intense. Conversely, those with low adaptive capacity had a higher probability of reacting but they didn't always have the energy to react and hence their reactions would be mild.

Provocation HRV

Most of the subjects (15/25, 60%) did not respond appreciable to the MW radiation generated by the cordless phone when it was plugged into a live outlet. The rhythmogram was unchanged and the heart rate, parasympathetic and sympathetic tone remained constant (figs. 3, 10, 12).

However, 10 subjects (40%) did respond to the MW challenge. Fig. 13 shows the response for six of those 10. Response and the recovery were immediate. MW provoca-

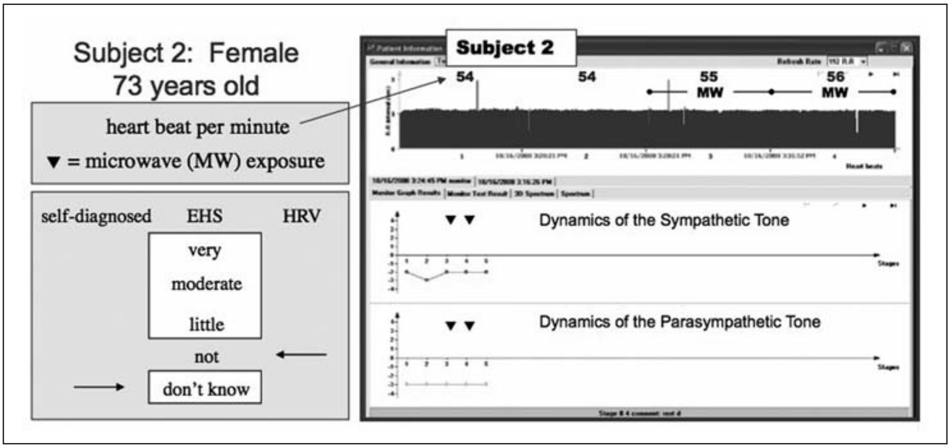

Fig. 10. Continuous monitoring of HRV during provocation part of this study for one subject who was non-reactive

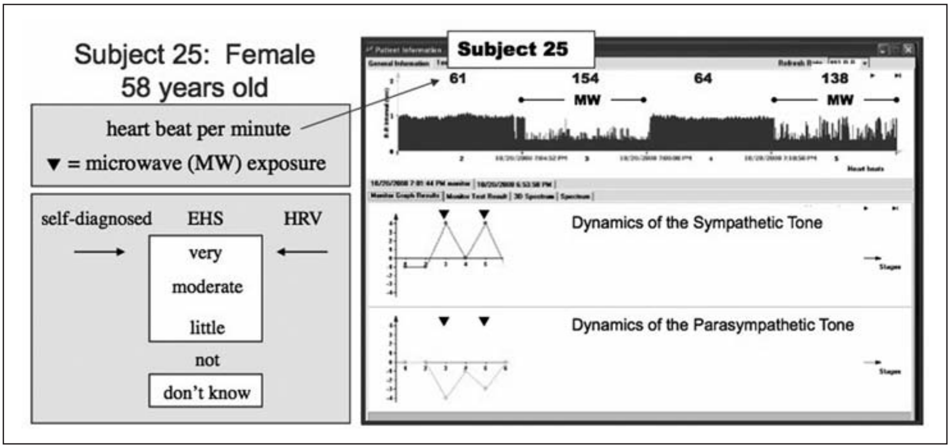

Fig. 11. Continuous monitoring of HRV during provocation part of this study for one subject who reacted to the MW radiation from a digital cordless 2.4 GHz phone

tion differed noticeably compared with sham exposure. Heart rate increased significantly for four of the subjects, resulting in tachycardia for three. The heart rate for subject 25 jumped from 61 bpm to 154 bpm (with real provocation) and returned to 64 bpm (with sham provocation) (fig. 11). The increase in heart rate was accompanied by up regulation of the SNS and down regulation of the PSNS during cordless phone exposure for four subjects in Table 4 (fig. 13). Response of the one subject (Subject 27) was paradoxical in that the heart rate increased from 72 to 82 bpm during which time the parasympathetic tone increased and the sympathetic tone remained constant.

Fig. 14 shows the range of responses of some non- or slightly reactive subjects to provocation.

Table 4 - Real-time monitoring of heart rate, sympathetic and parasympathetic tone before, during, and after exposure to a 2.4 GHz digital cordless phone radiating 3-5 microW/cm²

EHS	Subject Code	EHS Ranked	Heart Rate (bpm) bgrnd	pre	MW	post	Sympathetic Response bgrnd	pre	MW	post	Parasympathetic Response bgrnd	pre	MW	post
Intense	25	1	61	61	154	64	-1	-1	4	0	0	0	-4	-1
	17	2	66	68	122	66	0	0	4	0	0	-2	-3	0
	26	3	59	61	106	61	-1	-1	3	0	1	2	-3	1
	27	4	72	nd	82	69	0	nd	0	0	-3	nd	2	-2
Moderate	5	5	66	66	66	65	1	1	3	0	-1	-1	-3	-1
	9	6	77	75	75	73	1	1	0	1	-2	0	-3	-1
	3	7	48	50	53	nd	2	-2	0	nd	2	0	0	nd
	16	8	61	nd	62	63	0	nd	-2	0	-2	nd	-2	-2
	8	9	81	nd	81	80	1	nd	1	1	0	nd	-2	-1
	10	10	69	68	70	70	0	0	0	0	-2	-2	-3	-1
Mild	2	11	54	54	55	56	-2	-3	-2	-2	-3	-3	-3	-3
	23	12	59	nd	58	60	-1	nd	0	-2	-2	nd	-2	-3
	12	13	71	nd	69	74	0	nd	1	0	-1	nd	-1	-1
	18	14	60	61	61	61	-2	-1	-2	-1	-3	-3	-3	-2
	19	15	63	62	62	61	-1	0	-1	-1	-3	-3	-3	-2
	6	16	65	66	66	65	0	0	0	0	-3	-3	-4	-3
	4	17	61	62	61	61	-2	-1	-1	-2	-3	-2	-3	-2
	24	18	71	72	71	69	0	0	0	0	-3	-2	-1	-2
None	1	19	71	70	71	71	0	0	0	1	-3	-1	-1	-1
	11	20	57	nd	57	58	0	nd	0	0	3	nd	3	2
	21	21	78	78	78	nd	1	1	1	nd	-2	-3	-3	nd
	7	22	70	71	70	69	0	0	0	0	-3	-3	-3	-3
	14	23	69	68	67	66	0	0	0	0	-1	-2	-2	-1
	20	24	67	nd	66	66	0	nd	0	0	-1	nd	-1	-1
	13	25	80	78	76	nd	1	1	1	nd	-3	-2	-2	nd

Response	Mean Heart Rate (bmp)				Mean Sympathetic Response				Mean Parasympathetic Response			
Intense	65	63	116	65	-0.5	-0.7	2.8	0.0	-0.5	0.0	-2.0	-0.5
Moderate	67	65	68	70	0.8	0.0	0.3	0.4	-0.8	-0.8	-2.2	-1.2
Mild	63	63	63	63	-1.0	-0.8	-0.6	-1.0	-2.6	-2.7	-2.5	-2.3
None	70	73	69	66	0.3	0.4	0.3	0.2	-1.4	-2.2	-1.3	-0.8
All	66	66	74	66	-0.1	-0.3	0.4	-0.2	-1.5	-1.7	-2.0	-1.4

Note:
EHS categories described in text: bgrnd = background; pre=sham exposure before real exposure; MW=microwave exposure; post=sham exposure after real exposure; nd=no data

The pre- and post-MW cordless phone response (SNS & PSNS) differed significantly for this group (fig. 15) with up regulation of the SNS and down regulation of the PSNS with MW exposure and the reverse for post-MW exposure suggesting a recovery phase.

The severe and moderate responders had a much higher LF/HF ratio than those who either did not respond or had a mild reaction to the MW exposure from the cordless phone (fig. 16B). This indicates, yet again, a stimulation of the SNS (LF) and a down-

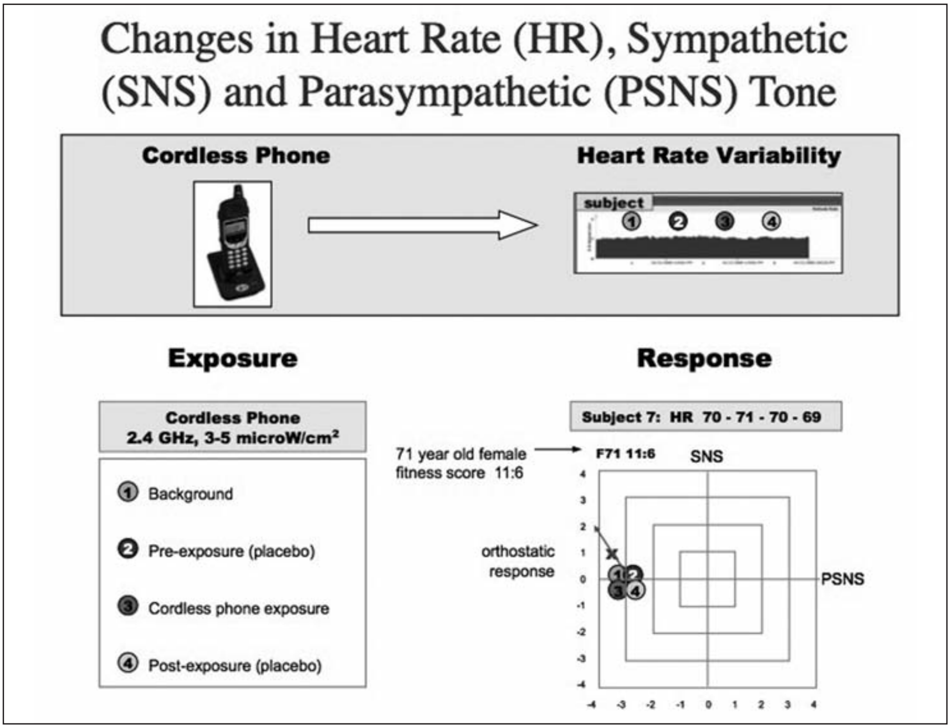

Fig. 12. Subject 7: no changes in heart rate, sympathetic, and parasympathetic tone before, during, and after blind provocation with a 2.4 GHz cordless phone generating exposure of 3 to 5 microW/cm²

regulation of the PSNS (HF). The up regulation was greater for LF2 than for LF1 (fig. 16A).

Based on self-assessment and the results from the provocation study, 2 subjects (8%) underestimated their sensitivity and 5 subjects (20%) overestimated their sensitivity to the cordless phone provocation. However, only two of the 5 claim to experience mild heart palpitations and only one of those responds "sometimes" to cordless phones.

Discussion

The most intriguing result in this study is that a small group of subjects responded immediately and dramatically to MW exposure generated by a digital cordless DECT phone with blinded exposure. Heart rate (HR) increased significantly for 4 subjects (16%) (10 to 93 beats per minute) and the sympathetic/parasympathetic balance changed for an additional 6 subjects (24%) while they remained in a supine position. This is the first study documenting such a dramatic change brought about immediately and lasting as long as the subject was exposed and is in sharp contrast to the provocation studies reviewed by Levallois[5], Rubin *et al.*[14], and Bergqvist *et al.*[31]. Authors of these reviews generally conclude that they were unable to establish a relationship between low or high frequency fields and electromagnetic hypersensitivity (EHS) or with symptoms typically occurring

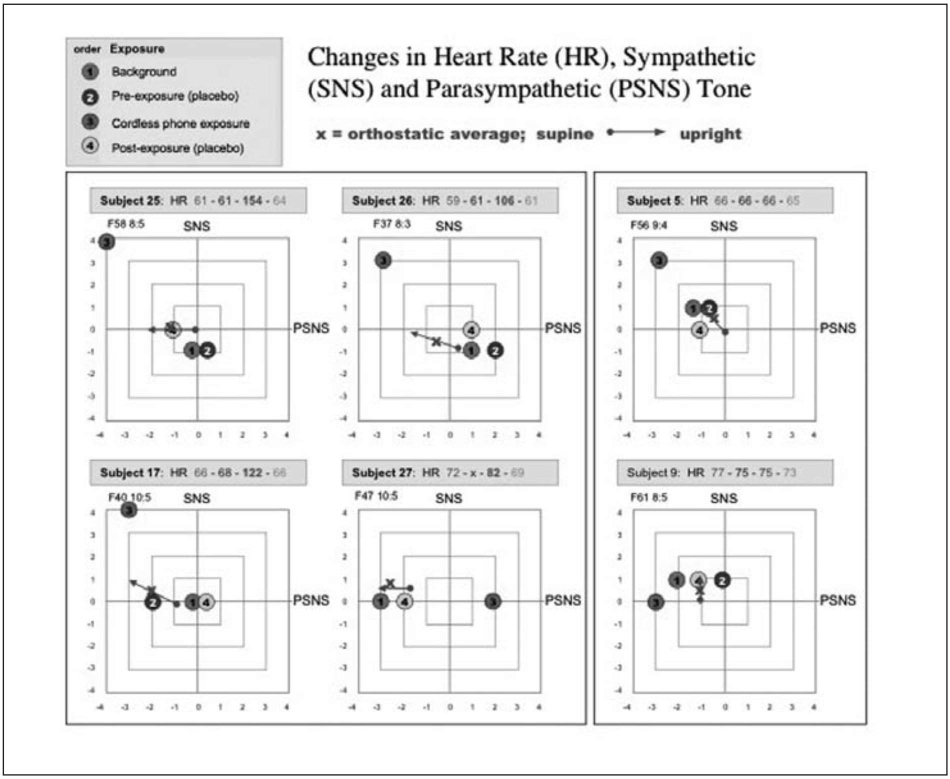

Fig. 13. Reactive Subjects: changes in heart rate, sympathetic, and parasympathetic tone before, during, and after blind provocation with a 2.4 GHz cordless phone that generates exposure of 3 to 5 microW/cm^2

among such afflicted individuals. Furthermore, several studies report no effect of mobile phones (various exposure conditions) on human HRV-parameters[32-39].

Our results clearly show a causal relationship between pulsed 100 Hz MW exposure and changes in the ANS that is physiological rather than psychological and that may explain at least some of the symptoms experienced by those sensitive to electromagnetic frequencies. Dysfunction of the ANS can lead to heart irregularities (arrhythmia, palpitations, flutter), altered blood pressure, dizziness, nausea, fatigue, sleep disturbances, profuse sweating and fainting spells, which are some of the symptoms of EHS.

When the SNS (fight or flight response) is stimulated and the PSNS (rest and digest) is suppressed the body is in a state of arousal and uses more energy. If this is a constant state of affairs, the subject may become tired and may have difficulty sleeping (unable to relax because of a down regulated PSNS and/or up regulated SNS). Interestingly, Sandstrom[40] found a disturbed pattern of circadian rhythms of HRV and the absence of the expected HF (parasympathetic) power-spectrum component during sleep in persons who perceived themselves as being electrically hypersensitive.

If the dysfunction of the ANS is intermittent it may be experienced as anxiety and/or panic attacks, and if the vagus nerve is affected it may lead to dizziness and/or nausea.

Our results show that the SNS is up regulated (increase in LF) and the PSNS is down regulated (decrease in HF) for some of the subjects during provocation. The greatest

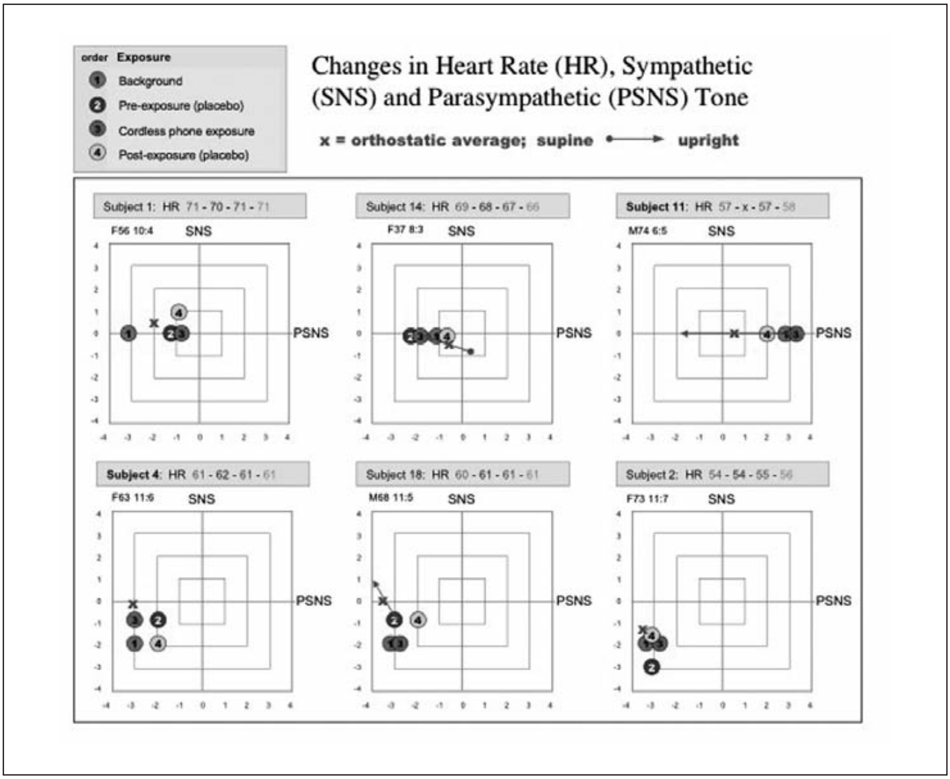

Fig. 14. Non or slightly reactive subjects: patterns of response for before, during, and after blind provocation with a 2.4 GHz cordless phone that generates exposure of 3 to 5 microW/cm^2

increase is in LF2, which is the adrenal stress response, although LF1 also increases. We not know the degree to which this is due to the 100 Hz pulse, the MW carrier, or their combination.

Several studies lend support to our results.

Lyskov *et al.*[41] monitored baseline neurophysiological characteristics of 20 patients with EHS and compared them to a group of controls. They found that the observed group of patients had a trend to hypersympathotone, hyper-responsiveness to sensor stimulation and heightened arousal. The EHS group at rest had on average lower HR and HRV and higher LF/HF ratio than controls. We found that subjects with intense and moderate reactions to the MW provocation also had higher LF/HF ratios than those who did not respond.

Kolesnyk *et al.*[42] describes an "adverse influence of mobile phone on HRV" and Rezk *et al.* [43] reports an increase of fetal and neonatal HR and a decrease in cardiac output after exposure of pregnant women to mobile phones.

Andrzejak *et al.*[44] reports an increased parasympathetic tone and a decreased sympathetic tone after a 20-minute telephone-call. While these results are contrary to our findings, the effect of speaking cannot be ruled out in Andrzejak's study. In our study the subject remained in a supine position, silent and still during the testing.

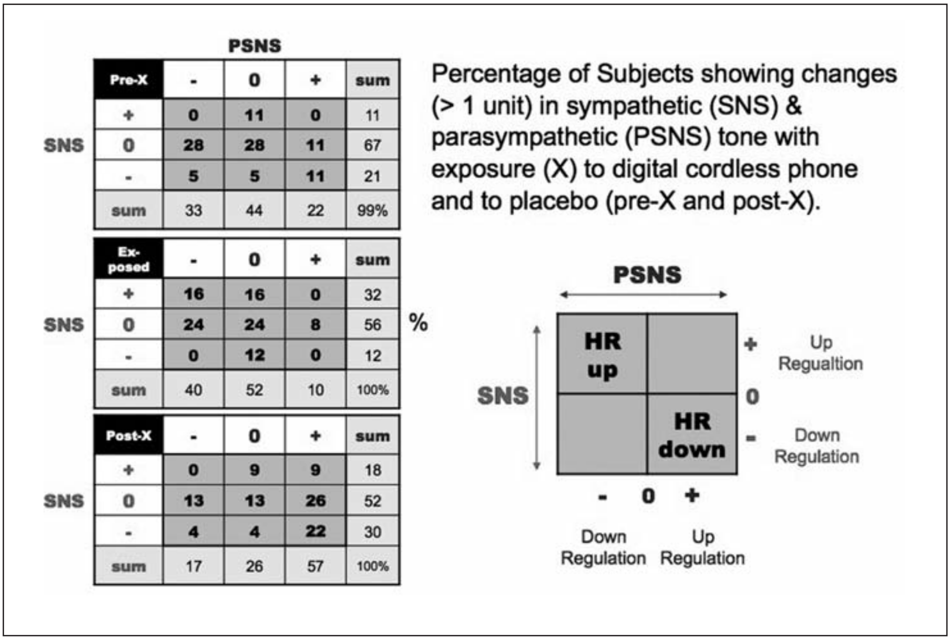

Fig. 15. Response of 25 subjects to blind provocation by a 2.4 GHz digital cordless phone that generates exposure of 3 to 5 microW/cm^2

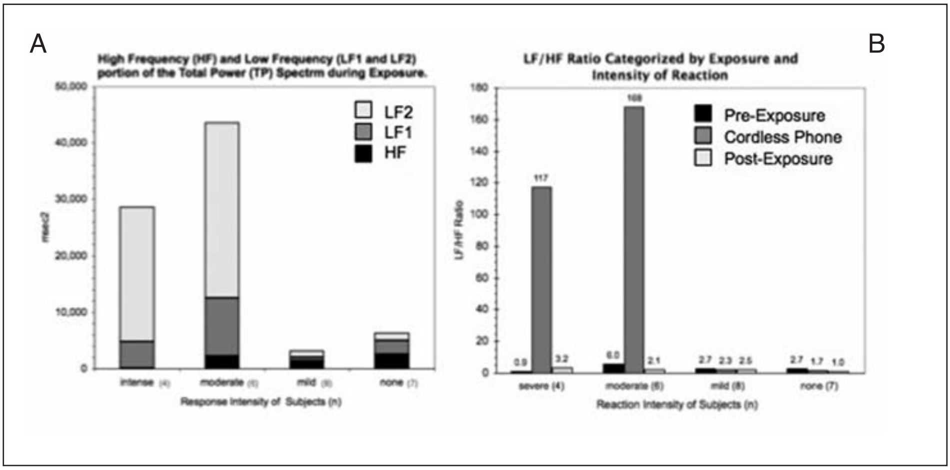

Fig. 16. A. Mean high frequency (parasympathetic) and low frequency (sympathetic) spectral distribution as a function of response intensity of 25 subjects exposed to a 2.4 GHz cordless phone. B. Low frequency (LF1 + LF2) to high frequency (HF) ratio for different exposures

Workers of radio broadcasting stations have an increased risk of disturbances in blood pressure and heart rhythm. They have a lower daily heart rate, a decreased HR variability, higher incidences of increased blood pressure and disturbances in parameters of diurnal rhythms of blood pressure and HR-all of no clinical significance, but showing a certain dysregulation of autonomic cardiac control[45-48].

Bortkiewicz *et al.*[49] reported that exposure to AM radio frequency EMF within hygienic standards affects the functions of the ANS of workers. Workers had higher frequency of abnormalities in resting and 24-h ECG than controls and an increased number of heart rhythm disturbances (ventricular premature beats). As in our study, RF exposure was associated with a reduced HF power spectrum suggesting that the EMF field reduce the influence of the PSNS on circulatory function.

Several studies report changes in blood pressure with electromagnetic exposure[50, 51]. Others show an increase of oxidative stress and a decrease of antioxidative defense-systems in heart-tissue irradiated with 2.45 GHz and 900 MHz respectively[52, 53]. Still others show a stress-response reaction following exposure to radio frequency radiation either in the form of heat shock proteins (hsp) or changes in enzymatic activity. Irradiation of rats with a low-intensity-field (0.2-20 MHz) resulted in an increase of myocardial hsp70[54]. Similarly 1.71 GHz MW exposure increased hsp70 in p53-deficient embryonic stem cells[55]. Abramov and Merkulova[56] report pulsed EMFs increase the enzymatic activity of acetylcholinesterase in the animal heart, which suppresses the parasympathetic and allows the sympathetic to dominate.

Most of the studies on humans, that did not show any effects of MW radiation in some of the studies mentioned above, were conducted with young, healthy subjects, giving rise to the question whether the experiments would have yielded different results with subjects with a "higher level of pathologic pre-load" and thus fewer possibilities to acutely compensate the possible stressor of radiation.

The studies on work-exposure to MW radiation were able to show different levels of effects on the cardiovascular system, and this could be interpreted as the necessity to remain regularly, repeatedly, and for a longer time under the influence of a certain EMF exposure, hence pointing out the great importance of the electromagnetic exposures in the work and home environment. Perhaps only chronic exposure to MW-EMF can influence various rhythms (e.g. cardiovascular biorhythms) sufficiently to cause detectable effects. Perhaps it is these individuals who become EHS and then respond to stressors if they have sufficient energy to mount a reaction.

In our study, half of those tested claimed to be moderately to extremely sensitive to electromagnetic energy and they ranged in age from 37 to 79 years old. The symptoms they identified are similar to those reported elsewhere and include poor short-term memory, difficulty concentrating, eye problems, sleep disorder, feeling unwell, headache, dizziness, tinnitus, chronic fatigue, and heart palpitations[2, 7, 57].

The common devices attributed to stress generation included fluorescent lights, antennas, cell phones, Wi-Fi, and cordless phones. The last 4 items all emit MW radiation.

Many of those claiming to have EHS also had food allergies, mold/pollen/dust allergies and were chemically sensitive. With so many other sensitivities it is difficult to determine whether the sensitivity to electromagnetic energy is a primary disorder attributable to high and/or prolonged EM exposures or a secondary disorder brought about by an impaired immune system attributable to other stressors.

Interestingly, the younger participants (37 to 58) displayed the most intense responses presumably because they were healthy enough to mount a response to a stressor. Those who did not respond to the MW exposure were either not sensitive, or they had a low adaptive capacity coupled with a poor fitness score and did not have enough energy to mount a reaction. Orthostatic HRV combined with provocation monitoring may help distinguish these three types of responses (sensitive, not sensitive, non-responsive reactors).

The term EHS was deemed to imply that a causal relationship has been established between the reported symptoms and EMF exposure and for that reason the WHO[8] has labeled EHS as *Idiopathic Environmental Intolerance* (IEI) to indicate that it is an acquired disorder with multiple recurrent symptoms, associated with diverse environmental factors tolerated by the majority of people, and not explained by any known medical, psychiatric or psychological disorder. We think this labeling needs to be changed especially in light of this study.

Conclusions

The orthostatic HRV provides information about the adaptive capacity of an individual based on fitness score and on the state of the SNS and PSNS. A person with high adaptive capacity is unlikely to respond to a stressor (because they are highly adaptive) but if they do respond the response is likely to be intense. Orthostatic HRV was able to predict the intensity of the response much better than the probability of a response to a stressor, which in this case was a 2.4 GHz digital cordless phone that generated a power density of 3 to 5 microW/cm^2.

Forty percent of those tested responded to the HRV provocation. Some experienced tachycardia, which corresponded to an up regulation of their SNS and a down regulation of their PSNS (increase in LF/HF ratio). This was deemed a severe response when the HR in supine subjects increased by 10 to 93 beats per minute during blinded exposure. HR returned to normal during sham exposure for all subjects tested. In total, 16% had a severe response, 24% had a moderate response (changes in SNS and/or PSNS but no change in HR); 32% had a slight response; and 28% were non-responders. Some of the non-responders were either highly adaptive (not sensitive) or non-responding reactors (not enough energy to mount a reaction). A few reactors had a potentiated reaction, such that their reaction increased with repeated exposure, while others showed re-regulation with repeated exposure.

These data show that HRV can be used to demonstrate a physiological response to a pulsed 100 Hz MW stressor. For some the response is extreme (tachycardia), for others moderate to mild (changes in SNS and/or PSNS), and for some there is no observable reaction because of high adaptive capacity or because of systemic neurovegetative exhaustion. Our results show that MW radiation affects the ANS and may put some individuals with pre-existing heart conditions at risk when exposed to electromagnetic radiation to which they are sensitive.

This study provides scientific evidence that some individuals may experience arrhythmia, heart palpitations, heart flutter, or rapid heartbeat and/or vasovagal symptoms such as dizziness, nausea, profuse sweating and syncope when exposed to electromagnetic devices. It is the first study to demonstrate such a dramatic response to pulsed MW radiation at 0.5% of existing federal guidelines (1000 microW/cm^2) in both Canada and the US.

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APPENDIX A: Summary of data based on blind assessment.

1		2	3	4		5		6					7			Notes:
					Orthostatic HRV				Changes in			Blind Assessment				
EHS	Subject Code	EHS Ranked	EHS Self Assessment	CV Tone	IOR Code	AC Code	POR Code	Actual Stages Exposed	HR	SNS	PSNS	Stages Exposed	Stages showing reaction	POR Code	IOR	
intense	25	1	very	3	3.5	4.5	1.5	3, 5 (6,7,9)	93	5	-4	**3, 5**	3, 5	5	high to extreme	8
	17	2	very	3	3.5	3.5	3.0	3, 5 (6)	54	4	-1	**3, 5, 6**	3, 5, 6	4.5	moderate	9
	26	3	moderate	1	5.0	5.0	1.5	3, 5, 6 (7, 8)	45	4	-5	**3, 5, 6, 7**	3, 5, 6, 7	5	moderate to intense	10
	27	4	little	3	3.0	3.0	3.5	2, 4 (5, 6)	10	0	5	**2, 4, 5**	2, 4, 5	5	mild	11
moderate	5	5	moderate	2	4.0	3.5	3.5	3, 5	0	2	-2	**3, 5**	3, 5	5	moderate to high	12
	9	6	don't know	2	3.5	4.5	2.0	3, 5, 6, 8	0	-1	-3	**3, 5, 6**	3, 5, 6	4	high	13
	3	7	don't know	-1	5.0	4.0	1.0	3, 4	3	2	0	2, **3**	3, 4	4	moderate	14
	16	8	very	1	4.0	4.0	3.5	2, 4, 6	1	-2	0	**2**	2	1	mild	15
	8	9	not	5	2.5	1.5	4.5	2, 3	0	0	-2	**2**, 4	2, 4	1	mild	16
	10	10	don't know	2	3.5	3.0	3.0	3 (7, 8, 9)	2	0	-1	**3, 7,8,9**	3 mild, 7,8,9 intense	5	intense	17
mild	2	11	don't know	2	2.0	1.0	3.5	3, 4	1	1	0	unknown	none	1.75	mild	18
	23	12	little	-1	5.0	1.5	4.5	2, 4 (5, 6)	-1	1	0	**2, 5**	2, 5	2	mild to moderate	19
	12	13	little	3	4.0	4.0	2.5	2, 3 (5)	-2	1	0	**3**	3, 4, 5	3	mild to moderate	20
	18	14	don't know	2	2.5	2.5	4.5	3	0	-1	0	**3**	3	1.5	mild	21
	19	15	don't know	4	2.0	2.5	3.0	3	0	-1	0	2, 4	2, 4	3	mild to moderate	22
	6	16	very	2	3.5	2.0	4.5	3, 4	0	0	-1	2	2	2	mild	23
	4	17	little	1	2.0	1.0	4.0	3, 4	-1	0	-1	**3, 4**	4, 5	2.25	moderate	24
	24	18	little	2	3.0	4.0	3.0	3, 5	-1	0	1	2, 4, **5**	2, 4, 5	2.5	mild	25
none	1	19	don't know	5	3.5	3.5	3.5	3, 4	1	0	0	**3, 4**	4, 5	1	mild	26
	11	20	not	1	1.0	5.0	1.5	2, 4, 5	0	0	0	3	3	1	mild or non-symptomatic	27
	21	21	little	3	2.5	2.0	3.5	3 (4, 5)	0	0	0	2, **5**	2, 5	1.5	none to mild	28
	7	22	very	2	2.5	1.5	4.0	3, 4	-1	0	0	unknown	unknown	1.5	mild	29
	14	23	don't know	5	2.5	3.5	3.0	3, 4	-1	0	0	2	2, 3, 4	1.75	mild	30
	20	24	little	3	3.5	4.0	4.5	2	-1	0	0	possibly 5?	6	1	mild	31
	13	25	very	4	3.0	2.5	3.5	3, 4	-2	0	0	unknown	unknown	1	mild	32

code	code	code	code	code	code	code
5	hypo	intense	high	high	high	intense
4		strong				strong
3	normal	moderate	moderate	moderate	moderate	moderate
2		mild				mild
≤ 1	hyper	don't know	low	low	low	don't know

Notes:

1 Electrohypersensitivity (EHS) response categories are based on HR = heart rate; SNS = sympathetic nervous system; PSNS = parasympathetic nervous system.

2 EHS was ranked based on changes in HR and changes in the SNS and PSNS during exposure to microwave (MW) radiation.

3 Self-assessment of sensitivity based on questionnaire response.

4 Cardiovascular (CV) Tone is based on the HR times the sum of the systolic and diastolic blood pressure; values at 1 or lower are hypotonic and values at 5 are hypertonic.

5 Intensity of reaction (IOR); adaptive capacity (AC), which is 6 - non adaptive capacity (NAC); and probability of reaction (POR) are based on the orthostatic heart rate variability (HRV) results and are described in the text.

6 Subjects were exposed to MW radiation at different stages. Stages in parentheses were not used in the study as they reflect multiple exposures with interference from other agents.

7 Blind assessment was based on the HRV during continuous monitoring with real and sham exposure to MW radiation from a 2.4 GHz digital cordless phone radiating and at a power density between 3 and 5 microW/cm^2.

8 Excellent subject.

9 Symptomatic at stage 3, parasympathetic rally begins to recovery but feels anxiety, stage 3 faint or dizziness predicted. Decent Chronotropic Myocardial Reaction Index (ChMR) and vascular compensation reaction (VC). Middle of bell curve.

10 The healthier a subject the more likely the reaction. This person has the energy to become symptomatic.

11 Mildly inflamed. Mildly fatigued but highly adaptive. ChMR and VC good. Has ability to react.

12 Adaptive person. Could use Mg and/or K based on high standing HR.

13 Has plenty of energy. Moderate response due to weakening. Stage 7 body re-regulating from exposure.

14 Shows a weakening reaction (down regulation of SNS). Positive reactor. Very healthy for age. Highly adaptive geriatric.

15 Lot of adaptive capacity. If she is exposed her reaction would be a fairly strong reaction.

16 Has diminished energy capacity (11:6). This person doesn't have enough energy to have a robust response.
17 Potentiated reactor, time sensitive, couldn't tolerate re-exposure. If she reacts it will be moderately strong because of ChMR. Needs minerals for VC factor slowed her down.
18 May be on heart medication. Cardiac rate and rhythm non-adaptive. CV tone hypertonic.
19 Any neurological insult will be met with a hard reaction since she has inverted response when she stands up.
20 If reactor, it will be strong because of ChMR strong. Highly adaptive capability and reserve. Slow VC could be mineral or vitamin D deficiency.
21 Don't have a strong PSNS resistance. Reactivity is based on inability to go parasympathetic, and then they will go more sympathetic if they have the energy to do so. No energy. Either a delayed reaction or a weak reaction.
22 Afibrillation, palpitations of heart probable. Strong girl. 11:6 fitness is OK for a person this age.
23 May have dental problems based on S/P response. Neurologically compromised.
24 Neurologically compromised. May be overmedicated on CV drug.
25 Strong gal. Decent reserve capacity but temporary fatigue. Doesn't feel bad but poor health for her age.
26 Normal reaction to stress, mild non-toxic reaction. Potential for reaction: moderately high because of the 10.4 but may tolerate an amount of exposure before they react because of the reserve capabilities.
27 Ridiculously healthy. Poster boy for his age. He can take a lot based on fitness of 6:5.
28 Lower end of bell curve. Doesn't have energy to react although may be symptomatic.
29 Either highly adaptive or non-reactive. Orthostatic response indicates that person doesn't have enough energy to have a robust response.
30 Normal CV tone for age, Decent Tension Index (TI). Good geriatric pattern. If she reacts it would be moderate to mild.
31 Strong girl. Has strong adrenal capacity. If she reacts it will be strong. May have chronic fatigue.
32 Moderate inflammation. Tired and has low adaptive reserve. If stressor comes along it will produce more stress. If reacting it would be medium.

Comparative assessment of models of electromagnetic absorption of the head for children and adults indicates the need for policy changes

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Abstract

Globally more than four billion phones are in use, with more than half of all users believed to be children and young adults. Over the past two decades, models of the human head have been devised based on imaging studies and used to estimate the extent and rate of radiation energy absorption to the brain, the Specific Absorption Rate (SAR). IEEE and ICNIRP SAR recommendations rest solely on avoiding thermal effects on the adult male head under conditions of a six minute long call and do not take into account the long-term cell phone use, the length of calls, non-thermal biological effects, the smaller size and greater physiological vulnerability and increased absorption to the heads of children and females. Currently recommended approaches by the IEEE calculate peak spatial average SAR for safety compliance testing of cell phones based on a physical model of an adult male head with an added 10 mm plastic spacer to model the ear (pinna). By incorporating such a spacer, the IEEE model assumes that the RF energy absorption in the ear (or pinna) may be treated like extremities of the body such as the legs and the arms that are not proximate to the brain. The 10 mm spacer artificially results in 2 to 4 times lower exposures to the head. Recent epidemiologic studies of adults from those few nations where cell phone use has been extensive for a decade or longer indicate significantly increased risk of a variety of brain tumors. These findings, together with the limitations of currently used head models and the growing use of phones by the young and females, indicate a clear and compelling need for improved, biologically-based

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models of the head in order to better estimate population-wide exposures of children and women to cell phones and provide the grounds for improved policies to reduce those exposures.

***Key Words*: health effects, mobile phones, Specific Absorption Rate (SAR), children and adults, radio frequency radiation, brain and cell phone.**

Introduction

Cell phone use has grown exponentially throughout the world in less than a decade. More than half of the world's population uses cell phones today as telephones as well as clocks, radio, video, and tools for exchanging information. Current technology of 2G and 3G phones operates in the microwave range, from 800 to 2450 megahertz (MHz). Standards for these phones rest on guidance developed by two non-governmental engineering-based groups, the Institute of Electrical and Electronics Engineers (IEEE) and International Commission on Non-Ionizing Radiation Protection (ICNIRP)[1, 2]. For compliance with IEEE and ICNIRP exposure limits, the quantification of exposure to the head, the 1 or 10 gram (g) Specific Absorption Rates (SAR), is based on a physical model of an adult male head with a 10 mm spacer at the ear, or pinna, to estimate radiofrequency (RF) thermal energy absorption that can take place in the course of a call with no accounting for the duration of the call assuming that it will not result in change in temperature of the brain. In the U.S., Canada, and most industrial nations, there is no independent review of these standards, monitoring of the cell phone manufacturers for compliance with these standards, or monitoring of cell phone use in real life.

A growing number of *in vitro* and *in vivo* studies have confirmed that both 2G and 3G signals at non-thermal levels are genotoxic[3, 4]. Potential mechanisms of such impact include changes in free-radical formation, alterations in electron conformation, and inhibition of proteins and other factors involved in DNA repair and synthesis. While molecular mechanisms for possible adverse effects have not been completely elucidated, energy absorption of higher frequency signals emitted by recently developed 3G, or even the new generation 4G cell phones, may result in greater biological effects. Based on these considerations, a growing number of national governmental agencies have issued precautionary advisories, urging that children avoid regular use cell phones next to their heads, restricting the marketing and development of cell phones for children, and recommending general methods for reducing direct exposure to the head of adults[5].

To complement such general precautions, this paper briefly reviews the underlying engineering and biology of RF signals associated with different generations of phones, synthesizes evolving evidence on the health effects of RF, clarifies and considers the strengths and limits of currently used models of the head used for testing phones, and summarizes efforts to promote precaution regarding the use of phones.

The changing nature of RF cell signals

Over the past four decades, cell phone types and uses have radically changed. The first generation, known as 1G, was a bulky cell phone introduced in the 1980s based on analog modulation with output power typically around 2 to 3 Watts (W). Examples of these systems are the Advanced Mobile Phone System (AMPS) in North America, Asia

Pacific, Russia, Africa and Israel in the frequency band between 800 and 900 MHz, and the Nordic Mobile Telephone (NMT) 900 system since 1986 in Scandinavia, Netherlands, Switzerland and Asia. The RF from 1G phone was presumed to produce mainly thermal effects, with any potential risks resulting from heating of the tissues.

The advanced generations of cell phones, namely 2G and 3G, employ higher data rates and a broader range of multimedia services and were launched in 1991 and 2001. Unlike 1G cell phones, the maximum radiated power was now controlled by the base station (cell tower or mast). The base station reduced the power emitted by 2G and 3G cellphones to a level that produces a good signal to noise ratio (SNR). These phones rely on digital modulation with mean (rms) output power typically around 250 or 125 mW (maximum 1-2W). Typical examples of these systems are: the North American Digital Cellular (NADC) system (824-894 MHz) since 1991 in USA; the Personal Communication Services (PCS) system (1850-1990 MHz) since 1996 in USA; the Global System for Mobile Communications (GSM) system (880-960 MHz) since 1991 in Europe and Asia Pacific; and the Digital Cellular System (DCS) 1800 (1710-1880 MHz) employed since 1993 in Europe. The modulation signals used in these digital systems are complex with the lowest rate of 217 Hz (e.g., GSM is encoded at 217 pulses/sec). This lower rate was reported to result in greater interaction with the biological tissues, inducing non-thermal effects and increased risks to living cells, even at low absorbed average powers[6]. Current 3G and 4G phones involve modulation with even lower minimum pulse rates and much higher data rates. As a result, 3G phones can result in greater cumulative average exposures, a result of the higher data rates.

Most contemporary cell phones use monopole or helix type antennas, which produce similar radiation patterns. The radiation pattern determines how the energy is distributed in the space. This can be represented by two planes that are orthogonal to each other, one is the electric field, the other is the magnetic field. When a monopole or helix antenna rests in a vertical direction and is unimpeded by any RF absorbing obstacle like the human head or body, it produces a nearly symmetrical pattern of RF around this antenna. In actual use about one half of the RF energy radiated by a cell phone is absorbed by the human head. The closer the cell phone is to the head the greater is the absorbed energy in the head tissues.

Biologic effects of non-ionizing radiation

Ionizing radiation (IR) is well known to have potent biological effects that break chemical bonds creating ions. This breakage of bonds results in diseases ranging from cancer to developmental and reproductive impairment, to death.[7] These biological impacts arises because 15% of the IR directly breaks ionic bonds at the backbone of DNA causing mutations that can lead to cancer; 85% of IR damage is caused by the creation of free radicals in the cell's cytoplasm near the DNA molecule, also resulting in DNA mutations, or through other mechanisms that are still being elucidated.

Non-ionizing radiation (NIR), found at all frequencies with energy levels too low to break chemical bonds from low-frequency electric power systems to microwave (MW) frequencies used by cell phones also produces biological effects when studied in cell cultures and in experimental animals. At low levels, equivalent to exposure from radiation from mobile phones, RF has been shown to result in damage to biological tissues, including both single and double DNA strand breaks, alterations in the permeability of the blood-brain barrier (BBB), oxidative stress, and damage to neural cells of the brain[8, 9].

Two mechanisms have been identified thus far to explain the variety of non-ionizing electromagnetic fields (EMFs) interactions with biological systems: thermal effects and non-thermal effects. Thermal effects arise directly from the increased movement of molecules results in tissue heating as a result of the absorption of EMFs in a dissipative medium. Absorption of energy at MW/RF frequencies is largely due to the motion of water dipoles and dissolved ions. At high frequencies (such as for the MW/RF band), tissues with high water content, such as occurs in the brains of young children, show electrical conductivity increasing with frequency. Thus, the net thermal response of the body will vary depending on SAR, ambient temperature, clothing, thermoregulatory system and physiological condition.

Non-thermal effects can result from direct interaction of the MW/RF fields on molecules or tissue components, changing electron conformation, altering stress proteins (previously known as heat shock proteins), immune-system function and having other impacts that remain to be clarified. Non-thermal effects are still not very well understood and their exact consequences on human health are still being investigated. Some reported non-thermal effects on tissue are biochemical and electrophysiological effects and can result in changes in the nervous, immune and cardiovascular systems, as well as in metabolism and hereditary factors[4, 10, 11].

In a pioneering research effort that created the widely used Comet Assay, Lai and Singh demonstrated that two hours of microwave radiation, comparable to that emitted by a cell phone, damaged DNA of the rat brain[12]. A European study team of a dozen collaborators under the aegis of REFLEX [Risk Evaluation of Potential Environmental Hazards from Low Energy Electromagnetic Field (EMF) Exposure Using Sensitive in vitro Methods], found evidence that low (non-thermal) energy levels of RF exposure induced double strand breaks in DNA of cells exposed to between 0.3 and 2 W/kg[13]. Although the mechanism(s) underlying such non-thermal effects of NIR remains unclear, it seems quite plausible, as with the cancer-promoting effects of inflammatory lesions, that mutagenic damage to DNA could be induced by generated free radicals. In contrast, many other studies of non-thermal or thermal effects of RF issue have yielded no evidence of DNA damage. But, the great preponderance of these negative studies have not reflected independent research but resulted from studies directly funded by the cell phone industry[14].

Current SAR calculations rest solely on avoiding thermal impacts. In principle, as the newer generation of digital phones radiate lower mean power in comparison to the analogue phones, the risk associated with the heating of tissues should be correspondingly reduced. However, most mobile communication systems are pulse-like in nature and modulated at low frequencies with high data rates. As a result, these newer systems can induce low-levels of currents in the brain tissues that have been linked with a variety of non- or thermal effects, e.g., BBB alterations, single and double strand DNA breaks, chromosomal aberrations, etc., at RF energy levels substantially below the thermal threshold.

Despite the growing industry-independent evidence that NIR has a range of biological impacts, intense controversy surrounds the interpretation of the limited available public health investigations regarding risk for cancer or other chronic diseases. Human studies on both cancer and non-cancer impacts of NIR are inconsistent for reasons that have been thoroughly discussed by a number of authors[15].

Epidemiologic studies

The biology and epidemiology of the often lethal cancer of the brain is complex. It is unreasonable to expect to be able to detect an increased risk of brain tumors in less than a decade, because brain tumors are known to have latencies that can be between a decade to four decades long[16]. Recently several authors have produced meta-analyses that show that only when studies have followed people for a decade is there evidence of increased risk (Table 1).

For more than a decade, Hardell and his colleagues conducted a series of studies in Sweden, a country where proportionally more of the population has heavily used cell phones for a longer period of time than in many other industrialized nations. Regarding acoustic neuroma (AN), the Swedish group reported an 2.7 to 5.1 fold increased risk of AN for those regularly using an analog cell phone for five years or more compared to those who never or rarely used a cell phone[17, 29]. Hardell's team also found long-term analogue cell phone use significantly increased the risks of meningioma and astrocytoma[22, 29]. Recently, Hardell and Carlberg found that persons who had used cell phones for 10 years or more also had the highest risk for astrocytoma. This study also included persons who had begun to use cell phones before age 20. Cases with first mobile phone use younger than 20 years age had five times more brain cancer for 1 or more years of use (OR=5.2, 95% CI=2.2-12). For AN, the highest risk was found for greater than 10 years of ipsilateral mobile phone use (OR=3.0, 95% CI=1.4-6.2)[30].

The International Agency for Research on Cancer (IARC) began an international collaborative case-control study on cell phone use and the incidence of brain tumors in 13 countries in 1997 (the INTERPHONE study). Among six INTERPHONE reports from different countries, which included persons who had used phones episodically for less than a decade, none reported a relationship between cell phone use and AN[18-20, 31-33]. They did not report any significant relationship between long term cell phone use and glioma, meningioma or other brain tumors[21, 24, 25, 27, 28]. However, the recently published Interphone study found that the heaviest cell phone users, cumulative call time $\geq$ 1640 hours have increased risk of glioma (OR=1.40, 95% CI=1.03-1.89) and meningioma (OR=1.15, 95% CI=0.81-1.62)[34]. Brain tumor risk was not found to be higher among those who use cell phone less frequently.

The lack of an observed association between published studies of cell phone use and risk for malignant or benign tumors in other published studies could reflect a number of methodological limits of study design. Most of these negative studies involved relatively short time periods of cell phone use, infrequent use of cell phones, or a small number of cases. In an effort to refine evaluation of the issue, studies have been carried out that separate out extent and type of cell phone use, including side of the head on which phones are typically used. The Hardell group found a consistent pattern of an association between ipsilateral AN and cell phone use providing that there was a 10-year latency period or longer (OR=2.4, 95% CI = 1.1-5.3)[23]. Two additional studies from other investigators in the Nordic region[19, 20] produced similar results. A study used interphone protocol that poold data from 5 North European countries similarly found an increased glioma risk after a decade of use for ipsilateral cell phone exposure (OR=1.4, 95% CI=1.0-1.9)[35]. A significant excess risk for reported ipsilateral phone use to the tumor was also found for glioma regardless of the duration of cell phone use[26].

A recent meta-analysis of studies produced by a team from California and Korea has corroborated this analysis, noting that the Hardell's work consistently reflects high

Table 1 - Summary of published articles on brain tumors and long term (≥ 10 years) cell phone use

Study	Population	Period	Study type	No. cases	No. controls	OR (95% CI)	Cell phone exposure
Acoustic Neuroma							
Hardell *et al.*, 2002[17]	Sweden	2000-2002	Case-control	46	26	1.8 (1.1-2.9)	regular analogue phone use
Christensen *et al.*, 2004[18]	Denmark	2000-2002	Case-control	2	15	0.2 (0.04-1.1)	regular use
Lönn *et al.*, 2004[19]	Sweden	1999-2002	Case-control	14 12	29 15	1.8 (0.8-4.3) 3.9 (1.6-9.5)	regular use ipsilateral exposure
Schoemaker *et al.*, 2005[20]	4 Nordic countries and UK	1999-2004	Case-control	47 23	212 72	1.1 (0.7-1.5) 1.8 (1.1-3.1)	regular use ipsilateral exposure
Schüz *et al.*, 2006[21]	Denmark	1982-2002	Cohort	28	42.5	0.7 (0.4-1.0)*	regular use
Hardell *et al.*, 2006[22]	Sweden	1997-2003	Pooled case-control	19 1	84 18	2.2 (1.4-3.8) 0.6 (0.1-5.0)	regular analogue phone use regular digital phone use
Hardell *et al.*, 2008[23]	Sweden		Meta-analysis	83	355	1.3 (0.6-2.8)**	regular use
				53	167	2.4 (1.1-5.3)****	ipsilateral exposure
Glioma							
Christensen *et al.*, 2005[24]	Denmark	2000-2002	Case-control	6****	9	1.6 (1.4-6.1)	regular use
Lonn *et al.*, 2005[25]	Sweden	2000-2002	Case-control	22 14	33 15	0.9 (0.5-1.6) 1.8 (0.8-3.9)	regular use ipsilateral exposure
Hepworth *et al.*, 2006[26]	UK	2000-2003	Case-control	48	67	1.1 (0.7-1.7)	regular use
Schüz *et al.*, 2006[27]	Germany	2000-2003	Case-control	12	11	2.2 (0.9-5.1)	regular use
Lahkola *et al.*, 2008[28]	5 European countries		Case-control	143 77	220 117	0.9 (0.7-1.3) 1.4 (1.0-1.9)	regular use ipsilateral exposure

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Table 1 - Summary of published articles on brain tumors and long term (≥ 10 years) cell phone use

Study	Population	Period	Study type	No. cases	No. controls	OR (95% CI)	Cell phone exposure
Meninglioma							
Lönn *et al.*, 2005[25]	Sweden	2000-2002	Case-control	8	32	0.7 (0.3-1.6)	regular use
				4	15	1.4 (0.4-4.4)	ipsilateral exposure
Christensen *et al.*, 2005[24]	Denmark	2000-2002	Case-control	6	8	1.0 (0.3-3.2)	regular use
Hardell *et al.*, 2006[22]	Sweden	1997-2003	Pooled case-control	34	84	1.6 (1.0-2.5)	regular analogue phone use
				8	18	1.3 (0.5-3.2)	regular digital phone use
Schüz *et al.*, 2006[27]	Germany	2000-2003	Case-control	5	9	1.1 (0.4-3.4)	regular use
Lahkola *et al.*, 2008[28]	5 European countries		Case-control	42	130	0.9 (0.6-1.3)	regular use
				21	73	1.0 (0.6-1.7)	ipsilateral exposure
Astrocytoma							
Hardell *et al.*, 2006[29]	Sweden	2000-2003	Case-control	40	40	3.7 (2.0-7.0)	regular analogue phone use
				16	18	2.2 (0.8-6.5)	regular digital phone use
All Malignant Brain Tumor							
Hardell *et al.*, 2006[29]	Sweden	2000-2003	Case-control	48	40	3.5 (2.0-6.4)	regular analogue phone use
				19	18	3.6 (1.7-7.5)	regular digital phone use

* Standardized incidence ratio was calculated based on observed and expected numbers
** Based on 4 case-control study (Lönn et al 2004, Christensen et al. 2004, Schoemaker et al. 2004, and Hardell et al., 2006)
*** Results from a Meta-analysis, based on three case-control studies (Lönn et al., 2004, Schoemaker et al., 2005 and Hardell et al., 2006)
**** low-grade glioma

quality methods and design. The researchers examined 465 articles published in major journals and focused on 23 studies involving 37,916 participants. In eight of the studies – those that were conducted with the most scientific rigor – cell phone users were shown to have a 10% to 30% increased risk of all types of tumors studied compared with people who rarely or never used cell phones (OR=1.2, 95% CI=1.0-1.3). The risk was highest among those who had used cell phones for 10 years or more[36].

The results of the entire literature on epidemiology and cell phone use remain controversial, because most studies suffer from a number of methodological shortcomings including: insufficient statistical power to detect an excess risk of brain tumors; reliance on small populations; short-term exposure periods; problems in recollection of past practices and difficulty in characterizing changing exposures throughout a lifetime in large populations. As a number of researchers have suggested, retrieving billing records from cell phone network providers to obtain cumulative duration and frequency of cell phone use and corroborating personal interview would provide the capability to validate self-reported cell phone exposure in future studies[37]. Assuring independent funding for future research will also be critical, given the widely reported biases associated with the design and interpretation of industry-funded studies to date.

Regarding short-term health impacts from RF exposure such as insomnia, impairment of short-term memory, headache, alteration of EEG and other behavioral problems, evidence has been fairly consistent that such effects are worsened in longer term cell phone users[38, 39]. Whether these relatively benign perturbations signal the likelihood that more serious health impacts will occur after longer-term RF exposure is a matter of critical importance for future studies.

Models of the head used to evaluate compliance with safety standards

Given the concerns that have been raised from the biological and epidemiological studies, it is important to establish standards for RF exposures from cell phones that incorporate the best scientific information regarding differences in the heads of people of various sizes, genders and ages. Children's skulls are thinner and their brains are less dense and more fluid, making them more vulnerable than adults to RF signals. Size alone affects absorption. In addition, other physiological properties such as permittivity, electrical conductivity and density also affect transmission and absorption of RF signals, as does myelination of the nerves of the brain, which is not complete until the early to mid-twenties[40].

The relative permittivity of a material under given conditions is measuring the extent to which it concentrates lines of flux. The relative permittivity of any material is expressed as the ratio of the amount of stored electrical energy when a potential is applied, relative to the permittivity of the vacuum. The relative permittivity or dielectric constant of the air is 1, while that of an adult brain is around 40 and that of a young child's brain is higher closer to 60 to 80[41]. This means that peak SAR in a child's head may be 50% to 100% higher than that for an adult[42].

Conductivity and absorption of RF signals are a function of the dimensions and dielectric properties of the tissues that are directly exposed, as well as their neural density, with nerve cells being much more active than bone, hair, or skin. Conductivity is a parameter relating the electric field to the current density. For the same intensity of electric field, the increase in the conductivity will increase the current density and the

SAR. The absorption of RF energy will then increase, resulting in greater electromagnetic dissipation. Based on the measurements described by Peyman *et al*, the permittivity and the conductivity in the children's head tissues are estimated to be around 20% greater than in adults[41, 43, 44].

The combination of both effects, the increase in the concentration of the electric field due to the increase in the electrical permittivity together with the increase of dissipation of RF/MW energy due to the increase in the conductivity, can result in a substantial SAR increase in the children's head in comparison to the adults.[42, 43]

The weight and size of the tissue being used for estimating the SAR will also affect assessments, with exposures averaged over 1 gram of the head being more stringent than those averaged over 10 grams of the whole body, as the latter involves bone and tissue of more varying electrical conductivities and mass densities than the former. The process of myelination of the brain protects nerves from damage by surrounding them with myelin sheaths, with myelination incomplete until the MID-205 could be yet another factor of concern for children and young adults using cellphones.

Recently, the use of cell phones by young and children has been modeled through a variety of simulations; some based on magnetic resonance imaging (MRI) others based on computerized tomography (CT) scans. Some studies have produced SAR simulations for the heads of adults [45, 46], while others took children into consideration[42-44]. A range of results was obtained (Table 2). In the Utah Model[47], the children's head was based on a scaled adult model and a SAR increase (compared with adult) of up to 153% was obtained.

In Schonborn's study, the head model was based on MRI using similar electromagnetic parameters as those for adults, and no significant differences between adult and children SAR results were observed[54]. In another study, the head model was approximated by spheres considering some variation of the electromagnetic parameters, and an increase of around 20% in the calculated SAR was shown[55].

Using a scaled model for the children's head with adult electromagnetic parameters, no significant variation for the average SAR in the whole head was observed, and when considering the brain, an increase of around 35% in the SAR was calculated[51]. In De Salles's study, a 10 year old child head was developed based on CTI from a healthy boy[43]. The physical and the electromagnetic parameters, such as the permittivity, the equivalent conductivity and the density were fitted to this age. SAR results around 60% higher than those simulated for the adults were observed for the children with fitted parameters.

Wiart and his colleagues developed child head models based on MRI. The combined results of these studies indicate that the maximum SAR in 1 g of peripheral brain tissues of the child models aged between 5 and 8 years is about two times higher than in adult models[52]. More recently in an internal IT'IS Foundation Report, Kuster *et al.*[53] report that spatial peak SAR of the CNS tissues of children is "significantly larger (~2x) because the RF source is closer and skin and bone layers are thinner".

In all models used, it is readily apparent that smaller heads will absorb proportionally more RF than larger heads, but size is not the only property of interest in estimating differential SAR absorption of younger and older brains. Neuro-development of the brain is an exquisitely complex process that occurs at a more rapid pace in young children than in adults. As a result, even if exposures were equal in persons of all ages, the brains of children are more vulnerable than those of adults. In 1996, Gandhi published a report modeling the greater absorption of RF into the brain of a child compared to that of an adult[47]. Subsequent work refined this analysis, taking into account a range of

Table 2 - Some tissue-classified models of the head and the whole body for estimating radiofrequency absorption of humans

Author, Year	Model	Height, Weight, Sex	Derived From	Voxel Size	# of Tissues, Organs	Percentage SAR Underestimation	Cumulative Percentage SAR Underestimation for Child	Comments
Gandhi *et al.*, 1996 [47]	Utah Model	1.75 m ht, 71 kg wt; also scaled models of 5- and 10-year old children	MRI scans	1.974x1.974x2.9 mm for the model of the adult; smaller cell sizes for models of children	32	<153%	<383%	Child's heads scaled from adult's head
Dimbylow, 1998 [45]	NORMAN*	1.7 m ht, 70 kg wt to correspond to "reference man" ICRP23 [45]	MRI scan single subject	2x2x2 mm, 2.04x2.04x1.95 mm	37			
Peyman *et al.*, 2001 [41]						40%	40%	Permittivity & conductivity in children is 60-80 compared to adult's 40
Gandhi and Kang, 2002 [42]	Utah Model	MRI-derived model of the adult and scaled models** of 5- and 10-year old children	MRI scans	Different scaling factors for the head and the rest of the body		50% + >100% from 10 mm spacer + 80% for electrical parameters	~200% @ 1900 MHz; 144% @ 835 MHz	10% smaller head results in 50% underestimation of SAR
Kang and Gandhi, 2002 [48]		model of the adult	MRI scans				15%/mm of spacer	
Wang and Fujiwara, 2003 [49]	Japanese Adult Model	Scaled Models of 7- and 3-year old children adult	MRI scans of the					Multiple studies find children absorb more radiation than adults. See also references 42, 47, 50-52, and 54.

(continued)

Table 2 - Some tissue-classified models of the head and the whole body for estimating radiofrequency absorption of humans

Author, Year	Model	Height, Weight, Sex	Derived From	Voxel Size	# of Tissues, Organs	Percentage SAR Underestimation	Cumulative Percentage SAR Underestimation for Child	Comments
Gandhi and Kang, 2004 [50]	Specific-anthropo-morp-hic phantom (SAM)	Plastic head-shaped phantom with a plastic spacer to represent the pinna	90 th percentile head size of military personnel		Filled with homogenous fluid	Underestimates SAR by a factor larger than 2	Not tested for the size of a child's head	Use of a 6-10mm thick plastic spacer makes it impossible to measure the highest SAR for the pinna
Martinez-Burdalo *et al.*, 2004 [51]		Child	Scaled model from adult electrical parameters				35%	As head size decreases, the percentage of energy absorbed in the brain increases
Fernandez *et al.*, 2005 [44]	10 years old Brazilian Model	10 year old child (1.2 m height, 35 kg, male)	102 CT scans	0.946 mm x 2.044 mm x 1.892 mm (3.10 mm^3)	10			Permittivity & conductivity of 10 year old
De Salles *et al.*, 2006 [43]	10 years old Brazilian Model	10 year old child (1.2 m height, 35 kg, male)	102 CT scans	0.946 mm x 2.269 mm x 1.601 mm (3.43 mm^3)	10	60%		permittivity & conductivity of 10 year old
Wiart *et al.*, 2008 [52]		Child's Head, 5 to 8 years old	MRI scans			100% (2x)		Antenna closer to skin and bone layers are thinner; penetration of radiation is twice as deep in child
Kuster *et al.*, 2009 [53]		Child				>100% CNS tissues		SAR of CNS of children ~twice that for adults

* NORMAN=NORmalized Man
** Scaled models of 5- and 10-year old children derived from the Utah Model using external dimensions typical of children from Geigy Scientific Tables (C. Lentner-Geigy Scientific Tables, Vol. 3, CIBA-Geigy, Basil, Switzerland, 1984).

anatomic differences between adults and children, including conductivity, density and dielectric constants. Gandhi and Kang reported that models with a head that was only about 10% smaller in size could have more than 50% greater SAR with two different antenna lengths, with proportionally deeper penetration of SAR[42]. This work also showed that incorporating a plastic ear model or pinna with a 10 mm spacer gave artificially lowered SAR-values, which are up to two or more times smaller than for realistic anatomic models, as a result of the larger distance to the absorptive tissues. The higher dielectric constant and conductivities likely for younger subjects will result in still higher SAR (up to 80% more) for children.

The peak 1-g body tissue SAR for the smaller head sizes calculated using the widely accepted Finite-Difference Time-Domain (FDTD) computational EMFs method can be up to 56% higher at 1900 MHz and up to 20% higher at 835 MHz compared to the larger models. For brain tissue, the proportionality was even higher where the peak 1-g SAR for the smaller model was up to 220% higher at 1900 MHz and up to 144% higher at 835 MHz of the SARs of the larger models. Similar to the results reported in the earlier 1996 paper for head models of adult and children, these latter results confirmed that there is a deeper penetration of absorbed energy for the smaller head models e.g. the children compared to that for the larger head models representative of adults.

In 2004, a IEEE Standards Coordinating Committee introduced a standard anthropomorphic mannequin (SAM) Model, with a 6-10 mm thick plastic spacer instead of "pinna" for determination of SAR of mobile phones for compliance testing against IEEE and ICNIRP Safety Guidelines (IEEE, 2003). That same year, Gandhi and Kang demonstrated that the "SAM model" with plastic spacer used for compliance testing (preferred by industry) gives SARs that grossly underestimate exposures[50]. In two different published studies, the use of plastic spacers results in an underestimation of the SAR by up to 15% for every additional millimeter of thickness of such spacers[48, 50]. Thus, the SAR obtained for SAM is up to two or more times smaller than for the anatomic models of the adult head. When other developmental variables are taken into account, this underestimation is even higher for exposure to the smaller heads of the children.

A modified SAM model with a lossy pinna similar to living tissue for which 1- and 10-g SARs are relatively close to those for anatomic models, could remedy this systematic underestimation of exposure of the children by using a fluid of higher conductivity than that currently used for compliance testing[42]. Without this correction, current IEEE limits[56] effectively allow RF that may be 8-16 times higher[50] than those permitted by previous IEEE guidelines[56, 57]. This is also due to increasing the SAR limit in the pinna from 1.6 W/kg for any 1-g of tissue to 4.0 W/kg for a larger 10-g of tissue that was originally suggested to apply only to the extremity tissues for the arms and the legs[57, 58].

In fact, multiple studies have reported that the brains of young children absorb more radiation compared to those of adults[43, 47-49, 51-53]. As the brains of children lack neural integration and are not fully myelinated until the twenties, the impact of such greater absorption may be considerable. In addition, this differential absorption of the brain may well render children more vulnerable to the development of both benign and malignant brain tumors, a point indicated in the review of this subject by the National Research Council[59]. Studies by Wiart for French Telecom published last year[52] and other work by Kuster[60] confirmed that a given signal is absorbed about twice as deeply into the bone marrow of the head and cortex of a child in contrast with that of an adult, even though systemic absorption may not differ substantially. A series of papers by De Salles also offers important modeling information regarding the increased vulnerability of a child's

Table 3 - Summary of the results confirming that children absorb more radiated electromagnetic energy of the cell phones resulting in higher specific absorption rate (SAR) as compared to adults

Author, Year	Highlights of results
Gandhi *et al.*, 1996[47]	Deeper penetration of absorbed energy for models of 10- and 5-year old children; peak 1-g SAR for children up to 53% higher than adults.
Gandhi and Kang, 2002[42]	Deeper penetration of absorbed energy for smaller heads typical of women and children; peak 1-g SAR for smaller heads up to 56% higher than for larger heads.
Wang and Fujiwara, 2003[49]	Compared to peak local SAR in the adult head, we found "a considerable increase in the children's heads" when we fixed the output power of radiation.
Martinez-Burdalo *et al.*, 2004[51]	As head size decreases, the percentage of energy absorbed in the brain increases; so higher SAR in children's brains can be expected.
DeSalles *et al.*, 2006[43]	The 1-g SAR for children is about 60% higher than for the adults.
Wiart *et al.*, 2008[52]	1-g SAR of brain tissues of children is about two times higher than adults.
Kuster *et al.*, 2009[53]	Spatial peak SAR of the CNS of children is " significantly larger (~2x) because the RF source is closer and skin and bone layers are thinner"; " bone marrow exposure strongly varies with age and is significantly larger for children(~10x)"

head[43]. Based on CT images of a 10 year old boy, these models confirm the greater absorption of the child and add further support regarding the need to eliminate the plastic spacer at the ear or pinna in estimating exposures to children. A summary of the results confirming that children (and smaller heads typical of women) absorb more radiated energy of cell phones resulting in higher SAR is given in Table 3.

Implications of modeling limitations for current standards

Both the IEEE and ICNIRP guidelines are based only on short-term EMFs exposure and long-term EMFs exposures are not considered. Please refer to page 496[2]:

"Induction of cancer from long-term EMFs exposure was not considered to be established, and so these guidelines are based on short-term, immediate health effects such as stimulation of peripheral nerves and muscles, shocks and burns caused by touching conducting objects, and elevated tissue temperatures resulting from absorption of energy during exposure to EMFs. In the case of potential long-term effects of exposure, such as an increased risk of cancer, ICNIRP concluded that available data are insufficient to provide a basis for setting exposure restrictions, although epidemiological research has provided suggestive, but unconvincing, evidence of an association between possible carcinogenic effects and exposure at levels of 50/60 Hz magnetic flux densities substantially lower than those recommended in these guidelines".

The increase in the SAR in the whole head, between the adult and the child, is expected due to the reduced dimensions in the child head, as well as the higher values of the permittivity and of the electrical conductivity of the child brain tissues. Also, children's skulls are thinner than those of adults, and therefore less resistant to radiation.

Another concern is that only thermal effects of RF are considered when estimating the SAR. However, since most mobile communication systems now are pulse-like in nature, modulated at low frequencies, such as in 2G and 3G (e.g., the GSM, UMTS, CDMA, TDMA systems), they are able to induce pulses of currents in the brain tissues and this can result in some low level non-thermal effects, e.g., BBB alterations, single and double strand DNA breaks, chromosomal aberrations, etc., at RF energy levels substantially below the thermal threshold. Several papers and reports have already shown adverse health effects at exposure levels well below the thermal limits[4, 6, 12, 13, 61]. Further epidemiological studies have shown a many-fold increase in risk for malignant brain tumors, with a larger than 10 years latency period for long-term mobile phone and cordless phone users[23]. As a substantial percentage of the population now uses mobile phones for a long time during each day and for several years, operating the antenna very close to their head, then this exposure can not be classified as short term and effectively may represent a serious risk for their health.

Future research needs

There is a need for exposure assessment of juveniles, children, pregnant women and fetuses from personal wireless devices (the wireless devices considered here are the cell phones, wireless PCs and text messaging devices), waist and pocket-mounted devices since mostly adult male models have been considered to date. These studies will focus on development and exposure quantification of anatomic models of several heights and weights of men, women and children of various ages as well as pregnant women and fetuses.

There is an urgent need for characterization of microwave radiated fields from the currently used multi-frequency, multi-element base station antennas; identification of exposed individuals and their locations e.g. school children, building maintenance personnel, etc. There is a paucity of data in regard to radiated electromagnetic fields and the daily variation in time for the newer 4-6 element or more collocated base station antennas and the exposures these antennas entail for the school children and the civilian population living close to such antennas.

An updated survey is needed of the civilian exposure to microwave electromagnetic fields strengths in the U.S. due to the rapidly expanding wireless infrastructure in the last 10-15 years. The last survey involving selected 15 metropolitan areas and mostly focused on VHF and UHF TV stations was reported back in 1980.[62] This data is totally out of date at the present time.

An expert (non-industry dominated) evaluation of the current IEEE and ICNIRP RF/microwave safety standards in the light of more recent biological experiments is also critical. All of the current safety standards are based on extrapolation from acute short-term exposures and do not account for the modulated signals used in cell phones and other personal wireless devices.

Discussion

The summary of modeling research presented here indicates three major shortcomings of the current IEEE and ICNIRP approaches: 1) the assumption that only thermal effects can occur is not valid. There is growing evidence from in vitro and in vivo studies indicating that RF exposures at levels not known to induce thermal effects commonly encountered today have a range of biological effects, affecting production of free radicals, permeability of the BBB, expression of in heat shock proteins, and direct damage to DNA, as indicated by the comet assay and a variety of in vitro measures of genotoxicity; 2) properties of the head models currently used fail to take into account differences in dielectric constant and conductivity and improper modeling of the pediatric brain, as well as developmental differences such as myelination between the young and older brains; 3) the assumptions as to typical use patterns used in setting these standards, with a six minute average call time, do not reflect current patterns, according to reports from the cell phone industry, where monthly use can easily top 2000 minutes with many calls well in excess of 6 minutes.

Excepting the occasional advertisement, there is no publicly accessible, independently confirmable, information on the details of rapidly expanding markets and uses of cell phones, which makes the development of standards especially challenging. Cell phones are used by many people for much of their waking hours, having replaced traditional phones, alarm clocks, newspapers, radios, global positioning devices, videocameras and televisions.

Regarding young children, we do not know the typical practice of the young at this point, because those behaviors are changing rapidly. However, we do know school districts are being urged to adopt cell phones for all middle school students as learning tools. This may well be an excellent idea for the purposes of learning, providing that phones are not used and held directly to the developing brain. Whether the use of cell phones as phones proves a potential hazard to the long-term health of the pediatric brain is an issue that merits serious attention. Radiation compliance standards for operation of cell phones are based exclusively on adult male models of the head. Emerging research indicates that long-term heavy users of cell phones face a doubled risk of several forms of brain tumors and risks may well be greater for those who begin regularly using phones before age 20. In light of these facts, the European Environment Agency and several other national advisory groups have adopted a precautionary approach to keep cell phone exposure to a minimum through use of ear-pieces and speaker phones, wired headsets, and to urge that children generally not use cell phones.

To enhance the ability to protect public health and foster better design of this widely used technology, we advise a three-pronged approach: major studies should be undertaken to construct and validate gender and age-appropriate head models further. More research is needed to identify and evaluate the mechanisms through which non- or thermal effects of RF arise and to determine more definitively the extent of health risks from long term use of cell phones, particularly by children. While that work is proceeding, precautionary policies should be advanced to limit potential harm to the developing brain. This should include consideration of directional antennas designed to send signals away from the head since the tissues absorb almost all of the energy radiated in the direction of the head anyway. Responsible public health authorities around the world should disseminate warnings for cell phone users such as those advocated recently in France, Finland and Israel. This involves advising children and their parents along with the young to make only short and essential calls, to use text messaging when possible, to use always hands free kits and wired headsets, and maintain the antenna far away from their body during the calls. Given the prevalence of this revolutionary technology, some evidence of its chronic toxicity, and the lack of solid information regarding its potential hazards to humans, it is important that major independent, multi-disciplinary research programs be carried out to study and monitor the long-term impact of RF exposures.

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Investigation on blood-brain barrier permeability and collagen synthesis under radiofrequency radiation exposure and SAR simulations of adult and child head

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Abstract

The effects of Radiofrequency Radiation (RFR) in the frequencies of mobile phones (835, 900, 1800 MHz) on the permeability of blood-brain barrier and hydroxyproline formation along with the modeling studies performed at the Gazi Biophysics Laboratory are reviewed in this paper. The close proximity of a mobile phone to a user's head leads to absorption of part of the mobile phone emitted energy by the head and the brain of the phone user. Permeability of the blood-brain barrier (BBB) of female and male rat brain tissues was examined under 900 MHz and 1800 MHz continuous-wave radiofrequency radiation (CW-RFR) exposure. Increase in BBB permeability was found to be statistically significant in all male rats exposed, whereas no significant difference was observed in female rats. Investigations of the mobile phone radiation effects on biomolecules were also carried out with guinea pigs. Alterations in protein synthesis were quantified by measuring hydroxyproline level in exposed and non-exposed liver tissues by using three different biochemical methods. There was no significant difference on hepatic hydroxyproline levels of RFR exposed guinea pig. In a simulation study, the effects of 835 MHz and 900 MHz RFR exposures on human head while using cellular phone (CP) were investigated. The effects of CP usage on specific absorption rate (SAR) were calculated by SEMCAD X software which uses FDTD method in details. Some parameters as the different head dimensions and dielectric properties of the head (adult and child), positions of the mobile phone (cheek and tilt), and rectangular metal frame spectacles as a widely used metallic accessory were considered. With this aim, dose values in the tissue for 10 g peak spatial-average SAR value were calculated. At both of the frequencies of 835 MHz and 900 MHz, higher SAR values were obtained in the cheek positions than the tilt positions for conditions of with or without metal frame spectacles.

Key words: **Radio Frequency Radiation (RFR), Blood-Brain Barrier (BBB), Collagen Synthesis (CS), Specific Absorption Rate (SAR), FDTD**

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Introduction

During recent years, mobile communication systems have experienced wide and rapidly growing use all over the world. Many studies have investigated whether mobile phone use and radiofrequency (RF) fields in general could have biological effects. The close proximity of the antenna of a mobile phone to the human body and especially the head has raised concerns about the biological interactions of electromagnetic radiation (EMR). Conflicting results were reported on whether low levels of radiofrequency fields increase the permeability of the barrier that keeps harmful substances from entering the brain (blood-brain barrier). In 2008, there was a review on the blood-brain barrier (BBB) which includes a complex picture indicating that some studies showed effects on the blood-brain barrier, whereas others did not. Possible mechanisms for the interactions between electromagnetic fields and living organisms were also discussed in that paper[1]. One of the important aims of the present study was to investigate the effects of 900 MHz and 1800 MHz continuous wave (CW) RFR on the permeability of BBB of young adult male and female rats.

Effects of static and ELF electric and magnetic fields on collagen have been studied at the Gazi Biophysics Department and hydroxyproline levels of skin, liver, kidney and lung tissues were found to change after exposure to these fields[2-8]. There is very limited number of studies on the effect of RFR at mobile phone range on the tissue level of collagen[9-10]. In this paper, we report our investigation on the effects of mobile phone radiation on collagen synthesis. Collagen was examined by using three different hydroxyproline detection methods such that we could repeat and cross-check our biochemical work and results by these three methods [11].

Dosimetry is an important issue on monitoring the biological effects of RFR exposure[12]. In a Specific Absorption Rate (SAR) simulation study, the aim was to investigate how SAR changes with various anatomical human head models[13, 14]. Generic Mobile Phone model which is accepted by the Mobile Manufacturers Forum (MMF) were used in this study[15]. Frequencies were selected as 835 MHz and 900 MHz to compare the dose rates of cellular phones (CP) which have been used in the United States and Europe, respectively. Dielectric properties and sizes of phantoms studied were according to the standards of IEEE 1528-2003 and IEC 62209-1 for adult SAM phantom. Children are more affected by RFR with respect to adults[16-18] because of the dimensions and the dielectric properties of their head. Furthermore, SAR simulations of children head models were done for the same frequencies by applying the data from the studies of Peyman and Gabriel's according to the standards of IEEE 1528-2003 and IEC 62209-1 2005[19,20].

Materials and methods

Blood brain barrier study

Twenty five male (268.13 ± 41.92 g) and twenty seven female (216.85 ± 24.72 g) young adult Wistar albino rats were used in the study. Four exposure and two control groups were used in the experiment: Group I (n=8)- control males, Group II (n=9)- control females, Group III (n=8)- 900 MHz exposed males, Group IV (n=9)- 900 MHz exposed females, Group V (n=9)- 1800 MHz exposed males, Group VI (n=9)-1800 MHz exposed females. Animals in the control groups were sham-exposed. The animals were anesthetized with ketamine (45 mg/kg) and xylazine (5 mg/kg) by intramuscular injection prior to the experiments[21].

Exposed groups were kept at 10 cm away from a horn antenna to satisfy the near field condition. Control (sham) groups were kept in the same setting without any RFR exposure. Synthesized signal generator was used for propagating the RF signal. Field strengths were monitored with a Narda EMR 300 and its appropriate probe (8.3) during the exposures. Background E-field level to which controls were exposed, was measured to be 0.265 ± 0.02 V/m. E-field levels at 900 MHz and 1800 MHz were 13.51 ± 0.41 V/m and 12.62 ± 0.22 V/m, respectively[22, 23]. RFR or sham exposure duration was 20 minutes for all animals. The experiments were performed with the anesthetized rats in a quiet laboratory with little noise to limit stress. ICNIRP general public E-field limits for these frequencies are 41.25 V/m and 58.34 V/m[24]. Since the E-field levels in this study are well below currently accepted limits, the exposure level used in this study can be considered non-thermal.

We investigated permeability of BBB using Evans Blue (EB) dye as a tracer which is known to bind to serum albumin after intravenous injection. Quantative method was used for measuring the amount of dye in the brain[25, 26]. EB dye (2% in saline, 4 ml/kg) was injected into the tail vein of a rat and was allowed to circulate for 20 min. An animal was then exposed to RFR or sham fields for 20 min period. At the end of each exposure, its chest was opened under anesthesia. Brains were perfused with saline through the left ventricle for approximately 15 min until fluid exiting from the right atrium became colorless. Brain was then removed and dissected into four regions: left and right cerebrum, left and right cerebellum. Each brain region was weighted for quantative estimation of EB dye - albumin extravasations. The samples were then homogenized in 2.5 ml phosphate buffered saline-PBS and mixed with a vortex after the addition of 2.5 ml of 60% trichloroacetic acid to precipitate the protein molecules, then centrifuged for 30 min in 3000 rpm (at 1000xg). The supernatant was measured at 620 nm for absorbance of EB dye using a spectrophotometer. The concentration of EB per gram of brain was determined from the absorption measurements using a standard curve. E-field levels and EB contents are presented as the mean ± SD for each group. Mann-Whitney U-Test was used to assess significance and $p<0.01$ was considered statistically significant.

Radio frequency radiation effect on collagen

In this investigation, 30 three-month-old male Guinea pigs (250-300 g) were used. They were divided into three groups: sham exposed, 10 minutes mobile phone-exposed, and 20 minutes mobile phone-exposed. Animals that had their own private cage were placed inside the cage just at the beginning of the experiment in order to reduce stress. Cages, made of transparent plastic with the dimensions of 8 cm x 10 cm x 18 cm, have efficient holes for ventilation. RF source was a Nokia 3210 mobile phone with 0.81 W/kg digital SAR value was positioned on the cage where the antenna of the mobile phone is maximum 5 cm above the head of the guinea pig. While mobile phone is at off mode for the sham exposure condition, it was in talking position during the exposure conditions. Measurements were taken instantaneously during the experiment by NARDA EMR 300 and a type 8.3 probe and the data saved to the computer connected to device via fiber optic cable. Guinea pigs were exposed to RFR averaged as 11.2 ± 0.5 V/m for 10 minutes[27] and 20 minutes a day during 7 days and analyzed for the effects on liver tissue hydroxyproline level.

After the last day of mobile phone exposure, liver tissues were removed from animals after decapitation. They were immediately frozen in liquid nitrogen and stored at -80ºC until analysis. Changes of hydroxyproline level were analyzed biochemically by three different hydroxyproline determination methods: "H. Stegemann-K. Stalder"[28-31], "I.S. Jamall-V.N. Finell"[32] and "ISO 3496"[33].

Principle of the first method, named "H. Stegemann-K. Stalder", is to get the hydroxyproline of the hydrolysis of the tissue sample after homogenization and measuring the optical density of the color formed by adding p-dimethylaminobenzaldehyde, perchloric acid and propan-2-ol at pH 8 and at λ (wavelength) = 560 nm.

The "I.S. Jamall-V.N. Finell" method is based on oxidation of hydroxyproline after the hydrolysis of the tissue sample by kloramin-T and formation of chomofor composites via the reaction with Ehrlich reactive including p-dimethylaminobenzaldehyde and perchloric acid. Optical density of the solution at pH 6 was measured with respect to water at λ =560 nm.

The third one known as "ISO 3496" is to get the hydroxyproline of the hydrolysis of the sample after homogenization and measuring the optical density of the color formed by adding sulphuric acid at pH 6.6 at λ = 558 nm.

For each method, hydroxyproline contents of the tissue samples were determined using standard curves for samples containing known concentrations of hydroxyproline (Sigma H-1637). Two samples were taken from each homogenized tissue, and the concentrations measured by spectrometry were averaged. For each group, hydroxyproline contents of tissues from groups exposed to RF radiation and their controls were compared with ANOVA, Welch ANOVA tests.

SAR simulations of adult and child head

SAR levels resulted from CP exposures were determined by the SEMCAD-X software. SAM phantom and generic CP model were used to assess peak SAR values averaged over 10 g of tissue. The effects of some parameters such as metallic accessories like spectacles, different positioning of CP, different head dimensions and different dielectric properties on SAR were determined at 835 MHz and 900 MHz frequencies[13, 14]. Selected general cell phone model which is approved by the Mobile Manufacturers Forum has three parts: a monopole antenna, a plastic chassis and a printed circuit board made by perfect electric conducting material inside this plastic chassis. SAR values were obtained by normalizing antenna input power to 1 Watt. It was assumed that phone model sizes are 102 mm x 42 mm x 21 mm (height x width x thickness) and it consists of a hard plastic chassis. Antenna was mounted on the top part of the chassis at the center. Antenna height was modeled as 20% shorter than quarter wave (λ/4) height to obtain reasonable input impedance near different head models [15,34].

Adult head phantom's circumference was scaled with 0.9 factors in order to obtain a child phantom for a 7-year-old child [35]. Dielectric properties of SAM phantom for adult and child are given in Table 1[19, 20, 36, 37].

In the study, a spectacles frame was modeled presuming that it was 37 mm width and 63 mm height and made of Perfect Electric Conducting metal. The length of spectacles' arm is 140 mm and Perspex lens was selected.

Table 1 - Dielectric properties of adult and child SAM phantoms

Frequency	Adult*		Child**	
	ε_r	σ (S/m)	ε_r 109,85 %	σ (S/m) 116 %
835 MHz	41,5	0,90	45,59	1,0440
900 MHz	41,5	0,97	45,59	1,1252

* Dielectric properties of adult SAM phantom taken from IEEE 1528 and IEC 62209–1
** Dielectric properties of child SAM phantom which was extrapolated from IEEE 1528 and IEC 62209-1 by using Gabriel and Peyman studies [19-20]

Results

Blood brain barrier study

In the study, we investigated the effects of exposure to continuous-wave (CW) RFR at 900 MHz and 1800 MHz for 20 min on the permeability of BBB of rats. Male and female rats (Groups III and IV, respectively) were exposed to 900 MHz at an electric (E) field of 13.51 ± 0.41 V/m and rats in 1800 MHz groups (Groups V and VI) were exposed to an E field of 12.62 ± 0.22 V/m**.** In all exposed and sham-exposed groups, albumin extravasations occurred largely from leptomeningeal blood vessels which, together with those in the choroid plexus and circumventricular organs, have no recognizable blood-brain barrier.

In the male groups Evans Blue dye content in the whole brain was found to be 0.072 ± 0.01 mg % in the controls, 0.1325 ± 0.02 mg % in 900-MHz exposed group and 0.1123 ± 0.02 mg % in the 1800-MHz exposed group (fig. 1). Difference between the exposed groups and controls was found to be significant (p<0.01). No statistically significant difference was found between the two RFR-exposed groups.

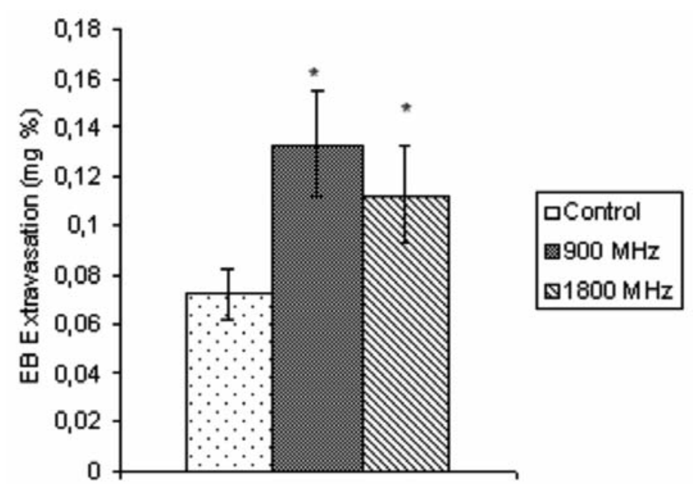

Fig. 1. Brain EB content of male rats. Data is shown as mean ± standard deviation of the mean (SD)

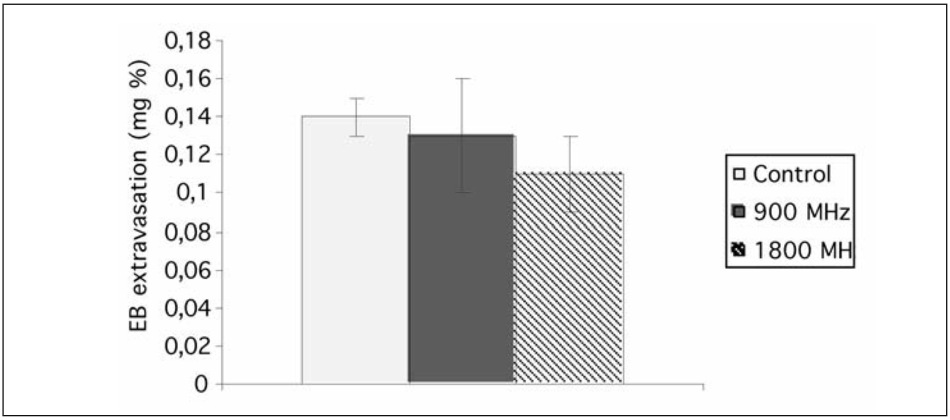

Fig. 2. Brain EB content of female rats

In the female groups, dye content in the whole brain was found to be 0.14 ± 0.01 mg % in controls, 0.13 ± 0.03 mg % in the 900-MHz exposed and 0.11 ± 0.02 mg % in the 1800-MHz exposed groups (fig. 2). No statistically significant difference was found between two RFR-exposed groups ($p>0.01$). There was also no statistically significant difference between the exposed females and the controls ($p>0.01$).

Our results showed that a 20-min exposure to 900-MHz and 1800-MHz RFR induced an increase in permeability of BBB of young adult male rats. However, similar exposure to RFR did not induce an effect on the permeability of BBB in young adult female rats.

Radiofrequency radiation effect on collagen

Results are shown in Table 2 and fig. 3. The outcome of the biochemical analysis indicated that hydroxyproline level increased with respect to control but this increase was not statistically significant for all three methods of analysis ($p>0.05$). The results showed no significant effect of RFR exposure on liver hydroxyproline in the guinea pig. However, difference in hydroxyproline determination accuracy of ISO 3496 method with respect to the other two methods was found to be statistically significant ($p<0.05$) (Table 2 - fig. 4).

Table 2 - Comparison of liver tissue hydroxyproline levels (µg/g tissue) in groups exposed to RFR for 10 and 20 minutes with controls measured by three different methods. The values in the table represent the least squares means ± standard deviation (mean ± Sd)

	H. Stegemann-K. Stalder	I.S. Jamall-V.N. Finell	ISO 3496
Sham exposed group	0.2716 ± 0.0289	0.2897±0.0622	0.3054 ± 0.0125
10 min. Exposure group	0.2773 ± 0.0251	0.2907±0.0185	0.3058 ± 0.0186
20 min. Exposure group	0.2794±0.0282	0.2907±0.0240	0.3075±0.0124

SAR simulations of adult and child head

Variations of 10-g averaged SAR values for 835- and 900-MHz exposure in SAM phantom for adult and child with or without metal frame spectacles, for cheek and tilt positions of CP are given in fig. 5[13, 14].

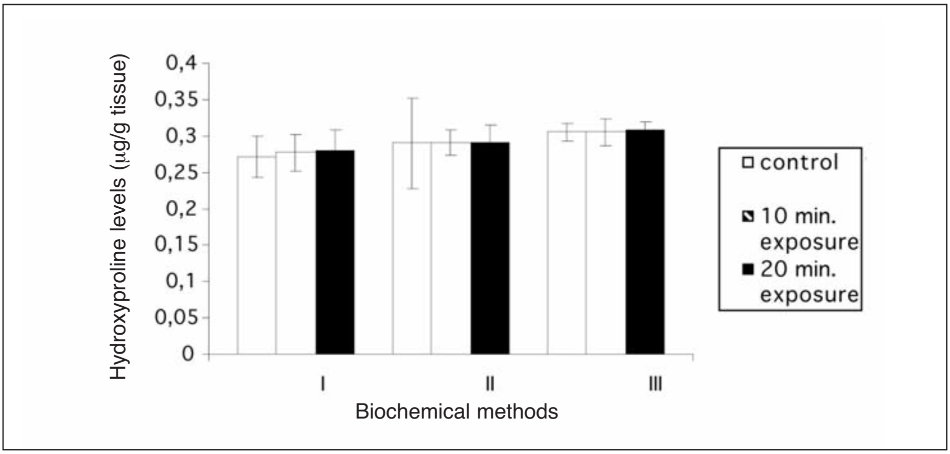

Fig. 3. Liver tissue hydroxyproline level determined by using three different biochemical methods. I: H. Stegemann-K. Stalder's method, II: I.S. Jamall-V.N. Finell's method and III: Method of ISO 3496

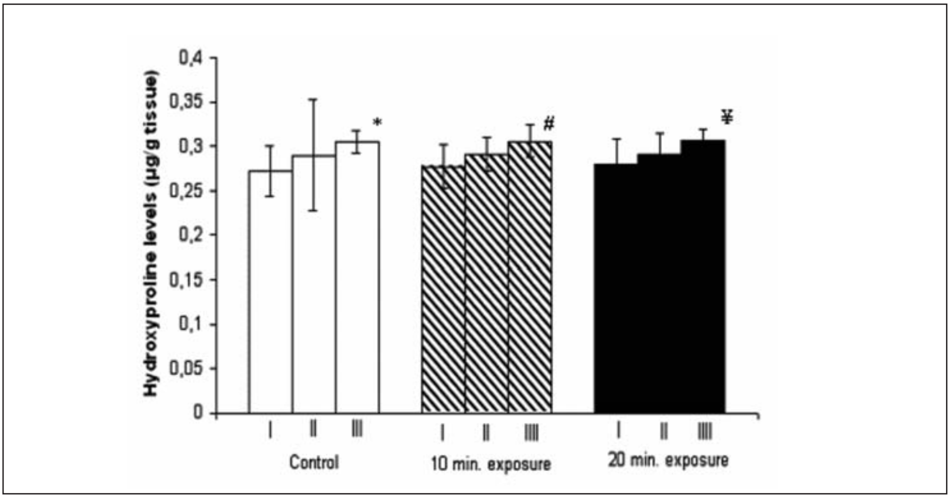

Fig. 4. Liver tissue hydroxyproline level determined by using three different biochemical methods for controls and exposure groups. I: H. Stegemann-K. Stalder's method, II: I.S. Jamall-V.N. Finell's method and III: Method of ISO 3496. *: p< 0.05 as compared to the hydroxyproline levels of controls determining by methods of I and II; #: p< 0.05 as compared to the hydroxyproline levels of 10 min. exposure determining by methods of I and II; ¥ : p< 0.05 as compared to the hydroxyproline levels of 20 min. exposure determining by methods of I and II

It was found that usage positions of CP were the most significant parameter affecting SAR values. The obtained 10-g SAR values from the cheek positions were significantly more those that of tilt positions. Higher SAR values were determined on cheek position at both frequencies.

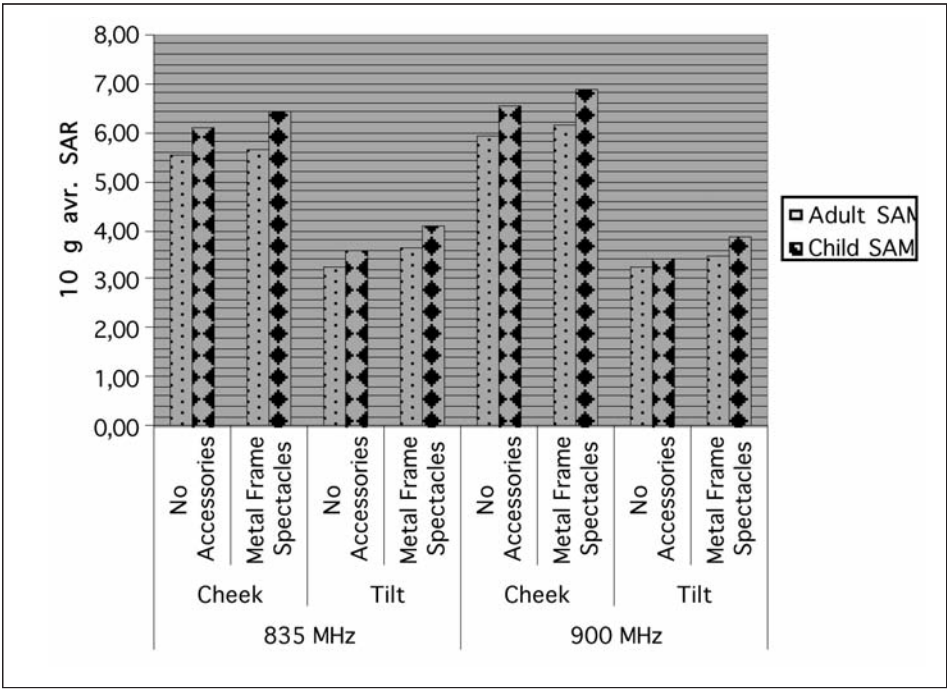

Fig. 5. Variations of peak SAR values for 835-MHz and 900-MHz RFR absorption in SAM phantoms for adult and child with or without metal frame spectacles, for cheek and tilt positions of CP

With the SAM phantom modeled for the child's dielectric characteristics and head size, increased SAR values were determined compared to adults. The reason why this increase occurred may be the change in head sizes, but the main reason is the difference in dielectric characteristics between the child and the adult. In the condition of usage of metal frame spectacles, higher SAR values were determined both at the cheek and tilt positions at both 835 MHz and 900 MHz compared to having no spectacles. It was also observed that local SAR values were higher at the head model near to the spectacles. It might be resulted from the currents induced at the metal frame of the spectacles.

Discussion

Blood brain barrier study

Our results indicate that RFR at non-thermal levels can induce disruption of the BBB. Disturbances to the integrity of BBB and external influences on its functions are critical to central nervous function and could influence and accelerate neurodegenerative processes. One of the possible mechanisms for tumor development is increase in the permeability of BBB, which may result in the entry of carcinogenic substances into the brain.

Our results suggest that 20 minutes of acute exposure of young adult male rats to CW RFR cause disruption to BBB integrity, whereas no significant change was found for the female rats. Gender differences have been reported for many structures and functions of central nervous system[38]. Lin *et al.*[39] argued that EB dye in the rat brains is closely related to intense RFR hyperthermia. Wijsman and Shivers[40] demonstrated that BBB permeability to Horse Radish Peroxidase (HRP) was increased in response to heat stress. We present here evidence for BBB disruption caused by non-thermal RFR exposure. Our observation finds support in the work of Salford *et al.*[41] which showed the short-term exposure effects of CW RFR on the BBB at non-thermal levels. It is unlikely that this increase of permeability in male exposed groups could be due to immobilization stress[42], since animals were exposed to 900-MHz and 1800-MHz RFR under anesthesia. Prato *et al.*[43] shown a temporarily increase in BBB permeability to HRP under MRI procedure. Fritze *et al.*[44] investigated the effects of 900-MHz RFR exposure on the permeability of BBB for duration of 4 h at SAR ranging from 0.3, 1.5 and 7.5 W/kg. The increase in serum albumin extravasations after RFR exposure reached significance only in the group exposed to the highest SAR of 7.5 W/kg. Gruenau *et al.*[45] evaluated the effects of CW or pulsed RFR at a frequency of 2.8 GHz on the permeability of BBB of unanesthetized rats and the findings indicated that RFR radiation under the given experimental conditions did not damage BBB.

Possible mechanisms of disruption of BBB by RFR are still under discussion. Some authors suggest pinocytotic transport across the endothelial cells[46]. Neubauer *et al.*[47] described that permeability increase of BBB to rhodamine-ferritin at whole body averaged SAR of 2 W/kg was almost blocked when rats were pretreated with colchicine. These results also suggest that pinocytotic mechanisms may be involved. Some authors argued that an increase of heat shock proteins (HSP) results in oxidative stress and this stress gives rise to brain tumors or the increase in the permeability of BBB[48, 49]. RFR exposure might produce an increase in HSP level. Researchers are also discussing the link between RFR exposure and the changes of BBB permeability and headaches and the dopamine opiate systems of brain[50]. An alternative explanation could be an opening of tight junctions or an increase of ornithine decarboxylase (ODC) activity which correlates with BBB disturbances[51].

We conclude that our data support the hypothesis that 900-MHz and 1800-MHz CW RFR at non-thermal RFR levels is related to an increase in the permeability of BBB in young adult male rats.

Radio frequency radiation effect on collagen

Since 1960, collagen draws the scientists' interests because it has piezoelectric characteristics and could be affected by external and/or internal natural electromagnetic fields because of its electrical charge. There are researches that focused on effects of electromagnetic radiation on collagen in several tissues but most are related with electric current, static, and ELF electromagnetic fields[2-8, 52-61]. In addition to these studies, some studies also investigated RFR effect on collagen. For instance, Masuda *et al.*[9] studied on hairless female rats exposed or sham-exposed for 2 h to GSM 900 or GSM 1800 signals, using a loop-antenna located on the right part of the rats' back. The local Specific Absorption Rate (SAR) at skin level was approximately 5 W/kg. Results on filaggrin, collagen and elastin levels showed an insignificant influence of RFR. Ozguner *et al.*[10] investigated the effects of 900-MHz RFR on the induction of histopathologic changes in skin and they found increased thickness of stratum corneum, atrophy of epidermis, papillamatosis, basal cell proliferation, increased granular cell layer (hyper-

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granulosis) in epidermis and capillary proliferation, impairment in collagen tissue distribution and separation of collagen bundles in dermis.

In the present study, effects of RFR generated by GSM 1800 mobile phones on liver tissue collagen were examined by using three different hydroxyproline detection methods. The outcome of the biochemical analysis pointed out that RFR did not significantly affect hydroxyproline level.

Since this is a pioneer study on the effect of mobile phone radiation on hydroxyproline level, using three different methods was needed to ensure validity. In addition to this, collagen composed of the amino acids: glycine (33.5 %), proline (12%) and hydroxyproline (10%), so especially liver hydroxyproline level determination is a difficult procedure because of low level of tissue collagen (4%). In the light of our evidences, hydroxyproline levels obtained by using ISO 3496 method is statistically more significant than the other two methods ($p<0.05$). In this study, "H. Stegemann-K. Stalder", "I.S. Jamall-V.N. Finell" and "ISO 3496" were chosen as biochemical methods of liver tissue hydroxyproline level determination after literature search. In each of these three methods, tissue hydrolysis of hydroxyproline was measured by spectrometry after adding Chloramin-T reactive which stains the solution. "ISO 3496" is a method which is nowadays used for determining the absolute value of hydroxyproline in the meat and meat product industry which should be very little collagen content in order to be fine product.

Even though our findings of hydroxyproline levels in liver tissue of RFR-exposed guinea pigs were statistically insignificant with respect to controls. A question to be asked is what would be the consequence of longer duration or prolonged exposure. It would be interesting to study prolonged exposure in further research.

SAR simulations of adult and child head

There is a rapid increase in the usage of wireless communication. While the working frequency of the cellular phone increases, the value of the SAR increases[15]. In this study, SAR values resulted by CP operating in 835-MHz and 900-MHz frequency bands were calculated in human head models for both adult and child. Moreover, the feature of this study gives a chance to compare the SAR levels resulted by the frequencies of 835 MHz and 900 MHz which are the CP operating frequencies of Europe and USA.

CPs were positioned near the head models in two positions according to IEEE 1528-2003, IEC 62209-1 2005 standards. In the first condition, CP was located near the cheek, and at the second one, CP was in tilt position. Consequently, SAR level was found to be less in the tilt position than the condition that CP was near the cheek. Our results are consistent with the results of other studies in the literature[15]. SAR level in the tilt position of CP was 40% less than the cheek position of CP for 835 MHz. Furthermore, this decrease was 55% for 10 g SAR value for 900 MHz frequency. This may be caused by the location of the current density in phone chassis being closer to the head phantom in the cheek position of CP.

Children of the growing age are more vulnerable to influence of environmental factors. Because of the size of children's head and their dielectric properties, their RF radiation dose rates caused by CP usage are higher than adults. For this reason, scaled head models are usually used for children head simulation. Gandhi et al[18] studied with scaled head models for the 5-year-old and the 10-year-old children for simulating the effect of CP with $\lambda/4$ monopole antenna operating both at 835-MHz and 1900-MHz frequency bands. They reported that 1 g peak spatial average SAR at 835 MHz frequency was 50% increased in the scaled model of the 5-year-old child head[18].

De Salles *et al.* found that 1 g peak spatial average SAR increased by 60% in the scaled model of 10-year-old child head exposed to CP with patch antenna and $\lambda/4$ monopole antenna at the operation frequencies of 835 MHz and 1850 MHz[62].

In this study, a significant increase was found in the child SAM phantom, modeled according to the dielectric properties of the children with respect to the adult model. 10 g peak spatial average SAR increases for 835 MHz and 900 MHz were calculated as 10% in the cheek position. It was determined that increasing ratios were 10% for 835 MHz and 6% for 900 MHz in the tilt position of CP.

It should be considered that children will be affected from CP more than adults and they should have precaution in using this technology.

According to the SAR calculated in this study, it is observed that the positioning of CP is the most effective parameter affecting SAR level. The spectacles, one of the most widely used accessories in daily life may be one of the important parameters that affect SAR values. Furthermore, sensitive organs like the eye can be exposed to high SAR because of the induced current at the spectacles. The rectangular metal frame spectacles used in this modeling study have a perfect electrical conductivity. Simulation revealed that metal frame spectacles increased the spatial peak SAR for 835-MHz and 900-MHz frequencies as 2-3% in cheek position, but this increase was 7-11.5% in CP's tilt position. In addition to this, it was observed that local SAR levels in the head model near spectacles were high.

SAR calculations for the studies of BBB and collagen synthesis is planned to be evaluated in our further study.

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Effects of microwave radiation upon the mammalian blood-brain barrier

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Abstract

Our research group has studied the effects of electromagnetic fields (EMF) upon the mammalian brain (rats) since 1988. Our major field of interest during the period has been the effects upon the blood-brain barrier (BBB) of the rat. The mammalian brain is protected by the BBB from potentially harmful compounds circulating in the blood. In the normal brain, the passage of compounds over the BBB is highly restricted. Our studies have revealed that the EMF radiation of the kind emitted by mobile phones leads to increased permeability of the BBB both immediately after 2 hours of exposure, but also after 7 days, 14 days and 50 days, all at non-thermal exposure levels. Also, damaging effects from radiofrequency EMF upon neurons has been shown after 28 days and 50 days. Of what is known today, the human BBB is very similar to the rodent BBB. With our research into the field, and comparison to other studies of BBB permeability in connection to EMF exposure, it is our sincere belief, that it is more probable than unlikely, that non-thermal EMF from mobile phones and base stations do have effects upon the human brain.

Key words: **blood-brain barrier, dark neurons, electromagnetic fields, mobile phone, rats**

Introduction

The environment for life on Earth has changed dramatically during the last decades. During the billions of years when life was formed, it was shaped to function in harmony with the naturally occurring physical forces such as gravitation, cosmic irradiation, heat and cold, mechanical forces and the terrestrial magnetism.

The power density of the microware (MW) background in space is about 0.4 $\mu W/m^2$, as obtained by integration of recorded spectral data. This results in a power density of

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an extremely low natural MW background on earth, estimated to be in the order of 10^{-15} to 10^{-8} μW/m^2.

Artificial MWs were not produced by humans until 1886. At that point, the German physicist Heinrich Hertz was the first to broadcast and receive radio waves. From then on, MWs have been the carriers of telegraphic data between stations on Earth and also between ground-based stations and satellites. In the 1950's, the high frequency Radio Frequency (RFs) became increasingly used as FM and television. Then the use of MWs in the mobile phone communications society has expanded drastically. Today about half of the world's population is owners of mobile phones, and an even larger number are exposed to the MW fields through the passive mobile phoning and MW-emitting base stations placed everywhere around us. All this results in an artificially produced general MW background in our environment in the order of 10^{11} to 10^{18} times the levels generated by the MW background radiation from space. The important question is, whether the exposure to these omnipresent MWs is only of good. The generation of today is the first to be exposed during a whole lifetime. Possibly, this may result in harmful effects. If so, these must be studied, revealed and reduced or avoided.

Our research group has studied the effects of EMF upon the mammalian brain (rats) since 1988. In later years we have included studies on cognition and gene expression where we have demonstrated significant effects of exposure to RF-EMF from mobile phones. However, our major field of interest during the period has been the effects upon the blood-brain barrier (BBB) of the rat. These studies have also revealed damaging effects from RF-EMF upon neurons. We report here our results on BBB effects and to a lesser extent on neuronal damage.

Review of the literature

The blood-brain barrier

The existence of the BBB was discovered in the late 19th century by the German bacteriologist Paul Ehrlich and his student, Edwin Goldman. Paul Ehrlich found, that when he injected dyes into the systemic blood circulation, the brain tissue did not take up any of the staining. However, Goldman described in 1909 that the brain tissue was stained after direct injection of trypan blue into the brain ventricular systems. A barrier surrounding the brain tissue at the site of the brain micro vessels seemed to be a logic explanation to these findings.

Today, it is well known that the mammalian brain is protected from potentially harmful compounds circulating in the blood by the BBB. In the normal brain, the passage of compounds over the BBB is highly restricted. Other barriers in the mammalian body include the eye (a protrusion of the brain), the blood-testis-barrier, the ovarian blood-follicle barrier and the less restrictive placental barrier.

A BBB exists not only in vertebrates, but also in insects[1], crustaceans and cephalopod molluscs (such as the cuttlefish)[2] and in elasmobranchs (cartilaginous fishes such as sharks)[3] and helices (landsnails)[4], maintaining ionic integrity of the neuronal bathing fluid. Several studies describe well developed blood-barrier functions in these invertebrates where the similarities with the vertebrate BBB are striking.

Anatomy of the mammalian blood-brain barrier

The BBB is formed by the vascular endothelial cells in the capillaries of the brain with glial cells wrapped around. The endothelial cells are sealed together with tight junctions, composed of the tight junction proteins occludin, claudin and zonula occludens[5]. No fenestrations are left between the endothelial cells (fig. 1).

The ablumenal membrane of the capillary surface is covered to 25% by pericytes[6]. The pericytes are a type of macrophages, with macrophage markers and capacity for phagocytosis and antigen presentation and seemingly, they are in a position to significantly contribute to central nervous system (CNS) immune mechanisms. They help maintain the stability of blood vessels by regulating the endothelial cells and the vascular permeability[7].

Surrounding the endothelial cells and the pericytes, there is a bilayer basal membrane. This basement membrane (basal lamina) supports the ablumenal surface of the endothelium and may act as a barrier to the passage of macromolecules.

The outer surface of the basal membrane is surrounded by protoplasmic astrocytes. These are implicated in the maintenance, functional regulation and repair of the BBB. Their protrusions, called end feet, cover the basal membrane and form a second barrier to hydrophilic molecules, but also connect the endothelium to the neurons.

The BBB is not only a physical barrier, but is also an enzymatic barrier with the capability of metabolizing certain solutes, such as drugs and nutrients[8]. Many of these enzymes reside selectively in the cerebral endothelial cells. For instance, enzymes like monoamine oxidase A and B, catechol O-methyltransferase, or pseudocholinesterase are involved in the degradation of neurotransmitters present in the CNS[9].

Differences between the human and the rodent BBB

The mammalian brain at large seems to have a uniform anatomy of its BBB constituents preserved through the evolution, and very little information about differences between mammalian species has been available. However, recently very inter-

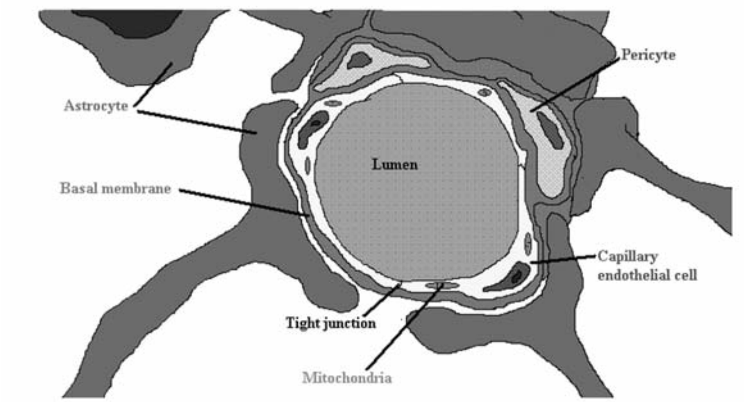


Fig. 1. The mammalian BBB

esting observations have been published. Humans have evolved protoplasmic astrocytes that are both larger (27-fold greater volume) and far more elaborate than their rodent counterparts. These astrocytes reside near blood vessels, and their processes contribute to the BBB[10]. When the end feet of human and rodent protoplasmic astrocytes are compared, it is shown that nearly all astrocytes in both species contact the vasculature, but in the human brain, the end feet completely encompass the vessels while the rodent astrocytes form rosettes of end feet around the vasculature. The number of mithochondria is however equally abundant in human and rodent end feet[11]. Even if the endothelial cells are considered as the major component of the BBB, it cannot be excluded that the observed astrocytic differences may be of importance for how the EMFs affect the BBB in rodents *vs* humans.

Comparisons between mammalian species concerning enzymatic functions in the BBB are few in number. Similarities are described: mouse *vs* human[12] and rat *vs* human[13], while differences are demonstrated between rodent and dog BBB leading to the conclusion that the canine BBB may be preferable to that of the rat as a model for studies of glucose transport relevant to human brain[14].

Transport across the blood-brain barrier

The microvasculature of the CNS differs physiologically from that of peripheral organs. The endothelial cells are characterised by the low number of pinocytic vesicles for nutrient transport through the cytoplasm and they have a five-fold higher number of mitochondria as compared to the muscular endothelium[15].

The size and hydrophobic or hydrophilic characteristics of substances affect whether or not they can pass the BBB:

- water, most lipid-soluble molecules, oxygen and carbon dioxide can diffuse from blood to the nerve cells;
- the BBB is slightly permeable to ions such as Na^+, K^+, Cl^-;
- proteins and most water-soluble chemicals pass poorly.

The flux of solutes into the brain parenchyma can be controlled by at least four mechanisms. First, the tight junctions and low number of pinocytic vesicles guarantee that proteins cannot pass freely into the brain parenchyma. Second, solutes which are not highly lipid soluble, or which do not bind to selective transporters with high affinity, are excluded from free exchange. Thus, the passage of sugars and many aminoacids depends on other, active mechanisms. Third, the BBB has a capacity to metabolize certain solutes, such as drugs and nutrients[8]. Fourth, active transporters maintain the levels of certain solutes at specific values within the brain interstitial fluid. This is made possible by active transport against the concentration gradients. These enzyme systems are differently distributed between the luminal and the ablumenal membranes of the endothelial cells, thus gaining the BBB polarity properties.

For the substances, which cannot diffuse over the BBB, certain mechanisms could be used to pass the BBB. These include:

- paracellular routes;
- transcellular routes, with pinocytosis or transcytosis, transendothelial channels, or disruption of endothelial cell membrane.

During certain pathological conditions, the selective permeability of the BBB is disturbed, resulting in a temporary increased BBB permeability. Such conditions include tumours, infarcts, infections or traumas. The BBB itself might play an active role in the mediation of the neuroimmune response seen in different conditions, by production of inflammatory mediators or by the expression of adhesion molecules[9]. The selective permeability of the BBB is altered also in cases of epileptic seizures[16, 17] and severe hypertension[18]. The result of this can be cerebral oedema, increased intracranial pressure and irreversible brain damage. Also, toxic substances from the blood circulation now reach the neurons.

In the study by Sokrab *et al.*[18], hypertensive opening of the BBB was induced by clamping the upper abdominal aorta in rats for 8-10 minutes. BBB leakage was demonstrated in all 3 rats surviving 2 hours after the clamping and in 5/12 rats sacrificed 7 days after the clamping, although the intensity in the BBB leakage had been reduced in the animals with a 7-day recovery time. The BBB leakage could be visualised in cortex, basal ganglia, hippocampus, cerebellum and the brain stem. Also, importantly, it was concluded that even transient openings of the BBB can lead to permanent tissue damage[18].

There is a time-dependence regarding insults leading to BBB opening. Hardebo evaluated the scale for opening and closure of the BBB after a reversible opening, achieved by a hypertensive or hyperosmolar insult[19]. The degree of Evans blue-albumin complex was estimated by gross inspection of the brain surface, and extravasation of inulin and noradrenaline was expressed as tissue radioactivity quotient. The absolute values for extravasation of inuline and noradrenaline were very similar, and all three test substances had an identical time profile. Thirty minutes after the hypertensive insult and 60 minutes after the hypertonic insult, the barrier was reclosed. With electron micrographs of the microvessels of the cortex, micro-pinocytotic vesicles within endothelial cells were seen. Also, vesicles were being formed and disintegrated in the luminal membranes of the endothelial cells. This increased transendothelial pinocytosis was observed as long as the barrier was open.

Hardebo and Nilsson also found that intracarotid infusions of hyperosmolar solutions induced cerebral vasodilatation and flow increase[20]. It was proposed that BBB opening caused by the acute hypertension could be related to a pressure-forced over-distension of the vessels along the vascular tree, and that increased transendothelial pinocytosis under these experimental conditions might be due to the dilatation and/or distension of the brain vessels.

The importance of the BBB is also revealed by its presence not only in vertebrates, but also in invertebrates. For instance, a glial vertebrate-like BBB has been found in scorpions[21]. Using radio-labelled polyethylene glycol and EDTA it was shown that the cuttlefish Sepia has a BBB as tight as the endothelial barrier of mammals[2]. Furthermore, it was concluded that the Sepia BBB is formed by perivascular glial processes in the microvessels and venous vessels, but by pericytes in the arterial vessels. Possibly, the glial BBB could be the primitive condition and a barrier associated with vascular elements such as endothelium or pericytes could be a later development[22].

Importantly, the BBB seems to be present very early in the foetal development. Also, at an early stage, there seems to be a cerebrospinal fluid barrier, which excludes cerebrospinal fluid (CST) protein from the brain extracellular space[23]. By measuring the protein composition and concentrations in the CSF and plasma of *Mondelphis domestica*, a small rodent-like marsupial, from birth until adulthood, it was found that protein content increased during day 5 and 10 after birth, and later on decreased and reached very low levels. Notably, these marsupials are born at a very early stage of their development, when almost all organ systems are at an embryonic level of development. This is different from many other animals, in which the development has reached a much more mature stage at the time of birth; for example, in rats the peak concentrations of proteins within the CSF are reached at birth or just before/after this, the protein content is kept low.

Electromagnetic fields

EMFs are produced by the mutual interaction of electric and magnetic fields; by the movement of a charge generating a magnetic field or a changing magnetic field generating an electric field. An Electromagnetic (EM) wave is characterised by its intensity (the amplitude), the frequency of the time variations of the electric and magnetic fields, the pulse width and the number of pulses per second. The different frequencies of EMFs result in a spectrum ranging from 1,000 MHz (10^9 cycles per second) to 300,000 MHz ($3x10^{11}$ cycles per second) and with wavelengths between 1 mm and 1 m.

An EMF spreads indefinitely in the empty space. Any charged object in the vicinity of this field is affected by the electromagnetic interactions. The result of this interaction depends on the amplitude of the field, but also seemingly weak amounts of electromagnetism can mediate significant effects through resonance interactions with sensitive systems.

The rate of EM energy absorbed in tissue per unit mass is called specific absorption rate (SAR). The maximally allowed SAR-value for occupational exposure is 10 W/kg, and 2 W/kg is the maximally allowed SAR-value for public exposure (localized SAR, head and trunk) according to limit values from the International Commission of Non-Ionizing Radiation Protection[24]. These values are set in order to avoid thermal effects of the EMF radiation, such as whole-body heat stress and excessive localized tissue heating.

In our laboratory, in order to generate uniform EMFs for standard measurements, we have used transverse electromagnetic transmission line chambers (TEM-cells) in the majority of our experiments on rats[25-32]. In each TEM-cell, two animals can be placed, one in an upper compartment and one in a lower compartment (fig. 2). It is important to point out that the position of the animals in upper or lower compartments does not effect the magnitude of observed albumin leakage. Also, we have concluded, with our total series of more than 2000 exposed animals, that there is no difference in the sensitivity to EMF exposure between male and female animals as far as albumin leakage is concerned.

The TEM-cells have mainly been used for exposure in the 900 MHz range. For generation of 1800 MHz-fields, an anechoic chamber has been used[33]. The EMFs are generated by means of a directional antenna placed in the top part of the anechoic chamber.

The experimental models used in our studies allow the animals, which are un-anaesthetized during the whole exposure, to move and turn around in the exposure chambers, thus minimising the effects of stress induced immobilization[34].

Early studies of electromagnetic field induced blood-brain barrier permeability

Already in 1968, Frey, a pioneer in the field, noted that “in recent years it has been recognized that low-power-density modulated RF energy can affect the functioning of higher living organisms”. In the 1970’s, he discussed possible mechanisms by which RF

Fig. 2. Rat in the upper compartment of a TEM-cell

energy could affect biological systems, and it was concluded that: "The question is not whether there is a possible mechanism, but rather which of numerous possible mechanisms"[35]. In order to try to find an answer to that question, the relationship between neural function and behaviour was investigated by Frey *et al.* in 1975. They demonstrated an increased leakage of fluorescein after 30 minutes of pulsed and Continuous Waves (CW) exposure at 1200 MHz[35]. In general, the fluorescence was seen at the diencephalon level of the brain. Fluorescence was particularly conspicuous in the vicinity of the lateral ventricles and often near the third ventricle. There was a significant difference between the pulsed and continuous waves, and both of these conditions were significantly different from the control condition.

Similar findings were made by Oscar and Hawkins, with 10 minutes of RF exposure at 1300 MHz leading to an increased uptake of D-mannitol in the brains of exposed rats[36]. The increased permeability was seen both immediately and 4 hours after the exposure, however, not after 24 hours. Notably, MWs of the same average power but with different pulse characteristics produced different uptake levels. Regarding CWs, the uptake of mannitol increased with increasing power up to 1.0 mW/cm^2 (corresponding to SAR of 0.4 W/kg), but at higher power densities it started to decrease. For pulsed MWs, a similar phenomenon was seen, but at different power densities. A power window was suggested to explain the fact that increase in the power above certain levels did not result in a corresponding increase of the BBB permeability. Comparing the CWs and pulsed MWs, there were differences in the permeability changes at the same average power. Also, different pulse characteristics of pulsed MWs resulted in different mannitol uptake, although the power density was the same. However, in later studies, Oscar *et al.*[37] emphasised that changes of BBB permeability after MW exposure partly could be explained by an increase of local cerebral blood flow. In accordance with this, they concluded that their initial findings[36] might be of less magnitude than originally thought[37].

Merritt *et al.*[38] tried to replicate the findings both by Frey *et al.*[35] from 1975 and Oscar and Hawkins[36] from 1977. Regarding the findings by Frey *et al.*[35], Merritt *et al.*[38] could not replicate them in rats exposed to a similar dose of RF radiation at 1,200 MHz, both CW and pulsed. However, Frey commented upon this in an article in 1998, where he pointed out that, in fact, statistical analysis by the editor and reviewer of the data from the study by Merritt *et al.*[38] provided a confirmation of the findings of Frey *et al.*[35] from 1975[39]. Regarding the findings by Oscar and Hawkins[36], the same lack of replication was reported, as Merritt *et al.*[38] found no significant change in the permeability of neither mannitol nor inulin after RF exposure similar to that of Oscar and Hawkins[36] from 1977. Similar attempts to replicate the Oscar and Hawkins[36] study from 1977 were made by Preston *et al.*, but no increase in the uptake of C-mannitol was found after 30 minutes of exposure to CW MWs at 2450 MHz[40].

Further lack of EMF induced BBB permeability was reported by Ward *et al.*[41] and by Ward and Ali[42] for C-sucrose and inulin (CWs exposure during 30 minutes at power densities of 0, 10, 20 and 30 mW/cm^2), or by Gruenau *et al.*[43] for sucrose (CW and pulsed exposure at 2.8 GHz at power densities between 0 and 40 mW/cm^2).

Ward *et al.*[41] found no increased permeation if inulin or sucrose after 2450 MHz irradiation (0-30 mW/cm^2 for 30 minutes), and with exposure concentrated to the head of the rat[42] (at 1700 MHz and the same power densities), similar lack of effects were reported. Absence of EMF induced BBB permeability was also reported by Gruenau *et al.*[43] (C-sucrose, 30 minutes pulsed or CW radiation at 2.8 GHz between 0-40 mW/cm^2).

With horseradish peroxidase (HRP) as and indicator of the BBB permeability, Albert and Kerns[44] found increases of the tracer in the brains of Chinese hamsters after RF exposure (2 hours CWs at 2450 MHz at 10 mW/cm^2). An increased number of pinocytotic vesicles were seen in the endothelial cells of the irradiated animals, but in animals recovering 1 or 2 hours after the RF exposure, almost no horseradish peroxidase permeation could be detected.

Effects of thermal irradiation

With more research into the area of EMF-induced BBB permeability, it became evident that with high-intensity EMF exposure resulting in tissue heating, the BBB permeability is temperature dependent[45]. Thus, the importance of differentiating between thermal and non thermal effects on the integrity of the BBB was realized.

In a series of studies, Williams *et al.*[45-48] investigated parameters affecting the BBB passage. Fluorescein was significantly elevated in the brains when rats had been subjected to thermal heating (> 41° C.), corresponding to CW exposure at SAR-levels of approximately 13.0 W/kg for 30 or 90 minutes. However, the authors believed that these findings were rather due to technical artefacts and not a breakdown of the BBB. Regarding HRP, no HRP leakage could be attributed to MW or thermally-induced breakdown of the BBB (2450 MHz CWs at 0, 20 or 65 mW/cm^2 for 30, 90 or 180 min)[47]. Regarding sucrose, MW exposure at 2450 MHz for 30 minutes at SAR approximately at 13 W/kg resulted in a decrease of the sucrose uptake, but this decrease was not apparent after 90 minutes[48].

It was speculated that thermal MW effects could be used to facilitate drug delivery over the BBB. Quock *et al.*[49] noted that 10 minutes of exposure to 2.45 GHz at 23.7 W/kg facilitated the transport methylatropine, a derivate of atropine. Under non-thermal conditions, the methylatropine does not normally cross the BBB, but after the single thermal MW exposure, anticholinergic effects of methylatropine could be identified (as a shift in the dose-response curves for both pilocarpine and oxotremorine).

Magnetic Resonance Imaging

With the introduction of the magnetic resonance imaging (MRI) technique, combined exposure to RF, pulsed and static magnetic fields was increasingly investigated.

Shivers *et al.* observed that the EMF exposure of the type emitted during a MRI procedure resulted in a temporarily increased permeability in the brains of rats[50]. HRP was used as an exogenous tracer. After 30 minutes of MRI exposure of rats, an amplified vesicle mediated transport could be detected. The vesicles were often attached to the luminal or abluminal cell membrane. These vesicular structures appeared to extend from the luminal to the abluminal cell membrane in some cases, thereby creating transendothelial passageways. Fifteen-thirty minutes after the exposure, the exclusion of protein tracer from subendothelial basal lamina and neuropil was completed. The distribution of the vesicles of the MRI exposed animals was compared to that of sham exposed rats, in which the tracer could be found only in the vascular lumen and luminal sides of the vessels. In neither the MRI or sham exposed rats, the tight junctions of the BBB were permeated with the tracer. This lead to the question, whether the RF radiation might modify the physiochemical membrane properties, thereby leading to the increase of vesicle mediated transport. This study was replicated by Garber *et al.*[51], whereas Adzamli *et al.*[52] and Preston *et al.*[53] could not repeat the findings. The Shivers group later produced quantitative support of their initial findings[54, 55]. In rats exposed to MRI, the BBB permeability to diethylenetriameninepentaacetic acid (DTPA) increased. A suggested mechanism explaining the increased permeability was a stimulation of endocytosis, made possible through the time-varying magnetic fields.

Research from our laboratory

Stimulated by the work of the London Ontario group, two from our group visited professor Shivers and his colleagues in 1988. LGS in the hope to find an elegant way to open the BBB by the use of controlled EMFs in order to facilitate passage of cytotoxins into the brain, surrounding the tumours of patients with malignant gliomas, BP with the goal to learn more about possible risks of the MRI technology. Thus, our group started work on effects of MRI on rat brain in 1988 and found, by the use of Evans Blue, the same increased permeability over BBB for albumin[27].

Our work was continued by separating the constituents of the MRI field: RF, time varying magnetic field and static magnetic field. Since RF turned out to be the most efficient component of the MRI in this aspect, the following studies focused mainly on the RF effects. In order to simulate the actual real-life situation, endogenous substances, which naturally circulate in the vessels of the animals, were used. Albumin and leakage over the BBB was identified with IgG fraction of rabbit anti-rat. All brains were examined histopathologically by our neuropathologist. Regarding albumin extravasation, the number of immunopositive extravasates (foci) were recorded under a microscope. None or occasional minor leakage was rated as normal, whereas one larger or several leakages were regarded as pathological. Immunopositive sites were, however, disregarded when localized in the hypothalamus, above the median eminence and laterally including the lateral hypothalamic nuclei, in the immediate vicinity of the third ventricle and just beneath the pial membrane. These structures are well known for their insufficient BBB. Also the presence and distribution of albumin uptake into neurons was judged semiquantitatively.

We started our RF experiments with the frequency modulation 16 Hz and its harmonics 4, 8, 16 and also 50 Hz, which was felt relevant as it is the standard line frequency of the European power system, with a carrier wave of 915 MHz. At an early stage also 217 Hz modulation was added as this was the frequency of the then planned GSM system. This work was published in 1994[29] and 1997[26] and comprised sham or 915 MHz exposure for in most cases 2 h but in a minority of the experiments lasting between 2 and 960 min (both continuous and pulsed modulated waves). These results based on 246 rats (1994) and more than 1,000 rats (1997) (the majority EMF exposed and about 1/3 sham-exposed) concluded that there was a significant difference between the albumin extravasation from brain capillaries into the brain tissue between the differently exposed groups and the controls.

It is important to point out that even though all animals in the 1997 series (and basically all of our experiments) are performed in inbred Fischer 344 rats, only at the most 50% of the identically exposed animals display albumin extravasation in CW animals and somewhat less in the other exposed animals. Also the sham-exposed animals have some albumin leakage though only in 17% as a mean of all controls (fig. 3). The leakage observed in unexposed animals presumably is due to our very sensitive immunohistological methods. The peculiar fact that at the most only every second exposed inbred animal displays leakage, is difficult to explain.

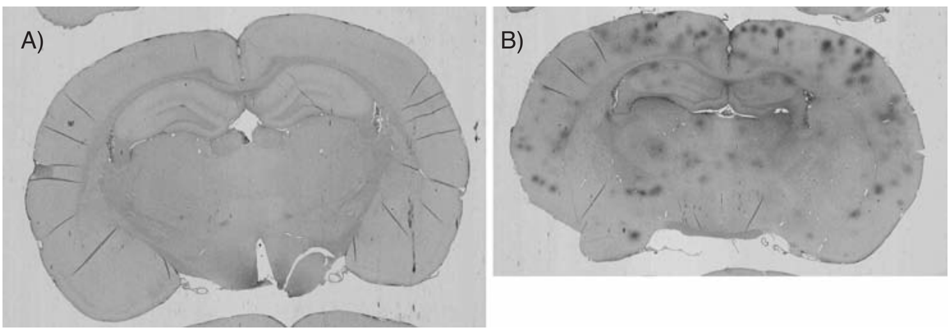


Fig. 3. A) Sham-exposed animal no albumin leakage Notify normal albumin extravasation in Hypothalamus (inbuilt control). B) RF-exposed animal, albumin leakage, Albumin score 3 (on a semi-quantitative score with 3 defined as pronounced albumin leakage and 0 as no albumin leakage)

In a statistical re-evaluation of our material published in 1997[26] where only exposed rats with a matched unexposed control rat are included, we found for the most interesting modulation frequency 217 Hz, i.e. that of GSM, that at SAR-values of 0.2 to 4 mW/kg 48 exposed rats had a significantly increased albumin leakage ($p < 0.001$) as compared their 48 matched controls. On the other hand, SAR-values of 25-50 mW/kg, gave no significant difference between 22 exposed rats *vs* their matched controls (Wilcoxon´s Rank Test, 2-sided p-value).

Thus, the most remarkable observation was that exposure with whole-body average power densities below 10 mW/kg gave rise to a more pronounced albumin leakage than higher power densities, all at non-thermal levels. If the reversed situation were at hand, we feel that the risk of cellular telephones, base-stations and other RF emitting sources could be managed by reduction of their emitted energy. The SAR value of around 1 mW/kg exists at a distance of more than 1 m away from the mobile phone antenna and at a distance of about 150–200 m from a base station (figs. 4 and 5).

In all our earlier studies we showed albumin extravasation immediately after exposure as described above. In later years we have performed a series of experiments where the animals were allowed to survive for 7 days[56], 14 days, 28 days[57] or 50 days[31] after one single 2-hour exposure to the radiation from a GSM mobile phone. All were exposed in TEM-cells to a 915 MHz carrier wave as described above. The peak power output from the GSM mobile phone fed into the TEM-cells was 1, 10, 100 and 1000 mW per cell respectively for the 7-14-28-days survival animals, resulting in average whole-body SAR of 0.12, 1.2, 12 and 120 mW/kg for four different exposure groups. The 50-days survival animals were exposed to SAR-values of 1.2, 12 and 120 mW/kg, corresponding to 10, 100 and 1000 mW fed into the TEM-cells.

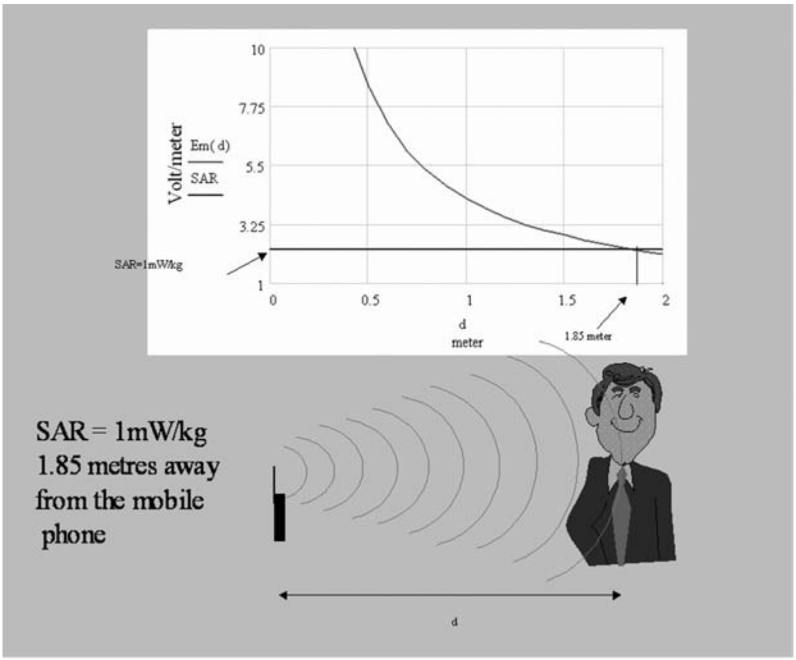


Fig. 4. The SAR-value of around 1 mW/kg exists at a distance of 1.85 meter away from the mobile phone

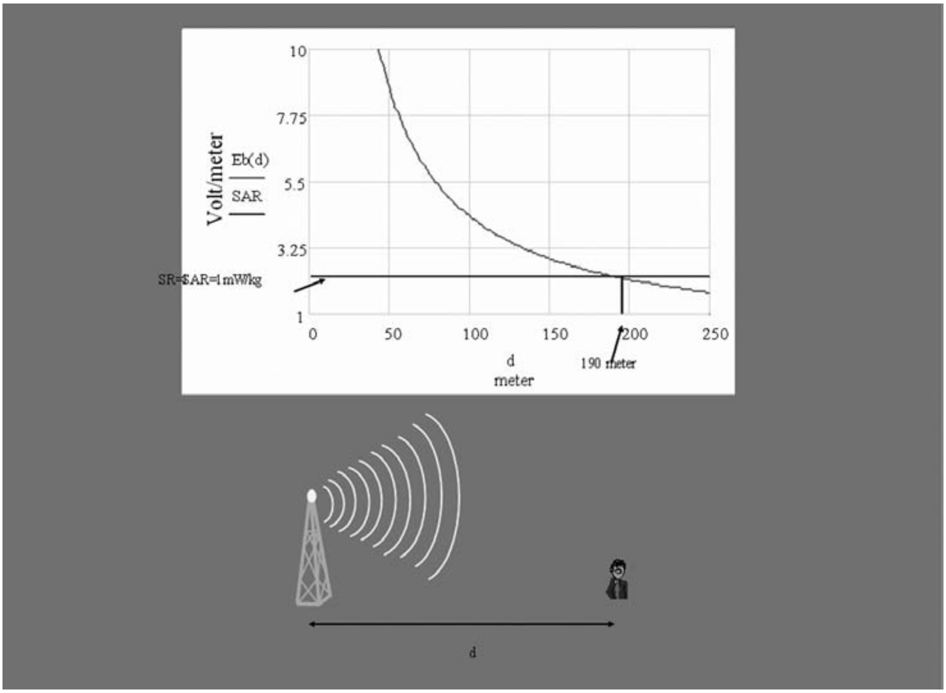


Fig. 5. The SAR-value of 1 mW/kg exists at a distance of 150-200 metres from a base station

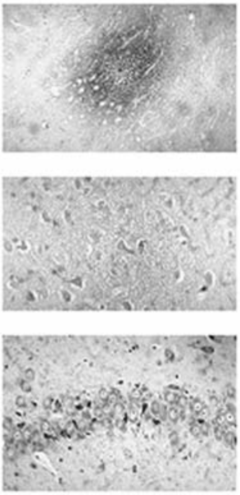
Albumin extravasation over the BBB after GSM exposure seemed to be time-dependent, with significantly increased albumin in the brain parenchyma of the rats, which had survived for 7 and 14 days, but not for those surviving 28 days. After 50 days, albumin extravasation was significantly increased again, with albumin-positive foci around the finer blood vessels in white and gray matter of the exposed animals (fig. 6).

In connection to the albumin passage over the BBB, albumin also spread in the surrounding brain tissue. A significantly increased uptake of albumin in the cytoplasm of neurons could be seen in the GSM exposed animals surviving 7 and 14 days after exposure, but not in those surviving 28 or 50 days.

Neuronal uptake

Extravasated albumin rapidly diffused down to, and beyond, concentrations possible to demonstrate accurately immunohistologically. However, the initial albumin leakage into the brain tissue (seen within hours in ~40% of exposed animals in our previous studies) most likely started a vicious circle of further BBB opening.

It has been postulated that albumin is the most likely neurotoxin in serum[58]. Hassel *et al.*[59] have demonstrated that injection of albumin into the brain parenchyma of rats gives rise to neuronal damage. When 25 μl of rat albumin is infused into rat neostriatum, 10 and 30, but not 3 mg/ml albumin causes neuronal cell death and axonal severe damage. It also causes leakage of endogenous albumin in and around the area of neuronal



Exposed vs sham	7d	14 d	28 d	50 d
Albumin foci	0.01	0.02	ns	0.04
Neuronal albumin	0.03	0.005	ns	ns
Dark neurons	ns	ns	0.01	0.001

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Fig. 6. Albumin extravasation, neuronal albumin and dark neurons in rats 7, 14, 28 and 50 days after 2 hours of GSM exposure

damage. Albumin in the dose 10 mg/ml is approximately equivalent to 25% of the serum concentration. However, it is less likely that the albumin leakage demonstrated in our experiments locally reaches such concentrations. However, we have seen that in the animals surviving 28 and 50 days after 2 hours of GSM exposure, there was a significantly increased incidence of neuronal damage as compared to the sham controls. In the 7-days and 14-days survival animals, on the other hand, no such increase of neuronal damage was seen.

The damaged neurons took the shape of so-called dark neurons. Three main characteristics of the damaged dark neurons have been proposed[60]: 1) irregular cellular outlines, 2) increased chromatin density in the nucleus and cytoplasm and 3) intensely and homogenously stained nucleus. The damaged dark neurons found in the 50 days-survival animals were investigated regarding signs of apoptotic markers, but we found no positive staining for Caspase-3, a marker for apoptosis[61]. However, the albumin leakage out in the neuropil in connection to EMF exposure might start other deleterious processes, leading to the formation of the dark neurons.

In a recent long-term study from our laboratory, rats were exposed to GSM radiation 2 hours weekly during 55 weeks (two different exposure groups with 0.6 mW/kg and 60 mW/kg at the initiation of the exposure period). After this protracted exposure, behaviour and memory of the exposed animals were tested. Whereas the behaviour of the animals was not affected, the GSM exposed rats had significantly impaired episodic memory as compared to the sham controls[62]. After the finalization of these tests, that is 5-7 weeks after the last exposure, the animals were sacrificed by perfusion fixation. Albumin extravasation, an indicator of BBB leakage, was increased in about 1 animal in each group of low GSM exposed, high GSM exposed, sham exposed and cage control rats. About 40% of the animals had neuronal damage. GFAP staining, as an indicator of glial reaction, revealed positive results in 31-69% of the animals for different groups and the aggregation product lipofuscin was increased in 44-71% of the animals for different groups. With the Gallyas staining (aiming at cytoskeletal structures), no changes were seen. When comparing the results between the different groups, it turned out that there was no statistically significant difference for any of these parameters due to GSM exposure[63]. When comparing these findings to those from animals which had been exposed only once for 2 hours, it seems likely that during the 55 weeks of repeated exposure, albumin leakage at an initial stage of the experimental period could have been absorbed after some time. At a certain but unknown time point during this protracted, more than 1 year long-exposure period, some adaptation process might have been activated. However, this could not compensate for cognitive alterations.

Other studies of blood-brain barrier permeability including the effects of GSM mobile phones

Since the 1990's, mobile phones have been increasingly used. The RF radiation emitted from these devices was initially of the CW type in NMT mobile phones, but were later almost replaced by the GSM mobile phones with pulsed fields, at frequency levels of 900 MHz (GSM-900) or 1, 800 MHz (GSM-1800), with pulse modulations of 217 Hz.

As mentioned above, in the Lund studies, it has been found that the pulsed fields of the GSM mobile phones increase the permeability of the BBB in exposed rats as compared to sham controls. In order to repeat these findings, studies have been performed by Fritze *et al.*[64] and Töre *et al.*[65, 66]. Töre *et al.* (Bordeaux) found that 2 hours of GSM-exposure at SAR-values at 0.5 and 2 W/kg increased the BBB permeability, with more pronounced effects seen for exposure at 2 W/kg as compared to 0.5 W/kg. An interesting aspect of this study is the measurement of the blood pressure of the exposed animals, since it is known that the BBB is prone to hypertensive opening. Töre *et al.* found that during the EMF exposure, there was no increase of the blood pressure; it remained within the 100-130 mmHg range. In order to open the BBB through hypertensive mechanisms, it would have been necessary to increase the blood pressure up to 170 mmHg. Another finding in the studies by Töre *et al.* was sympathectomised rats were more sensitive to GSM radiation with a more pronounced increase of the BBB permeability as compared to the non-sympathectomised rats.

In the study by Fritze *et al.*[64], rats were exposed during 4 hours to GSM-900 MHz radiation with SAR of 0.3, 1.3 and 7.5 W/kg. In the paper published in 1997, Fritze *et al.* reported that there was a significant difference between exposed and sham controls only for the power level of 7.5 W/kg. However, when the Fisher exact probability test was used on the original data, there was a significant difference between the GSM and sham exposed rats also when the 10 animals in each of the power level groups of 0.3 and 1.3 W/kg were pooled (p=0.01 Fisher exact probability test)[30].

A major concentration of the involved research groups took place at Schloss Reisensburg in Germany in 2003, where the technical approaches in the studies of BBB effects especially were discussed. Two world-renowned researchers in the BBB field, Dr. David Begley of Kings College, London, and Prof. Olaf Poulsen of Copenhagen, Denmark, chaired the FGF/COST 281 Reisensburg, November 2–6 meeting. They made the final statement as a summary of the meeting: ''It seems clear that RF fields can have some effects on tissues''. The statement was made to a large extent on the basis of the concordant findings of the Bordeaux group, represented by Prof. Aubineau, and the Lund group, represented by Prof. Salford and Prof. Persson.

The permeability of the BBB was investigated after exposure to pulsed RF radiation at 2450 MHz for 15, 30, 60 or 120 minutes[67]. Immediately after the exposure, capillary endothelial cells from the cerebral cortex were isolated and with a fluorescien technique, the amount of rhodamine-ferritin complex within these cells was determined. The uptake of rhodamine-ferritin was increased after exposure at an average power density of 10 mW/cm^2 (corresponding to a SAR-value of 2 W/kg), but not at the power density of 0.5 mW/cm^2. Also, the duration of exposure influenced the uptake of the substance; with increased uptake after 30, 60 and 120 minutes, but not after 15 minutes. A pinocytotic-like mechanism was proposed to explain the increased uptake after RF exposure[50]. A very interesting finding in this study was that the RF induced rhodamine-ferritin uptake could be blocked by pre-treatment with colchicine. Colchicine inhibits the microtubule function. Thus, it could be seen that RF induced uptake of the systemically administered rhodamine-ferritin by capillary endothelial cells of the cerebral cortex depended both on the power and the duration of the RF exposure, as well as well-functioning microtubules.

In other studies, no EMF induced BBB permeability has been reported[68-71]. Finnie *et al.*[68] exposed mice to GSM-900 radiation at the SAR-level of 4 W/kg. Albumin immunohistochemistry was used for evaluation. In a second study of BBB permeability, Finnie *et al.*[69] reported the same lack of GSM EMF induced BBB permeability, in this case after long-term exposure of mice for 104 weeks at SAR-levels of 0.25, 1.0, 2.0 and 4.0 W/kg. Tsurita *et al.*[71] exposed rats to RFs at 1, 439 MHz at SAR-values of 0.25 W/kg. Immunostaining was used to detect albumin extravasation, which however was not increased in this small group of totally 12 EMF exposed animals. Kuribayashi *et al.*[70] investigated EMF induced BBB permeability in immature and young rats after exposure to 1439 MHz at SAR-levels of 0.2 and 6 W/kg. A dextran tracer was used to evaluate BBB permeability, which was not changed after the exposure. The same group also reported that the immature BBB was insensitive to mobile phone exposure, seen after GSM-900 irradiation of pregnant mice from day 1 to day 19 of gestation (SAR of 4 W/kg, exposure for 60 minutes daily). No increased albumin extravasation was seen in the new-born mice immediately after parturition[72]. Further lack of BBB disruption in young rats, as seen using the Evans blue tracer, was reported by Kumlin *et al.*[73] (GSM-900 EMF exposure of young male Wistar rats for 2 hours daily, 5 days weekly for totally 5 weeks at average whole-body SAR of 0.3 and 3 W/kg). However, of the 48 exposed rats, only 12 were examined histopathologically. The remaining animals were included in behavioural tests, where an improvement of learning and memory was seen in a water maze test when comparing the EMF exposed animals to the sham controls. Notably, in all these above mentioned studies with lack of observable EMF induced BBB effects, the SAR-values for exposure are relatively high; never including the low SAR-values in the range of < 10 mW/kg.

Recently, *in vitro* models of the BBB have been used in order to evaluate the EMF induced permeability alterations. Schirmacher *et al.*[74] used a co-culture consisting of rat astrocytes and porcine brain capillary endothelial cells as a BBB model, including zona occludens proteins, the markers for tight junctions, and with no intercellular clefts. Exposure to GSM-1800 EMFs was found to increase the permeability for sucrose. In a second model, with an improved BBB tightness, the BBB was less sensitive to the EMF exposure, with no increased sucrose passage after GSM-1800 exposure[75]. In a third study by the same group, the BBB permeability in connection to EMF exposure of the kind emitted by a UMTS mobile phone (3G) was investigated, however, with no findings of increased permeability in connection to the exposure[76].

Opinions and implications

Mechanisms

Taken together, a large number of studies have been performed within the field of EMF effects upon the mammalian brain. What can be concluded is that the picture of response is highly complex. Whereas some studies show clear effects of increased brain tumour incidence, genetic alterations, EEG changes, altered memory functions and changed neurotransmitter levels; other studies show no significant changes at all. A problem within the field is that the underlying mechanisms are not yet understood. If these had been clearly defined, the possibilities of replicating previous positive findings would have increased significantly. Therefore, the need to define these mechanisms should be obvious. Ways of doing this include both genetic investigations and studies of cell signalling pathways, but also physical and mathematical models are needed in order to clearly define the relationships between EMF radiation and biology.

As described above, in our studies of BBB permeability, we have seen significant biological response at very low SAR levels. This could possibly represent the "inverse U-curve response", which has also been reported in connection with other kinds of MW exposure previously[36, 77, 78]. Along these lines, we have specifically studied a Quantum-mechanical model for interaction with protein-bound ions involving Ca^{2+}-transport with resonances at certain frequencies[79]. Appropriate combinations of frequency and amplitude affected the Ca^{2+}-ion transport systems at various degrees and directions. At fixed values of the static and time varying magnetic fields, resonances were found at certain frequencies (7, 21, 24 and 31 Hz). The interaction of ELF magnetic fields with calcium bound proteins fitted extremely well with the quantum mechanical interaction model described by Blanchard and Blackman[80] and it was concluded that the resonance could be attributed to 45 Ca^{2+}.

In this connection it might be of interest to mention the recent statement that "astrocytic complexity may be the basis for the superior functional competence of the human brain"[11]. Human protoplasmic astrocytes propagate Ca^{2+} waves with a speed of 35 µm/s, which is fourfold faster than rodent astrocytes. Human astrocytes are larger and structurally more complex than those of rodents[11]. If EMFs excert their effects, at least to some extent, upon the astrocytes, our experimental findings in spinach vesicles are clearly interesting. It may also give rise to different effects upon the human and the rodent brain.

Other approaches for explaining these effects have been suggested.

The EMF interaction with free ions, where external oscillating fields induce forced vibrations of the ions, leading to increase of intra cellular ion concentration and an osmotically driven entrance of water. This in turn would lead to disruption of plasma membranes[81].

Auto-oxidative processes induced by externally applied MWs. For example, GSM exposure increased the levels of malondialdehyde (MDA), an index for lipid peroxidation, nitric oxide (NO), xanthine oxidase (XO) and adenosine deaminase (ADA) in rats.

These increased were prevented by treatment with anti-oxidant (Ginko Biloba)[82]. Reactive oxygen species also mediated a rapid activation of ERK/MAPKs (mitogenactivated protein kinase) after EMF exposure[83]. The resulting signalling cascade could ultimately affect transcription, by the central key role of ERKs in signalling pathways. Another signalling pathway activated by MW exposure includes the hsp27/p38MAPK stress signalling pathway, which might lead to stabilisation of endothelial stress fibres[84].

Alterations of protein conformation of serum albumin, where it has been shown that EMFs can affect the conformation of proteins and thus their biological function. For example, the aggregation of bovine serum albumin is enhanced *in vitro* after exposure to MW radiation at 1.0 GHz and 0.5 W[85]. Both exposure duration and the surrounding temperature influenced the aggregation process. At 60ºC amyloid fibril formation of bovine insulin was promoted. Importantly, the alterations of protein conformation were not accompanied by measurable temperature changes. The possibility of protein conformation changes in connection to EMF exposure raises the questions of links to human diseases such as the amyloidopathies (including Creutzfeldt-Jakob disease, Alzheimer's and Parkinson's diseases).

Recently, we described a soliton model, which could be the link between mathematical explanations of EMF interactions and the biological response[86]. A soliton is a non-linear wave. It has been shown that solitons are generated and propagated along the microtubule protofilaments in neurons of the brain[87]. The propagation of solitons in the lipids of biological membranes could play a vital role in the action potential propagation along nerve membranes[88]. Interestingly, the trancription bubble could correspond to a soliton travelling along the DNA chain[89]. The diverse actions of the solitons could be the explanation for the vast number of biological responses, which have been seen throughout the years of studies of EMF effects.

Translation to the human situation

Very few studies on the effects of EMF upon biology include the very low whole-body average power densities that our group works with, e.g. below 10 mW/kg. Our observation that it is SAR values at this level that give rise to the most pronounced albumin leakage, whilst higher power densities, still at non-thermal levels, give less leakage. This is complicated! If the reverse situation were at hand, we feel that the risk of radiation from cellular telephones, base-stations and other RF emitting sources could be managed by reduction of their emitted energy. The SAR value of around 1 mW/kg exists at a distance of more than 1 m away from the mobile phone antenna and at a distance of about 150-200 m from a base station. This also means that when the mobile phone is held next to the ear, the SAR value of about 1 mW/kg exists in the most central portion of the brain (fig. 7), and when a hands-free is used and the phone is *e.g.* in the pocket, there will still be microwaves reaching the brain, though the value of around 1 mW/kg will exist in more superficial portions of the brain.

A new tool to directly study the human BBB has recently been presented[90]. It provides a non-radioactive methodology for *in vivo* non-invasive, real-time imaging of BBB permeability for conventional drugs, using nitroxyl radicals as spin-labels and MRI. This technology should have a chance to substantially advance our direct knowledge of the human BBB permeability.

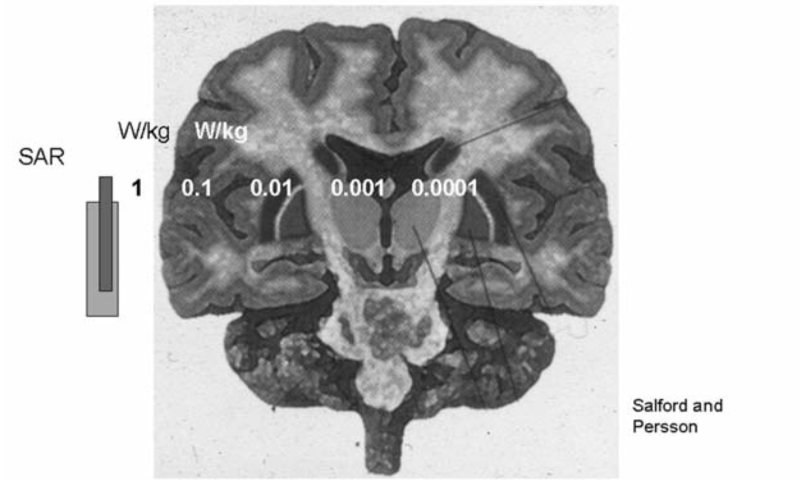

Fig. 7. Mobile phone antenna 1.4 cm from the human head, operating at 915 MHz. The very low SAR-levels of 10 mW/kg exist in deep-lying parts of the human brain such as the basal ganglia, and the power density of 1 mW/kg is absorbed in thalamus

Non-thermal vs thermal effects

These non-thermal effects are very important to clarify, considering that the exposure limits set up today mainly focus on preventing thermal effects. In many safety standard documents, a SAR-limit of 4 W/kg is referred to localized SAR of limbs and 2 W/kg for localized SAR of head and trunk[24]. The reason for choosing this SAR-value is a series of studies performed by deLorge and co-workers in the 1970's and early 1980's. In these studies, the trained behavioural performance of rats, squirrel monkeys and rhesus monkeys was tested after MW exposure. It was found that body temperature increases of 1°C or more above the baseline body temperature resulted in changes of this kind of behaviour in the animals. Notably, a SAR of near 4 W/kg was needed to produce this 1°C increase of body temperature[91, 92].

These safety limits for thermal exposure are inadequate for all the described non-thermal effects! New standards are required for the non-thermal effects.

Positive vs negative effects

In a situation where series of studies show significant effects of radiation and other studies have failed to show effects, it is important to remember, that the demonstrated effects cannot be disregarded because other studies have shown no effects. According to the Rio declaration, the precautionary principle has to be followed. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing effective measures to prevent damage. Thus precautionary measures are needed, including, not least, extensive future research within this field.

Conclusion

Having personally demonstrated a long series of significant effects of RF-EMF in our animal models, it is our sincere belief, that it is more probable than unlikely, that non-thermal electromagnetic fields from mobile phones and base stations do have effects upon the human brain.

In this context it should, however, be remembered that recently, observations on differences between astrocytic endfeet in the human and the rodent BBB have been published[11]. More research in this field is important for the translation of results from animal studies to the human situation.

If mobile communication, even at extremely low SAR values, causes the users' own albumin to pass the BBB, which is meant to protect the brain, also other unwanted and toxic molecules in the blood, may pass into the brain tissue and concentrate in and damage the neurons and glial cells of the brain.

The intense use of mobile phones, not least by youngsters, is a serious memento. A neuronal damage may not have immediately demonstrable consequences, even if repeated. It may, however, in the long run, result in reduced brain reserve capacity that might be unveiled by other later neuronal disease or even the wear and tear of ageing. We can not exclude that after some decades of (often), daily use, a whole generation of users, may suffer negative effects such as autoimmune and neuro-degenerative diseases maybe already in their middle age.

We conclude that the suppliers of mobile communication - and our politicians - have an extensive responsibility to support the exploration of these possible risks for the users and the society.

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Chapter 3

MOBILE TELEPHONY RADIATION EFFECTS ON LIVING ORGANISMS

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Abstract

A number of serious non thermal biological effects, ranging from changes in cellular function like proliferation rate changes or gene expression changes to cell death induction, decrease in the rate of melatonin production and changes in electroencephalogram patterns in humans, population declinations of birds and insects, and small but statistically significant increases of certain types of cancer, are attributed in our days to the radiations emitted by mobile telephony antennas of both handsets and base stations. This chapter reviews briefly the most important experimental, clinical and statistical findings and presents more extensively a series of experiments, concerning cell death induction on a model biological system. Mobile telephony radiation is found to decrease significantly and non thermally insect reproduction by up to 60%, after a few minutes daily exposure for only few days. Both sexes were found to be affected. The effect is due to DNA fragmentation in the gonads caused by both types of digital mobile telephony radiation used in Europe, GSM 900MHz, (Global System for Mobile telecommunications), and DCS 1800MHz, (Digital Cellular System). GSM was found to be even more bioactive than DCS, due to its higher intensity under equal conditions. The decrease in reproductive capacity seems to be non-linearly depended on radiation intensity, exhibiting a peak for intensities higher than 200 $\mu W/cm^2$ and an intensity “window” around $10\mu W/cm^2$ were it becomes maximum. In terms of the distance from a mobile phone antenna, the intensity of this “window”corresponds under usual conditions to a distance of 20-30 cm. The importance of different parameters of the radiation like intensity, carrier frequency and pulse repetition frequency, in relation to the recorded effects are discussed. Finally, this chapter describes a plausible biophysical and biochemical mechanism which can explain the recorded effects of mobile telephony radiations on living organisms.

Keywords: mobile telephony radiation, GSM, DCS, RF, ELF, electromagnetic fields, non-ionizing electromagnetic radiation, biological effects, health effects, *Drosophila*, reproductive capacity, cell death, intensity windows.

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Introduction

As mobile telephony becomes more and more a necessary tool in our daily life enabling modern man to communicate easily with everyone at any place and any moment, serious threats arise from the exposure of all living organisms and the environment to a type of radiation unknown until now. Man made electromagnetic fields and radiations differ substantially from natural electromagnetic radiations like natural light, mainly because artificial ones are polarised, able to induce coherent forced vibrations to any electric charge in their space. All living organisms are made of cells and all cellular functions are of electrical nature, involving movements of electrical charges like clouds of free ions or charged macromolecules. Certain movements of certain type of charges within the cells induce or interrupt corresponding cellular functions. Any wrong, synchronized net movement of charge within the cell, would induce a wrong cellular function. The cell as a highly organized unit of life, has protective mechanisms against wrong cellular function, for example by activating certain genes and consequently producing certain proteins like the "heat shock" ones, made to protect the cell from excessive heat. But if the cell fails to protect itself from an external disturbance, a malfunction may start which can be transferred to a whole tissue or the whole organism. Electromagnetic fields (EMFs) are perceived by the cells as external disturbances or external stress but the cells don't seem to have special genes to be activated for protection against electromagnetic stress. This might be the reason why in response to electromagnetic stress, cells activate heat shock genes and produce heat shock proteins very rapidly (within minutes) and at a much higher rate than for heat itself, (Weisbrot et al, 2003). It seems to be for the same reason why electromagnetic stress from mobile telephony radiation induces cell death to the reproductive cells much more than other types of external stress examined before like food deprivation or chemicals, (Panagopoulos et al 2007a). Thus it seems that cells are much more sensitive to man-made electromagnetic fields (EMFs) than to other types of stress previously known. This is probably due to the fact that man-made EMFs constitute a new and perhaps more intense type of external stress, against which, cells have not developed defensive mechanisms. If cells activate heat shock genes to protect themselves from electromagnetic stress and this happens at a much higher rate than for heat itself, this might be dangerous, since repetitive stress leading to continuous expression of heat shock genes may result to cancer induction, (French et al, 2001).

A number of biological effects induced by man-made (EMFs) and radiations of different frequencies including digital mobile telephony and microwave radiations, have already been reported and documented by many research groups. These include changes in intracellular ionic concentrations, changes in the synthesis rate of different biomolecules, changes in cell proliferation rates, changes in the reproductive capacity of animals, changes in gene expression and even DNA damage and cell death,, (Aitken et al 2005; Bawin and Adey 1976; Bawin et al. 1975; 1978; Barteri et al 2005; Belyaev et al 2005; Blackman et al 1980; 1989; Caraglia et al 2005; Diem et al 2005; Dutta et al 1984; Kwee and Raskmark 1998; Velizarov et al 1999; Magras and Xenos 2001; Xenos and Magras 2003; Panagopoulos et al 2004; 2007a; 2007b; Lai and Singh 1995; 1996; 1997; 2004; Remondini et al 2006; Nylund and Leszczynski 2006; Diem et al 2005; Salford et al 2003). At the same time, some epidemiological studies are starting more and more to indicate a connection between the use of cellular mobile phones and certain types of cancer, (Hardell et al 2007a; Hardell et al 2006; Hardell and Hansson-Mild, 2006; Kundi 2004).

In several cases, melatonin, a hormone which controls the daily biological cycle and has an oncostatic action, produced by the epiphysis (pineal gland) in mammals, mainly during the night, is found to reduce the action of EMR exposure, but the synthesis of melatonin itself seems to be reduced by EMR, (Burch et al, 2002; Ozguner et al, 2006; Oktem et al, 2005).

Technical Characteristics of Digital Mobile Telephony Radiation

Both systems of Digital Mobile Telephony Radiation used in Europe, GSM 900 MHz and DCS 1800 MHz and also the system used in USA, GSM 1900 MHz, use different carrier frequencies, (900, 1800, and 1900 MHz respectively), but the same pulse repetition frequency of 217 Hz, (Hillebrand 2002; Clark 2001; Hyland 2000; Hamnerius and Uddmar 2000; Tisal 1998). As is obvious, the signals of Digital Mobile Telephony Radiation, combine “radio frequencies” (RF) and “extremely low frequencies” (ELF). All three systems use the “Time Division Multiple Access” (TDMA) code to increase the number of people that can simultaneously communicate with a base station. The radiation is emitted in frames of 4.615 msec duration, at a repetition rate of 217 Hz. Each frame consists of eight “time slots” and each user occupies one of them. Within each time slot the microwave radiation uses a type of phase modulation called “Gausian Minimum Shift Keying” modulation (GMSK) to carry the information, (Tisal 1998; Hamnerius and Uddmar 2000). The transmitted frames by both handsets and base stations are grouped into multi-frames of 25 by the absence of every 26th frame. This results to an additional multi-frame repetition frequency of 8.34 Hz. Finally, handsets emit an even lower frequency at 2 Hz whenever the user is not speaking, for energy saving reasons, (“non-modulated” or “non-speaking” emission or “discontinuous transmission mode”- DTX), (Hyland 2000). Of course, when the handsets operate at DTX mode, the average emitted power is much less (about one tenth of the emitted power when they operate at “speaking” mode, (Panagopoulos et al, 2000a; 2004).

Except of the carrier frequency, another important difference between the three systems of digital mobile telephony radiation is that GSM 900MHz antennas of both mobile phones and base stations operate with double the output power than the corresponding DCS 1800MHz ones or the GSM 1900 MHz ones. GSM 900 MHz handsets operate with 2 W peak power output, while DCS 1800 MHz and GSM 1900 MHz ones operate with 1 W peak power output.

Radiation from base station antennas is almost identical to that from mobile phones of the same system (GSM or DCS), except that it is about 100 times more powerful, or to be more accurate, from several tens up to several hundred times more powerful. Thereby, effects produced by mobile phones at certain distances, can be extrapolated to represent effects from base station antennas at about 100 times longer distances. Another difference is that handset signals include one pulse per frame occupying one time slot, whereas base station signals include again one pulse per frame but this pulse may occupy 1-8 time slots depending on the number of subscribers each moment. In other words the ratio between pulse peak power and time-averaged power is usually higher for the handset signals compared to the base station signals, (Hillebrand 2002; Clark 2001; Hyland 2000; Hamnerius and Uddmar 2000; Tisal 1998).

Established Exposure Criteria for Mobile Telephony Radiations

The most stringent international exposure limits in the western world for RF radiation used by digital mobile telephony were set by the International Radiation Protection Association (IRPA) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP). These criteria were established to protect biological tissue from temperature increases, (thermal effects).

The ICNIRP exposure limits are given either in terms of Radiation Intensity (Power Density) usually in mW/cm^2, either in terms of Specific Absorption Rate (SAR) which is defined as the radiation power, absorbed by the unit mass of tissue, in W/kg. Only the radiation intensity in air outside the body can be readily and objectively measured in exposed individuals. The SAR is difficult to be determined for every single tissue as is different for different tissues and radiations. The best way for determining SAR is by computational approximate methods like the Finite Difference Time Domain (FDTP) method, the Finite Element Method (FEM), or the Method of Moments (MoM), (Meyer and Jacobus, 2003).

According to the ICNIRP exposure criteria, the maximum permitted radiation intensity (in mW/cm^2) for the general population exposure, is given according to radiation frequency and it is $f/2$ (f in GHz). Therefore, at 900MHz, the intensity limit according to these criteria is $0.45mW/cm^2$. At 1800 MHz the corresponding limit is 0.9 mW/cm^2, e.t.c). In terms of SAR the ICNIRP limits for the general population are 0.08 W/Kg (for whole-body average absorbed power) and 2 W/Kg (for the head and trunk). All the above values are to be averaged over any 6min period during the 24-h day. (IRPA 1988; ICNIRP 1998).

For the frequency 25-800 Hz, the IRPA-ICNIRP limits for the general population are for electric field intensity E, the value $250/f$ and for magnetic induction B, the value $50/f$, (E in kV/m, B in G, f in Hz). Therefore, at 217 Hz, (the pulse repetition frequency of digital mobile telephony radiations), the ICNIRP limits are 1.15kV/m and 0.23 G for up to 24h exposure during the day, (IRPA 1990; ICNIRP 1998).

As we shall see, during the years after the establishment of the IRPA-ICNIRP exposure criteria, it has been shown that the vast majority of health effects of digital mobile telephony radiations are non-thermal and a lot of biological effects were recorded at radiation intensities much lower than the values of these criteria. This is the reason why several countries in Europe have established much more stringent national exposure criteria, like Italy, Poland, Russia (10 $\mu W/cm^2$), or Salzburg (Austria), (0.1 $\mu W/cm^2$), ("EMF World Wide Standards").

A Review of Biological, Clinical and Epidemiological Data

There is already a very large number of published studies regarding research on possible health risks from cellular mobile telephony radiations. While a large and increasing number of studies (biological, clinical and epidemiological) have recorded a variety of non-physiological changes with increased probabilities for health hazards including several types of cancer, a lot of other studies find no connection between exposure to mobile telephony radiations and health risks. Inconsistencies observed between studies are partly expected since no identical conditions can ever be attained between different studies and different labs, but also they are explained by some authors to be due to biased samples. According to a recent article in which possible secret ties between industries and University researchers are discussed, (Hardell et al, 2007b). Since a large number of studies are funded by companies, a matter arises on how much independent these studies can be.

In the present review we shall emphasize on the studies that indicate different possible effects on living organisms, since we consider that we must take most seriously and focus the most on the possibility that is worse for living organisms and the natural environment. Additionally because of the large number of studies relating RF-microwave radiations in general, we shall concentrate on those that regard to radiations with frequencies and intensities close to those utilized by digital mobile telephony radiations (800-2450 MHz).

A. Biological Effects

Microwaves are found to produce thermally and non-thermally a large number of biological effects, in many cellular and animal studies, (Banik et al, 2003). In the case of radiations emitted by mobile telephony antennas at intensities that people are normally exposed, the effects are non-thermal as verified by different experimenters, (Diem et al, 2005; Panagopoulos et al, 2004; 2007a; 2007b; Leszczynski et al, 2002; Schirmacher et al, 2000; Velizarov et al, 1999)

Regarding non-thermal effects of RF radiations, it is a must to refer to the pioneer works of Bawin et. al. and Blackman et. al. back in the seventies and eighties although these works were relating lower frequency RF radiations. In those pioneer experiments, RF radiation with carrier frequencies 147 and 450 MHz, modulated by sinusoidal ELF signals 0-40 Hz, was found to decrease Ca^{2+} concentration in chicken brain cells. The effect was found to become maximum at modulation frequencies 6-20 Hz and at intensities 0.6-1 mW/cm^2, (Bawin et al 1975; 1978). Non-modulated RF signals were not found to be as bioactive as modulated ones by ELFs and additionally, these effects were found to be non-linearly depended on radiation intensity and frequency, exhibiting “windows” within which the phenomena appeared and then disappeared for values outside, (Blackman et al, 1980; 1989).

Repairable DNA damage and increased expression of heat shock protein Hsp 70 without changes in cell proliferation rates was detected in human lens epithelial cells after 2h exposure to 1.8GHz RF field, amplitude modulated at 217 Hz with 3 W/kg SAR. The DNA damage was determined by use of the comet assay, (Lixia et al, 2006).

Increased expression of genes encoding ribosomal proteins and consequently up-regulating the cellular metabolism in human cell types, was found after in vitro exposure to 900 and 1800MHz mobile phone radiation, (Remondini et al, 2006). In an other study, gene and protein expression were altered in human endothelial cell lines, after 900 MHz GSM mobile phone radiation exposure at an average SAR of 2.8 W/kg. Genes and proteins were differently affected by the exposure in each of the cell lines, suggesting that cell response to this type of radiation might be genome and proteome- dependent which in turn might explain to some extend the discrepancies in replication studies between different laboratories, (Nylund and Leszczynski, 2006).

Exposure of human endothelial cells in vitro, to GSM 900 MHz mobile phone radiation for 1h at non-thermal levels, average SAR 2 W/kg, caused transient increase in heat shock protein hsp27 phosphorylation and transient changes in protein expression levels, (Leszczynski et al, 2002).

Rapid (within minutes) induction of heat shock protein hsp70 synthesis, was found in the insect *Drosophila melanogaster*, after in vivo exposure to GSM 1900 MHz mobile phone radiation, (Weisbrot et al, 2003).

According to a theoretical report, repetitive stress caused by mobile phone radiation, leading to continuous expression of heat shock genes in exposed cells and tissues may result to cancer induction, (French et al, 2001).

Two hours of exposure by a cellular mobile phone, changed the structural and biochemical characteristics of acetylcholinesterase, an important central nervous system enzyme, resulting to a significant alteration of its activity. The enzyme was exposed within an aqueous solution at 5 cm distance from the mobile phone, (Barteri et al, 2004).

Exposure of myoglobin solution to 1.95 MHz microwave radiation for 3h at non-thermal levels was found to affect the folding of the protein and thereby changing its biochemical properties, (Mancinelli et al, 2004).

In vitro exposure for 1h of human skin fibroblasts to GSM radiation, induced alterations in cell morphology and increased the expression of mitogenic signal transduction genes, cell growth inhibitors and genes controlling apoptosis, (Pacini et al, 2002).

In an earlier study, 960 MHz GSM-like signal at SAR 0.021, 0.21 and 2.1 mW/cm^2 with exposure times 20, 30 and 40 min respectively, was found to decrease the proliferation rate of transformed human epithelial amnion cells. The maximum effect was reached at lower power level with a longer exposure time than at higher power level, (Kwee and Raskmark, 1998).

In another study, in vitro exposure of human peripheral blood lymphocytes to continuous 830 MHz radiation, with average SAR 1.6-8.8 W/kg, was found to produce losses and gains of chromosomes (aneuploidy), a somatic mutation leading to cancer. The effect was found to be activated via a non-thermal pathway, (Mashevich et al, 2003).

Long term exposure of rats to 900 MHz mobile phone radiation produced oxidative stress (increased oxidant products of free radicals) in retinal tissue. Melatonin and caffeic acid phenethyl ester (CAPE)- component of honeybee propolis administered daily to the animals prior to their EMR exposure, caused a significant reduction in the levels of the oxidant products, (Ozguner et al, 2006). In a previous study of the same group, melatonin was found to reverse oxidative tissue injury in rat kidneys, after 10 days exposure-30 min per day, to 900 MHz GSM radiation emitted by mobile phone, (Oktem et al, 2005).

Male mice were exposed to 1800 MHz GSM-like microwaves, 0.1 mW/cm^2 for two weeks on workdays, 2h per day. Then mice were anesthetized and blood samples were taken for hematology, serum chemistry and serum testosterone determinations. Additionaly, testicles, epididymes, adrenals, prostates and pituitary glands were removed for histology. Red blood cell count and serum testosterone level were found to be significantly higher in the exposed groups but no significant alterations were found in the other investigated variables, (Forgacs et al, 2005).

Mice prone to the development of lymphomas, exposed for two 30 min periods per day for up to 18 months, to 900 MHz pulsed microwave radiation with a 217 Hz pulse repetition frequency at SAR ranging from 0.007 to 4.3 W/kg, developed twice the number of tumors than the unexposed ones, (Repacholi et al, 1997).

Male Wistar 35-day-old rats were exposed to 2.45 GHz radiation for 2 h/day for a period of 35 days at a power density of 0.344 mW/cm^2, (SAR 0.11 W/kg). After 35 days the rats were sacrificed and whole brain tissue was isolated for protein kinase C (PKC) assay. The study revealed a decrease in PKC activity. Electron microscopy study showed an increase in the glial cell population in the exposed group. The results indicated that chronic exposures may affect brain growth and development, (Paulraj and Behari, 2006a). In another study of the same group, single strand DNA breaks were measured as tail length of comet. Fifty cells from each slide and two slides per animal were observed. The study showed that chronic exposure to microwave radiation at non-thermal levels (SAR 1 and 2 W/kg) causes statistically significant increase in DNA single strand breaks in rat brain cells, (Paulraj and Behari, 2006b).

In another study mice placed within an RF antenna park were repeatedly mated for five times while they were continuously exposed at very low levels of RF radiation (0.168-1.053 $\mu W/cm^2$). A progressive decrease in the number of newborns per maternal mouse was observed after each mating, which ended to irreversible infertility, (Magras and Xenos, 1997). In a more recent study of the same group, it was found that exposure of pregnant rats to GSM-like 940 MHz radiation at 5 $\mu W/cm^2$, resulted in aberrant expression of bone morphogenetic proteins (BMP)-(major endocrine and autocrine morphogens known to be involved in renal development), in the kidneys of newborn rats, (Pyrpasopoulou et al, 2004).

Increase in the number of micronuclei in rat bone marrow erythrocytes, a sign of genotoxicity, was observed after 30 days exposure for 2h daily, to 910 MHz microwave radiation, (Demsia et al, 2004).

In several other mammal studies, no effects were found, in regards to genotoxicity of second generation mobile telephony (GSM, DCS) and third generation, "universal mobile telecommunication system" (UTMS) radiations, (Sommer et al 2007; Oberto et al 2007; Juutilainen et al 2007;Tillmann et al 2007; Gatta et al 2003).

The mortality of chicken embryos was found to increase to 75% from 16% in the control group, after exposure to radiation from a GSM mobile phone, (Grigor'ev, 2003). This result is in agreement with the increased mortality of fertilised chicken eggs that was recorded after irradiation by low power 9.152 GHz pulsed and continuous-wave microwaves, (Xenos and Magras, 2003).

Several studies have reported that microwave exposures increase the permeability of the blood-brain barrier (BBB), an hydrophobic barrier made by endothelial cells to protect the mammalian brain from harmful compounds in the blood. A Swedish group has reported that 915 MHz microwaves at non-thermal intensities causes leakage of albumin into the brain through the BBB in rats, accumulating in the neurons and glial cells which surround the capillaries in the brain, (Salford et al, 1994). The same group reported that GSM mobile phone radiation from a test mobile phone with a programmable constant power output, opens the BBB for albumin, resulting to damage of brain cells in rats. The power density and SAR were within the ICNIRP limits, (Salford et al 2003). These were the first experiments that indicated cell damage caused by mobile phone radiation although this radiation was not a real mobile phone signal. However in an earlier study of the same group, continuous-wave and pulsed 915 MHz radiation at relatively high intensities, 1 W and 2 W respectively, was not found to damage brain or promote brain tumour development in rats, (Salford et al. 1993).

Exposure of an in vitro BBB model, consisted by rat brain cells growing in a culture with pig blood cells, exposed to 1800 MHz microwave radiation pulsed at 217 Hz repetition rate (DCS-like), at SAR 0.3-0.46 W/kg, increased the permeability to sucrose of the BBB twice compared to the control culture. No significant temperature rise was detected during the exposures, (Schirmacher et al, 2000). In a latter study of the same group, in vitro exposure of three other BBB models with distinctly higher barrier tightness than the previously used one, did not cause any effect on the permeability of the BBB of the models, (Franke et al, 2005).

In regards to DNA damage or cell death induction due to microwave exposure, in a series of early experiments, rats were exposed to pulsed and continuous-wave 2450 MHz radiation for two hours at an average power density of 2 mW/cm^2 and their brain cells were subsequently examined for DNA breaks by "comet" assay. The authors found a dose-dependent (0.6 and 1.2 W/kg whole body SAR) increase in DNA single-strand and double-strand breaks, four hours after the exposure to either the pulsed or the continuous-wave radiation, (Lai and Singh 1995; 1996). The same authors found that melatonin and PBN (N-tert-butyl-alpha-phenylnitrone) both known free radical scavengers, block the above effect of DNA damage by the microwave radiation, (Lai and Singh 1997). Although these experiments were the first to report DNA damage by microwaves, the radiation intensity ($2mW/cm^2$) was relatively high, exceeding the international exposure limits (ICNIRP 1998) and additionally the radiation frequency was the same as in microwave ovens. This is why the authors of this review cannot be sure on whether the reported effects were thermal or non-thermal.

In vitro exposure of mouse fibroblasts and human glioblastoma cells to 2450 MHz, (Malyapa et al, 1997a), 835.62 MHz and 847.74 MHz (Malyapa et al, 1997b), radiations at SAR 0.6 W/kg, was not reported to damage DNA as measured by comet assay.

A number of recent studies have reported DNA damage, or cell damage, or cell death, induced by mobile telephony or similar RF radiations at non-thermal intensity levels, (Aitken et al, 2005; Diem et al 2005; Panagopoulos et al 2007; Salford et al, 2003; Markova et al, 2005; Caraglia et al, 2005; Nikolova et al, 2005), while some other studies did not find any such connection, (Hook et al, 2004; Capri et al, 2004a; 2004b; Meltz 2003; Cranfield et al, 2003). Aitken et al 2005, reported damage to mitochondrial genome and the nuclear beta-globin locus in the spermatozoa of mice exposed to 900 MHz, 0.09 W/kg SAR, for 7 days, 12h per day. Diem et al 2005, reported single and double-strand DNA breakage in cultured human and rat cells exposed to 1800 MHz mobile phone-like radiation. Panagopoulos et al 2007a, found DNA fragmentation at a very high degree, caused in the reproductive cells of female *Drosophila* insects only by few min daily exposure to a real mobile phone signal for only few days. These were the first experiments that showed extensive DNA damage and cell death by real digital mobile phone GSM and DCS signals. Previous experiments of the same group had shown a large decrease in the reproductive capacity of the same insect, caused by real mobile phone similar exposures, (Panagopoulos et al, 2004).

B. Clinical Studies on Humans. Effects on EEG, EDA, Melatonin, etc

Mobile telephony radiation is found in several studies to affect electroencephalograms (EEG), electrodermal activity (EDA) and the synthesis rate of hormones like melatonin, in humans.

In a series of early experiments performed by a Finish group, GSM mobile phone exposure was found to alter the EEG oscillatory activity of healthy adult subjects, in the 6-8 and 8-10 Hz frequency bands during cognitive (visual memory) tasks, (Krause et al, 2000). In more recent experiments of the same group, exposure of 10-14 year old children to mobile phone GSM field while performing an auditory memory task, induced changes in their brain oscillatory EEG responses in the frequencies 4-8 Hz and 15 Hz, (Krause et al, 2006).

Exposure for 30 min to pulse modulated 900 MHz mobile phones-like EMF, increased waking regional cerebral blood flow (rCBF) and enhanced EEG power in the alpha frequency range (8-12 Hz) prior to sleep onset and during sleep. Exposure to the same field without pulse modulation did not enhance power in waking or sleep EEG, (Huber et al, 2002). In another set of experiments of the same group, 30 min exposure to the same 900 MHz GSM-like field during waking period preceding sleep, increased the spectral power of the EEG in non-rapid eye movement sleep. The maximum increase occurred in the 9.75-11.25 Hz and 12.5-13.25 Hz frequency ranges during the initial part of the sleep. Since exposure during waking, modified the EEG during subsequent sleep, the changes in the brain function induced by mobile telephony radiation are considered to outlast the exposure period, (Huber et al, 2000).

Mobile phone exposure prior to sleep was found to decrease rapid eye movement sleep latency and to increase EEG spectral power in the 11.5-12.5 Hz frequency, during the initial part of sleep following exposure, (Loughran et al, 2005).

Some other studies have failed to find any effects of mobile phone-microwave exposures on EEG during cognitive testing, or to replicate earlier findings, (Röschke and Mann, 1997; Wagner et al., 1998).

Mobile phone radiation was found to affect the evoked neuronal activity of the central nervous system (CNN) as represented by EDA, an index of the sympathetic nervous system. Mobile phone exposure was found to lengthen the latency of EDA (Skin Resistance Response), irrespectively of the head side next to mobile phone, (Esen and Esen, 2006). Therefore, mobile phone exposure may increase the response time of users with different negative consequences, like for example the increase in the risk of phone-related driving hazards, e.t.c.

A statistically significant increase of chromosomal damage was found in blood lymphocytes of people who used GSM 900 MHz mobile phones, compared to a control group of non-users, matched according to age, sex, health status, drinking and smoking habits, working habits, and professional careers. The increase was even greater for users who were smoker-alcoholic, (Gadhia et al, 2003)

In another type of clinical study, exposures of humans to GSM 900 MHz and DCS 1800 MHz mobile phones fields for 35 min, were not found to change significantly arterial blood pressure or heart rate during or after the exposure, (Tahvanainen et al, 2004).

Prolonged use of mobile phone, (more than 25 min per day), was found to induce a reduction in melatonin production among male users. The effect was enhanced by additional exposure to 60 Hz ELF magnetic field, (Burch et al, 2002).

Two studies about possible immediate- short term effects of GSM and UTMS (third generation of mobile networks)-like exposure on well being and cognitive performance in humans based on questionnaires, found contradictive results. The first (Zwamborn et al, 2003) reported no effects of GSM-like exposure, while the UTMS-like exposure was found to reduce well-being and cognitive performance. The second, (Regel et al, 2006) reported no effects at all from either type of radiation. The opinion of the authors of this review is that studies based on questionnaires cannot be as much objective as studies based on measurable indexes like EEG or EDA. Besides, it would be unlikely that subjects would report themselves immediate effects on their well-being.

C. Epidemiological Studies

According to the Swedish Prof. L. Hardell and his research group, the concluding results of up to date epidemiological studies among users for more than ten years use of mobile phones indicate consistently an increased risk for acoustic neuroma and glioma, especially for ipsilateral exposure, (Hardell et al, 2007a). Earlier work of the same research group had found a connection between digital (2nd generation) and analogue (1st generation) mobile phones use and malignant brain tumors, highest for more than ten years latency period, (Hardell et al, 2006).

Another review study of the Austrian Prof. M.Kundi conducted few years ago, states as the resume from several epidemiological and experimental studies, that long term exposure to mobile phone emissions (analogue and digital) constitutes a small to moderate increased risk for developing certain types of cancer, (Kundi, 2004).

Several other studies had not found any association between mobile phone use and cancer, (Inskip et al, 2001; Johansen et al, 2001; Muscat et al, 2002).

A major difficulty in epidemiological studies among mobile phone users is the variation of parameters governing the exposure from hand held mobile phones, i.e. the distance from the nearest base station which can considerably change the intensity of the radiation emitted by the phone, the actual duration of daily use, e.t.c. Nevertheless, the studies done on habitants living close to base stations are more consistent since the station emits a more constant radiation level on a daily basis and therefore a person residing nearby, receives a measurable radiation at least for several hours per day.

A recent Egyptian study (Abdel-Rassoul et al, 2007) found that inhabitants living nearby mobile telephony base stations may develop a number of neuropsychiatric problems like headaches, memory changes, dizziness, tremors, depression, sleep disturbances, reported also in previous studies as “microwave syndrome” (Navarro et al 2003), plus changes in the performance of neurobehavioral functions. Similar results were found by other studies in different countries like in France, (Santini et al 2003), Poland (Bortkiewicz et al 2004), Spain (Navarro et al 2003), Austria (Hutter et al 2006).

Other epidemiological studies have reported diminishes in the populations of birds around mobile telephony base stations at distances 100-600m from the masts in Belgium, (Everaert and Bauwens 2007) and within 200m from the masts in Spain (Balmori 2005). These studies are in agreement with earlier biological studies which had reported increased mortality of avian embryos, exposed to low levels (5-120 $\mu W/cm^2$) of RF antennae radiation, (Xenos and Magras, 2003).

The Design of Bioelectromagnetic Experiments and a Reason for Inconsistencies

As described in the previous paragraphs, there are frequently contradictory results in the bioelectromagnetic experiments performed by different labs. One factor that we have found to be very important and able to completely change the results of a biological experiment is the influence of the stray electromagnetic fields that exist inside any lab.

Within a usual room inside a house or laboratory there are 50-60 Hz fields due to the electric wirings and electrical appliances. Close to the walls, near to sockets or close to electrical appliances one can measure electric fields up to 50 V/m and magnetic fields up to 10 mG. Such fields are found to affect biomolecules, cells and whole organisms in different ways and therefore to affect the outcome of any biological experiment, (Goodman E. et al. 1995; Panagopoulos et al. 2002; Weaver and Astumian 1990). Prior to the design of any biological experiment, a careful scanning of stray fields inside the lab is necessary. The experiments should be performed at the place with the minimum stray fields and special care should be taken in having the control under identical conditions with the exposed groups except only for the factor studied. Temperature, light and humidity are additional important factors that should be identical between exposed and control groups.

Before the relatively recent evolution of knowledge in the field of Bioelectromagnetism, ambient electromagnetic fields within the labs were not taken into account in biological experiments. But living organisms are very sensitive to external electromagnetic fields, natural or artificial ones. Rooms or devices used as incubators, are constructed to keep a constant temperature, humidity, e.t.c. in their internal space, but usually are sources of EMFs from their own electrical circuits. A specialized physicist should always be member of any experimental team for taking good care of such factors.

Effects of Mobile Telephony Radiation on a Model Organism

Introduction

In order to study the ability of the electromagnetic signals emitted by cellular mobile telephony antennas to affect the biological function of living organisms, we used a biological model, the reproductive capacity of the insect *Drosophila melanogaster*, a well studied experimental animal with many advantages, including its short life cycle and the good timing of its metamorphic stages and developmental processes, (King 1970). Especially the good timing of this insect's early developmental stages (oogenesis, spermatogenesis, embryogenesis, larval and pupal stages), under certain environmental conditions (i.e. temperature, humidity, food e.t.c.), is a very important feature, on which our experimental protocols were based.

In order to study the effects of mobile telephony radiation on the reproductive capacity, we exposed the insects to real mobile phone signals, emitted by commercially available handsets.

The basic cellular processes are identical in insect and mammalian cells. In addition, insects (particularly *Drosophila*) are much more resistant, at least to ionizing electromagnetic radiation, than mammals, (Koval and Kazmar 1988, Koval et al 1979, 1977, Abrahamson et al 1973). Therefore, a proper experimental protocol relating *Drosophila* can be very useful in assessing the bioactivity of electromagnetic radiation in general, (including non-ionizing radiation and electromagnetic fields).

Our experiments, regarding few minutes daily exposure of this model organism for only few days, to cellular mobile phone signals, have shown a large decrease in the reproductive capacity, affecting both sexes (Panagopoulos et al 2004). Both systems of digital mobile telephony radiation used in Europe, GSM 900 MHz and DCS 1800 MHz were found to decrease the insect's reproductive capacity, but GSM 900 MHz was found to be even more bioactive than DCS 1800 MHz, mainly due to the higher intensity of GSM 900 MHz antennas compared to DCS 1800 MHz ones, (Panagopoulos et al 2007b; 2007a). The decrease in the reproductive capacity was found to be due to induced cell death (DNA fragmentation) in the gonads, caused by both types of mobile telephony signals, (Panagopoulos et al 2007a). Unpublished experiments of ours presented here for the first time, show that the bioactivity is strongly and non-linearly dependent on the intensity of the radiation, becoming maximum for intensities higher than 200 $\mu W/cm^2$ and within an "intensity window" around 10 $\mu W/cm^2$.

Materials and Methods

Experimental Animal

We used *Drosophila melanogaster* flies, wild-type strain, Oregon R, held in glass bottles with standard food, kept in incubator at 25 °C, with 12-h periods of light and darkness and 70% relative humidity, cultured according to standard methods, (Panagopoulos et al 2004).

The food consisted of 450ml water, 4g agar, 13g yeast, 32g rice flour, 16g sugar, 25g tomato pulp. The mixture was boiled for over 10min to ensure sterility, which was preserved by the addition of 2ml propionic acid and 2ml ethanol. This food quantity was enough for 25-30 glass vials which were sterilized before the food was added.

In each experiment, we collected newly emerged adult flies from the stock early in the afternoon, anesthetized them lightly with diethyl ether and separated males from females. We divided the collected flies in groups of ten in standard laboratory cylindrical glass vials, with 2.5cm diameter and 10cm height, with standard food, which formed a smooth plane surface, 1cm thick at the bottom of the vials. The vials were closed with cotton plugs.

Exposure System

Before each set of experiments we measured the mean power density of the radiation emitted by the mobile phone handset in the RF range at 900MHz and/or 1800MHz, with the field-meter, "RF Radiation Survey Meter, NARDA 8718", with its probe inside a glass vial similar to the ones we used for the insects in our experiments. In addition, we measured in the same way the mean electric and magnetic field intensities at the Extremely Low Frequency (ELF) range, with the field-meter, "Holaday HI-3604, ELF Survey Meter".

The experimenter's position in relation to the mobile phone during the measurements was the same as during the exposures. The mobile phone was held close to the experimenter's head with its antenna facing downward. The exposures and the field measurements, took place in a quiet but not sound-isolated room to simulate the actual conditions to which a user is subjected during a normal conversation on the mobile phone. The room conditions and the positions of all items around the experimental bench were always the same. Exposures and measurements of mobile phone emissions were always conducted at the same place where the mobile phone had full perception of both GSM and DCS signals. The handset was fully charged before each set of exposures or measurements.

In the most new digital cell phone handsets, the antenna is in the back and upper side of the device. This can be easily verified by measuring the emitted radiation holding the probe of the field meter in contact with different parts of the handset's surface.

The measured exposure values were in general within the established exposure limits, (ICNIRP 1998).

We used commercially available digital mobile phone handsets in all the sets of our experiments, in order to analyze effects of real mobile telephony exposure conditions. As far as we know, we were the first to use a commercially available mobile phone handset itself in biological experiments, (Panagopoulos et al 2000a). The obvious reason was that these devices are the most powerful RF transmitters in our immediate daily environment. Thus, instead of using simulations of digital mobile telephony signals with constant parameters (frequency, intensity etc), or even "test mobile phones" programmed to emit mobile telephony signals with controllable power or frequency, we used real GSM, DCS signals which are never constant, since there are continuous changes in their intensity and frequency. Electromagnetic fields with changing parameters are found to be more bioactive than fields with constant parameters, (Goodman E.M. et al 1995; Diem et al 2005), probably because it is more difficult for living organisms to get adapted to them. Experiments with constant GSM or DCS signals can be performed, but they do not simulate actual conditions. Later other experimenters also started to use mobile phone handsets as exposure devices apparently for the same reasons, (Weisbrot et al 2003; Barteri et al 2005).

We exposed the flies within the glass vials by placing the antenna of the mobile phone outside of the vials, in contact with or at different distances from the glass wall and parallel to the vial's axis. The total duration of exposure was 6min per day in one dose and we started the exposures on the first day of each experiment (day of eclosion). The exposures took place for a total of 2 to 6 days in each experiment depending on the kind of the experiment, as described below. The daily exposure duration of 6min, was chosen in order to have exposure conditions that can be compared with the established exposure criteria, (ICNIRP 1998). Besides, early experiments had shown that only few minutes of daily exposure were enough to produce a significant effect on the insect's reproductive capacity (Panagopoulos et al, 2000a).

The experimenter could speak on the mobile phone during connection (this we called, "modulated" or "speaking" emission), or could just stay silent, ("non-modulated" or "non-speaking" emission, or DTX mode). The intensity of the emitted radiation increases about ten times when the user speaks during connection, than when there is no speaking, (Panagopoulos et al, 2000a).

Exposure Procedures

We carried out six sets of experiments: In the first set, we exposed the insects to the mobile phone's GSM 900 MHz field while the mobile phone was operating in non-speaking mode, (non-modulated emission or DTX). In the second set of experiments, the mobile phone was operating in speaking mode, (modulated emission) during the exposures. In the third set of experiments we investigated the effect of the mobile phone signal on the reproductive capacity of each sex separately. In the fourth set of experiments we compared the bioactivity between GSM 900 MHz and DCS 1800 MHz types of mobile telephony signals. In the fifth set of experiments we exposed the insects to different distances (intensities), from the mobile phone antenna from 0 to 100 cm, for both types of radiation. Finally, in the sixth set of experiments we tested the ability of GSM and DCS fields to induce DNA fragmentation (cell death) in the ovarian cells of the female insects during oogenesis.

In every single experiment we separated the newly emerged collected adult flies to exposed (E) and sham-exposed (SE)/control (C) groups. Each one of the groups consisted always of ten female and ten male, newly emerged flies. The sham exposed groups had identical treatment as the exposed ones, except that the mobile phone during the 6-min "exposures", was turned off.

Every time before each exposure, the cotton plugs were pushed down in the glass vials in order to confine the flies to a small area of about 1cm height between the cotton and the food so as to provide roughly even exposure to all flies. After the exposure, the cotton plugs were pulled back to the top of the vials, and the vials were put back in the culture room.

In every group of insects in all the sets of experiments, we kept the ten males and the ten females for the first 48h of the experiment in separate glass tubes. At eclosion, adult female flies have already in their ovaries eggs at the first preyolk stages and oogenesis has already started. The eggs develop through 14 distinct stages, until they are ready to be fertilized and laid, and the whole process of oogenesis lasts about 48h. By the end of the second day of their adult life, the female flies have in their ovipositors the first fully developed egg chambers of stage 14^{th}, ready to be fertilized and laid, (King 1970; Panagopoulos et al 2004). At the same time, the first mature spermatozoa, (about 6h after eclosion) and the necessary paragonial substances (about 12h after eclosion) in male flies have already been developed (King 1970; Stromnaes and Kvelland 1962; Connolly and Tully 1998). Keeping males separately from females for the first 48h of the experiment ensures that the flies are in complete sexual maturity and ready for immediate mating and laying of fertilized eggs.

After the first 48h of each experiment, the flies were anesthetized very lightly again and males and females of each group were put together (ten pairs) in another glass tube with fresh food, allowed to mate and lay eggs for 72h. During these three days, the daily egg production of *Drosophila* is at its maximum (from the 3^{rd} to 5^{th} day of its adult life), then stays at a plateau or declines slightly for the next 5 days and diminishes considerably after the 10^{th} day of adult life (Bos and Boerema 1981; Shorrocks 1972; Ramirez et al 1983).

On the sixth day of each experiment in all six sets of experiments, the flies were removed from the glass vials and the vials were maintained in the culture room for six additional days, without further exposure.

After the last six days, most F_1 embryos (deriving from the laid eggs) are in the stage of pupation, where they can be clearly seen with bare eyes and easily counted on the walls of the glass tubes, as at the last stages before pupation, the larvae leave the food, crawling up the walls of the glass vials. There may be a few embryos still in the last stages as larvae, which are big enough and ready for pupation (on the surface or already away from the food), so that they can be easily counted. [If the remaining larvae are still many and the counting is imprecise, the experimenter can wait an additional day and recount the pupae]. There may be also already a few newly emerged F_1 adult flies, which can also be counted easily.

During the last six days, we inspected the surface of the food within the glass vials under the stereo-microscope for any non-developed laid eggs or dead larvae, something that we did not see in our experiments (empty egg-shells can be seen after hatching). The number of observed exceptions (non-developed eggs or dead larvae), both in exposed and control groups (less than 5%) was within the Standard Deviation of progeny number. [The insignificant percentage of F_1 egg and larvae mortality is due to the fact that the paternal-maternal flies were newly emerged during the first 2-5 days of their adult lives]. Therefore the number of pupae in our experiments corresponded to the number of laid eggs (oviposition). Furthermore, the counting of pupae can be done without any error at all, whereas the counting of laid eggs under a stereo-microscope is subject to considerable error.

The oviposition of *Drosophila* is influenced by many factors, like temperature, humidity, prior anesthesia, crowding, food, (King 1970). Special care must be taken to keep all these factors constant. Experience in handling the flies is necessary to prevent accidental deaths.

This number of F_1 pupae under the above described conditions, during the insect's three days of highest oviposition, is that we have defined as the Insect's Reproductive Capacity and this is the biological index we have used to examine the bioactivity of electromagnetic radiation-field.

The temperature during the exposures was monitored within the vials with a mercury thermometer with an accuracy of 0.05°C.

In the sixth set of experiments, after the additional last exposure in the morning of the sixth day from the beginning of each experiment, the flies were removed from the glass vials, and the ovaries of females were dissected into individual ovarioles and fixed for TUNEL assay. The vials were then maintained in the culture room for six additional days, without further exposure, in order to count the F_1 pupae as in all the sets of experiments.

TUNEL Assay

A widely used method for identifying cell death is TUNEL assay. By use of this method, fluorescein dUTP is bound through the action of terminal transferase, onto fragmented genomic DNA which then becomes labelled by characteristic fluorescence. The label incorporated at the damaged sites of DNA is visualized by fluorescence microscopy, (Gavrieli et al, 1992).

Each Drosophila ovary consists of 16 to 20 ovarioles. Each ovariole is an individual egg assembly line, with new egg chambers in the anterior moving toward the posterior as they develop, through the 14 successive stages as described, until the mature egg reaches the oviduct.

To determine the ability of GSM and DCS radiation to act as possible stress factors able to induce cell death during early and mid oogenesis, we used TUNEL assay, as follows: Ovaries were dissected in Ringer's solution and separated into individual ovarioles from which we took away egg chambers of stages 11-14. In egg chambers of stages 11-14 programmed cell death takes place normally in the nurse cells and follicle cells. Thereby we kept and treated ovarioles and individual egg chambers from germarium up to stage 10. Samples were fixed in PBS solution containing 4% formaldehyde plus 0.1% Triton X-100 (Sigma Chemical Co., Germany) for 30min and then rinsed three times and washed twice in PBS for 5 min each. Then samples were incubated with PBS containing 20 μg/ml proteinase K for 10 minutes and washed three times in PBS for 5 min each. In situ detection of fragmented genomic DNA was performed with Boehringer Mannheim kit containing fluorescein dUTP for 3h at 37°C in the dark. Samples were then washed six times in PBS for 1h and 30 min in the dark and finally mounted in antifading mounting medium (90% glycerol containing 1.4-diazabicyclo (2.2.2) octane (Sigma Chemical Co., Germany) to prevent from fading and viewed under a Nikon Eclipse TE 2000-S fluorescence microscope.

Results and Discussion

In the first two sets of experiments, we separated the insects into two groups: a) the Exposed group (E) and b) the Sham Exposed group (SE). The 6-min daily exposures took place for the first five days of each experiment.

In the first three sets of experiments, the exposures were performed by GSM 900 MHz mobile phone radiation-field. Before the exposures, we measured radiation and field intensities, as described above. In the RF range, the measured mean power density for 6min of modulated emission (M), with the antenna of the mobile phone outside of the glass vial in contact with the glass wall and parallel to the vial's axis was 0.436±0.060 mW/cm^2. The non-modulated (NM) corresponding measured mean value, was 0.041±0.006 mW/cm^2. In the ELF range, the measured values for modulated field, excluding the ambient electric and magnetic fields of 50Hz, were 6.05±1.62 V/m electric field intensity and 0.10±0.06 mG magnetic field intensity. The corresponding non-modulated values were 3.18±1.10 V/m and 0.030±0.003 mG. All given values are average from eight separate measurements of each kind ± Standard Deviation (SD). These values are typical for all commonly used GSM 900 MHz mobile phone handsets.

1. Effect of Non-Modulated GSM radiation-field on the Reproductive Capacity

We carried out four experiments (1.1-1.4) with non-modulated field, (non-speaking emission). The exposure parameters in this case simulate the situation when a user listens through the mobile phone during connection.

Results are listed in Table 1.

Table 1 shows the mean number of F_1 pupae (corresponding to the number of laid eggs) per maternal fly in the groups E(NM) exposed to Non-Modulated (NM), GSM 900 MHz mobile phone field and in the corresponding sham exposed (control) groups SE(NM) during the first three days of the insect's maximum oviposition.

The Non-Modulated GSM 900 MHz signalss, decreased the insect's reproductive capacity by up to 20% in relation to the unexposed groups with six min daily exposure for five days. No temperature increases were detected within the vials during the exposures.

Table 1. Effect of Non-Modulated GSM field on the Reproductive Capacity of *Drosophila melanogaster*

Experiment No	Groups	Mean Number of F_1 Pupae per Maternal Fly	Deviation from Control
1.1	E(NM)	9.7	-16.38%
	SE(NM)	11.6	
1.2	E(NM)	10	-15.96%
	SE(NM)	11.9	
1.3	E(NM)	9.8	-20.16%
	SE(NM)	12.4	
1.4	E(NM)	10.4	-19.38%
	SE(NM)	12.9	
Average ± SD	E(NM)	9.975 ± 0.31	-18.24%
	SE(NM)	12.2 ± 0.57	

Statistical analysis, (single factor ANOVA test) shows that the probability that mean oviposition differs between the exposed and the sham exposed groups, owing to random variations, is $P < 5\times10^{-4}$. Therefore, the decrease in the reproductive capacity is due to the effect of the GSM field.

2. Effect of Modulated GSM Radiation-field on the Reproductive Capacity

We carried out four experiments (2.1-2.4), with modulated emission (the experimenter was speaking close to the mobile phone's microphone, during the exposures). The exposure parameters in this case simulate the situation when a user speaks on the mobile phone during connection. Results are listed in Table 2.

Table 2 shows the mean number of F_1 pupae (corresponding to the number of laid eggs) per maternal fly in the groups E, exposed to "Modulated" GSM field and in the corresponding sham exposed groups, SE, during the first three days of the insect's maximum oviposition.

The Modulated GSM 900 MHz signals induced a large decrease in the insect's reproductive capacity up to 60% as compared to the unexposed groups. No temperature increases were detected during the exposures and thus these effects are considered as non-thermal.

Table 2. Effect of Modulated GSM field on the Reproductive Capacity of *Drosophila melanogaster*

Experiment No	Groups	Mean Number of F_1 Pupae per Maternal Fly	Deviation from Control
2.1	E(M)	6.7	-48.85%
	SE (M) (Control)	13.1	
2.2	E	5.1	-56.78%
	SE (M) (Control)	11.8	
2.3	E	5.6	-53.72%
	SE (M) (Control)	12.1	
2.4	E	6	-53.125%
	SE (M) (Control)	12.8	
Average ± SD	E (M)	5.85 ± 0.67	-53.01%
	SE (M) (Control)	12.45 ± 0.6	

The reproductive capacity was much more decreased by modulated emission, (50-60%), than by non-modulated emission, (15-20%). Thus the effect is strongly dependent on radiation-field intensity. At the same time, the intensity of the modulated signal, is about ten times more powerful than the non-modulated signal. Thereby, the effect is not linearly dependent on radiation intensity.

The results from the first two sets of experiments are represented, in Figure 1.

The statistical analysis shows that the probability that mean oviposition differs between the exposed and the sham exposed groups, owing to random variations, is very small, $P < 10^{-5}$. Thus the recorded effect is due to the GSM signal.

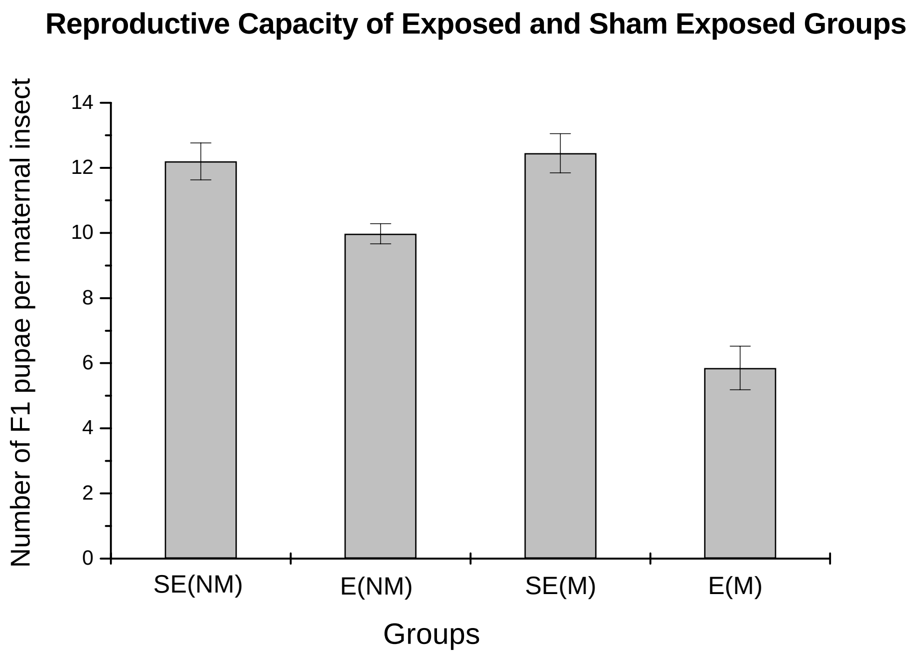


Figure 1. Reproductive Capacity of the groups exposed to non-modulated and modulated GSM 900 MHz field [E(NM), E(M)] and the corresponding sham exposed, [SE(NM), SE(M)], groups. [The error bars correspond to Standard Deviation].

3. Effects on the Reproductive Capacity of Each Sex

A third set of experiments (C) was carried out in order to record the effect of the GSM 900 MHz field on the reproductive capacity of each sex separately. The mobile phone was operating in speaking mode during the 6 min exposures, and the insects were separated into four groups (each one consisting again 10 male and 10 female insects): In the first group (E1), both male and female insects were exposed. In the second group (E2), only the females were exposed. In the third group (E3), we exposed only the males and the fourth group (SE) was sham exposed (control). Therefore in this third set of experiments, the 6-min daily exposures took place only during the first two days of each experiment while the males and females of each group were separated and the total number of exposures in each experiment was 2 instead of 5.

The results from this set of experiments are listed in Table 3 and represented graphically in Figure 2.

The results of this set of experiments show that the GSM field affects the reproductive capacity of both female and male insects. The female insects (E2) were more affected than males (E3) in these experiments. This is expected to be due to the fact that, by the time we started the exposures, spermatogenesis was already almost completed in male flies, while oogenesis had just started, (King 1970; Panagopoulos et al 2004).

Statistical analysis (single factor ANOVA test) shows that the probability that mean oviposition differs between the four groups because of random variations is $P < 10^{-7}$.

Table 3. Effect of "Modulated" GSM field on the Reproductive Capacity of each sex

Experiment No	Groups	Mean Number of F_1 Pupae Per Maternal Fly	Deviation from Control
3.1	SE(Control)	13.2	
	E1	8.5	-35.61%
	E2	9.4	-28.79%
	E3	11.7	-11.36%
3.2	SE (Control)	13.8	
	E1	7.6	-44.93%
	E2	8.9	-35.51%
	E3	12.1	-12.32%
3.3	SE (Control)	12.9	
	E1	7.8	-39.53%
	E2	9.3	-27.91%
	E3	11	-14.73%
3.4	SE (Control)	13.5	
	E1	6.9	-48.89%
	E2	7.8	-42.22%
	E3	12.2	-9.63%
Average ±SD	SE (Control)	13.35 ± 0.39	
	E1	7.7 ± 0.66	-42.32%
	E2	8.85 ± 0.73	-33.71%
	E3	11.75 ± 0.54	-11.985%

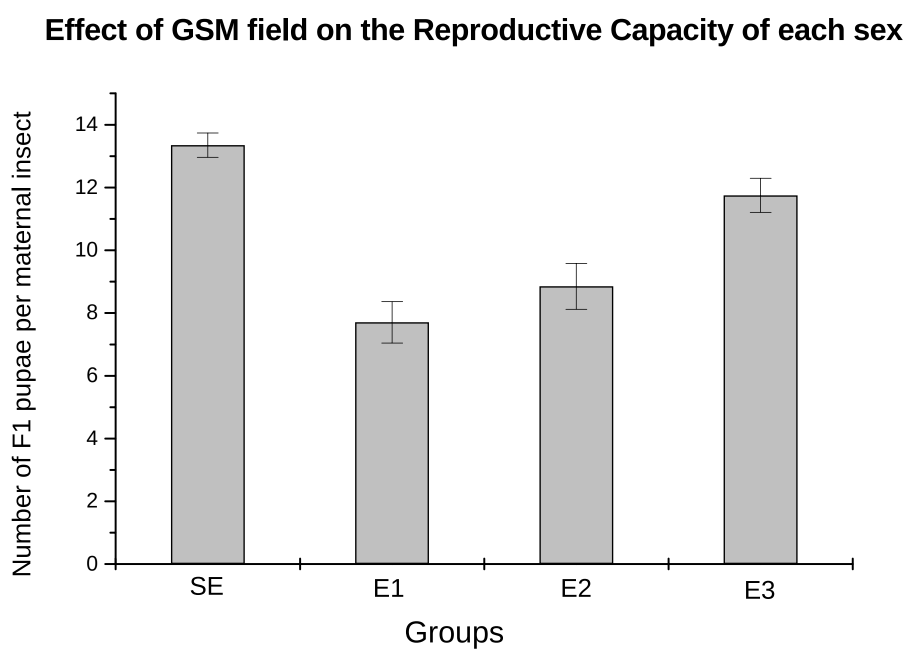


Figure 2. Effect of Modulated GSM field on the reproductive capacity of each sex of *Drosophila melanogaster*. Average mean number of F_1 pupae ±SD per maternal insect. SE: sham exposed groups, E1: groups that both sexes were exposed, E2: groups in which only the females were exposed, E3: groups in which only the males were exposed.

In the following fourth, fifth and sixth set of experiments, we used a dual band cellular mobile phone that could be connected to either GSM 900 or DCS 1800 networks simply by changing SIM ("Subscriber Identity Module") cards on the same handset. The highest Specific Absorption Rate (SAR), given by the manufacturer for human head, was 0.89 W/Kg. The exposure procedure was the same. The experimenter spoke on the mobile phone's microphone during the exposures. The GSM and DCS fields were thus "modulated" by the human voice, ("speaking emissions" or "GSM basic").

4. Comparison of Bioactivity between GSM 900 MHz and DCS 1800 MHz

In this set of experiments we separated the insects into four groups: a) the group Exposed to GSM 900MHz field with the mobile phone antenna in contact with the glass vial containing the flies (named as "900"), b) the group exposed to GSM 900MHz field with the antenna of the mobile phone at 1cm distance from the vial (named as "900A"), c) the group exposed to DCS 1800MHz field with the mobile phone antenna in contact with the glass vial (named as "1800"), and d) the Sham Exposed (Control) group (named as "SE"). The comparison between first and third group represents comparison with the usual exposure conditions between GSM 900 and DCS 1800 users, while comparison between second and third group represents comparison between possible effects of the RF frequencies of the two systems under equal radiation intensities. Therefore the second group (900A) was introduced for better comparison of effects between the two types of radiation.

Measured mean power densities in contact with the mobile phone antenna for six min of modulated emission, were 0.407 ± 0.061 mW/cm^2 for GSM 900 MHz and 0.283 ± 0.043 mW/cm^2 for DCS 1800 MHz. As was expected GSM 900 MHz intensity at the same distance from the antenna and with the same handset was higher than the corresponding DCS 1800 MHz. For the better comparison between the two systems of radiation we measured the GSM power density at different distances from the antenna and found that at 1cm distance, the GSM 900 MHz intensity was 0.286± 0.050 mW/cm^2, almost equal to DCS 1800 MHz at zero distance. Measured electric and magnetic field intensities in the ELF range for modulated field, excluding the ambient electric and magnetic fields of 50Hz, were 22.3±2.2 V/m electric field intensity and 0.50±0.08 mG magnetic field intensity for GSM at zero distance, 13.9±1.6 V/m, 0.40±0.07 mG correspondingly for GSM at 1 cm distance and 14.2 ±1.7 V/m, 0.38±0.07 mG correspondingly for DCS at zero distance. All these values are averaged over ten separate measurements of each kind ± standard deviation (SD).

Except for the power density - field measurements of the mobile phone emissions, we obtained the spectra of both types of radiation, plus the background spectrum in our lab, (Fig. 3). Each one of the two types of radiation gave a unique frequency spectrum. While GSM 900MHz gives a single peak around 900MHz, (Fig. 3b), DCS 1800MHz gives a main peak around 1800MHz and a smaller one around 900MHz, (Fig. 3c). The spectra were obtained by a Hewlett Packard 8595 E, (9 kHz-6.5 GHz), spectrum analyzer (USA).

We carried out ten replicate experiments. Results are listed in Table 4 and represented graphically, in Figure 4.

The results from this set of experiments show that the reproductive capacity in all the exposed groups is significantly decreased compared to the sham exposed groups. The decrease is maximum in the 900 groups, (48.25% compared to SE) and smaller in the 900A and the 1800 groups, (32.75% and 31.08% respectively), (Table 4). Although the decrease was even smaller in the 1800 groups than in 900A, differences between the 900A and 1800 groups were found to be within the standard deviation, (Table 4, Figure 4).

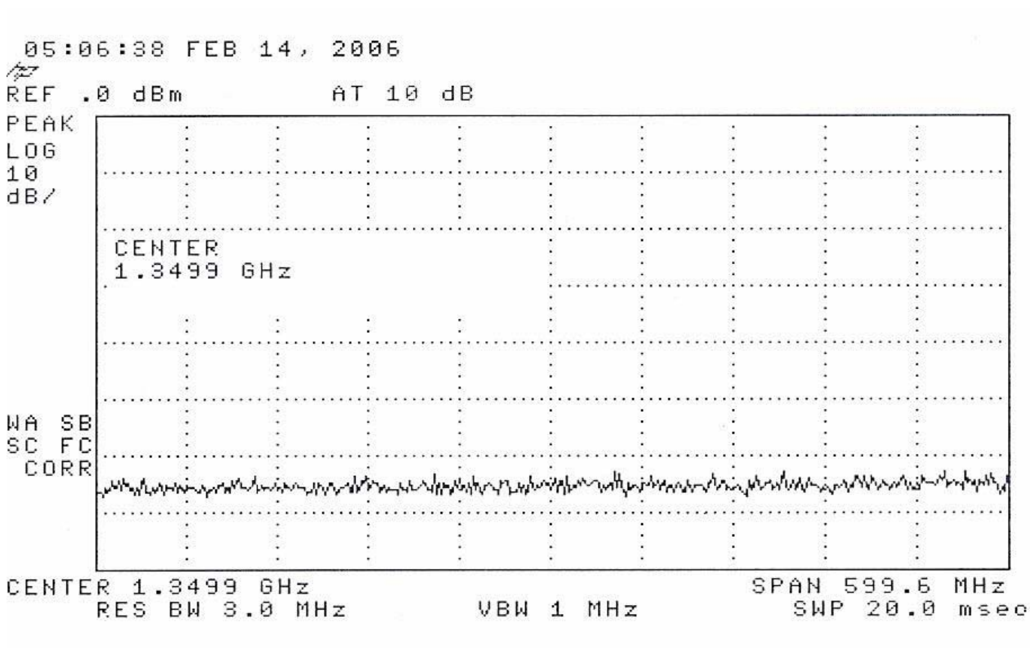
The statistical analysis shows that the probability that the reproductive capacity differs between groups, owing to random variations, is negligible, $P < 10^{-18}$.

Again, we did not detect any temperature increases, within the glass vials during the exposures.

The differences in the reproductive capacity between the groups were greater between 900 and 900A (owing to intensity differences between the two types of radiation) and much smaller between 900A and 1800, (owing to frequency differences between GSM and DCS), (Table 4).

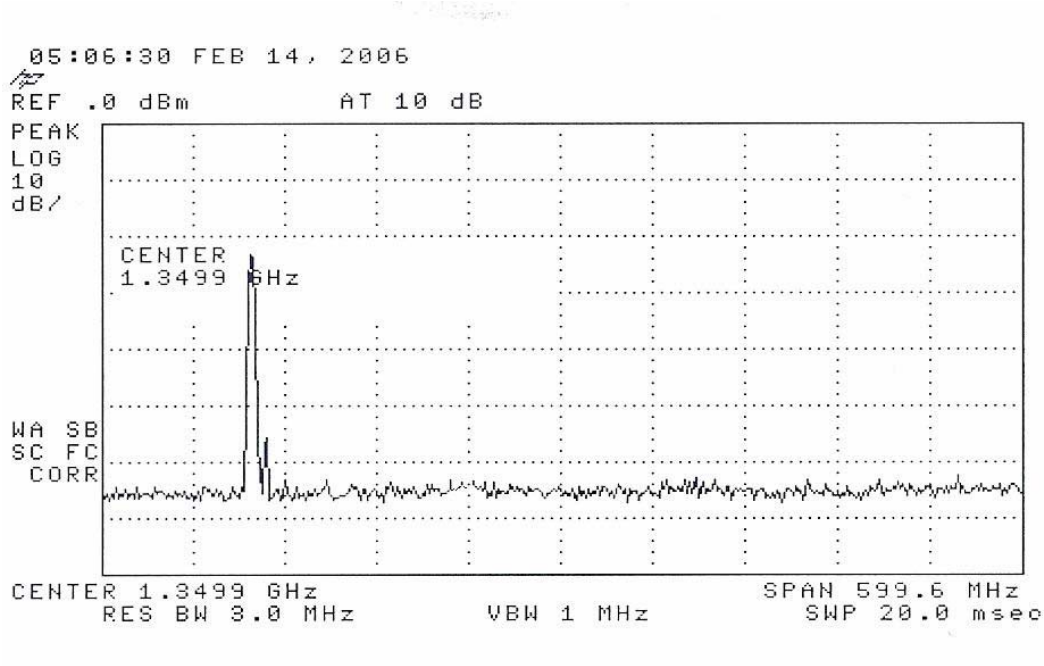
This set of experiments shows that there is a difference in the bioactivity between GSM 900 MHz and DCS 1800 MHz and this difference is mainly due to the higher intensity of GSM 900 under the same exposure conditions, (differences between groups 900 and 900A) and not due to the different RF carrier frequencies, (differences between 900A and 1800 groups).

Intensity differences between the two types of cellular mobile telephony radiation depend also on the ability of communication between the antennas of the mobile phone and the corresponding base station. Even if GSM 900 usually has a higher intensity than DCS 1800, this situation can be reversed in certain places if GSM 900 has a much better signal perception between its antennas than DCS 1800, (Tisal 1998). Our results count for equal signal perception conditions between the two types of radiation.

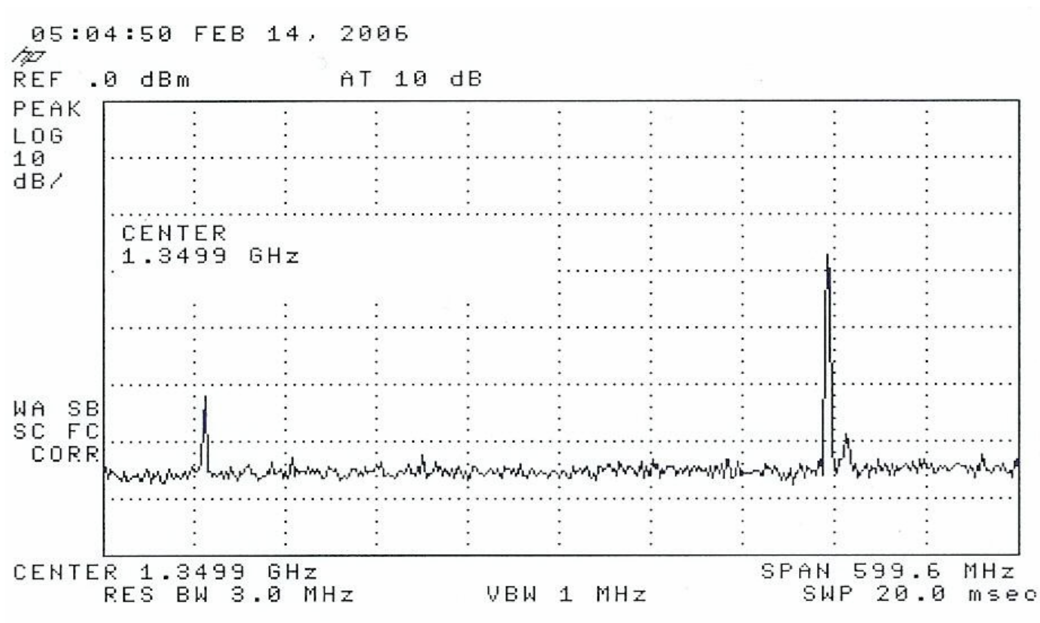


a. Background spectrum.

Figure 3. Continued on next page.



b. Spectrum of GSM 900 MHz.



c. Spectrum of DCS 1800 MHz.

Figure 3. Background, GSM 900 MHz and DCS 1800 MHz spectra.

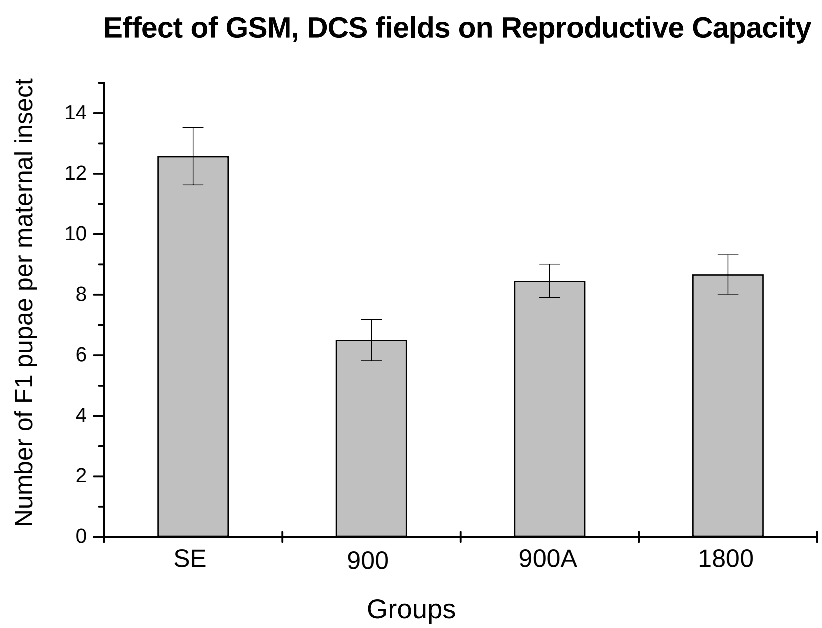


Figure 4. Reproductive Capacity (mean number of F1 pupae per maternal fly) of exposed (900, 900A, 1800) and sham exposed (SE) groups.

Table 4. Effect of Modulated GSM and DCS fields on the Reproductive Capacity of *Drosophila melanogaster*

Experiment No	Groups	Mean Number of F_1 Pupae per Maternal Fly	Deviation from Control
1	900	7.7	-42.54%
	900A	8.9	-33.58%
	1800	9.2	-31.34%
	SE (Control)	13.4	
2	900	5.8	-51.26%
	900A	8.1	-31.93%
	1800	7.9	-33.61%
	SE (Control)	11.9	
3	900	6.8	-46.03%
	900A	7.9	-37.30%
	1800	8.7	-30.95%
	SE (Control)	12.6	
4	900	7.4	-47.52%
	900A	9.7	-31.21%
	1800	9.9	-29.79%
	SE (Control)	14.1	
5	900	6.2	-52.31%
	900A	8.5	-34.62%
	1800	8.2	-36.92%
	SE (Control)	13	

Table 4. Continued

Experiment No	Groups	Mean Number of F_1 Pupae per Maternal Fly	Deviation from Control
6	900	6.1	-43.52%
	900A	8.2	-24.07%
	1800	7.8	-27.78%
	SE (Control)	10.8	
7	900	6.7	-47.66%
	900A	8.3	-35.16%
	1800	9	-29.69%
	SE (Control)	12.8	
8	900	6	-48.72%
	900A	7.9	-32.48%
	1800	8.4	-28.21%
	SE (Control)	11.7	
9	900	6.7	-49.24%
	900A	8.8	-33.33%
	1800	9.1	-31.06%
	SE (Control)	13.2	
10	900	5.7	-53.66%
	900A	8.3	-32.52%
	1800	8.5	-30.89%
	SE (Control)	12.3	
Average ± SD	900	6.51 ± 0.67	-48.25%
	900A	8.46 ± 0.55	-32.75%
	1800	8.67 ± 0.65	-31.08%
	SE (Control)	12.58 ± 0.95	

5. Radiation Bioactivity According to its Intensity (or According to the Distance from the Antenna)

The aim of this set of experiments was to investigate the dependence of GSM 900 MHz and DCS 1800 MHz bioactivity on their intensity, at different intensity levels that people are exposed to, from mobile phones and base station antennas. The radiation from base station antennas is almost identical to that of corresponding mobile phones but it is about 100 times stronger. Thus distances from mobile phones antennas correspond to about 100 times longer distances from base station antennas of the same type of radiation.

It is difficult to set up experiments regarding exposures from base station antennas since there is no way to have a sham exposed group of experimental animals under identical environmental conditions but without being exposed to the radiation at the same time. Thus we thought that the only way to simulate the reality of the exposure by a base station antenna is to expose the animals at different distances from a mobile phone within the lab.

Biological effects of mobile telephony signals at different intensities- distances from the antenna of a mobile phone handset, resembling effects from base station signals within residential areas, were not performed until now.

In each single experiment of this set, we separated the collected insects into thirteen groups: The first group (named "0") was exposed to GSM 900 MHz or to DCS 1800 MHz field with the mobile phone antenna in contact with the glass vial containing the flies. The second (named "1"), was exposed to GSM 900 MHz or to DCS 1800 MHz field, at 1cm distance from the mobile phone antenna. The third group (named "10") was exposed to GSM 900 MHz or to DCS 1800 MHz field at 10 cm distance from the mobile phone antenna. The fourth group (named "20") was exposed to GSM 900 MHz or to DCS 1800 MHz field at 20 cm distance from the mobile phone antenna, etc, the twelveth group (named "100") was exposed to GSM 900 MHz or to DCS 1800 MHz field at 100 cm distance from the mobile phone antenna. Finally, the thirteenth group (named "SE") was the sham exposed. Each group consisted of ten male and ten female insects as previously.

Radiation and field measurements in contact and at different distances from the mobile phone antenna, for six min of modulated emission, for GSM 900 MHz and DCS 1800 MHz in the RF and ELF ranges excluding the background electric and magnetic fields of 50 Hz, are given in Table 5. All the values shown in Table 5, are averaged over ten separate measurements of each kind ± standard deviation (S.D.).

The measurements reveal that although ELF electric and magnetic fields fall at almost zero levels for distances longer than 50 cm from both GSM 900 and DCS 1800 mobile phone antennas, the RF components of the signals are still evident for distances up to 100 cm, (Table 5).

The Average mean values of reproductive capacity (number of F_1 pupae) from six identical experiments with each kind of radiation are shown in Table 6 and represented in Figures 5, 6. The statistical analysis (single factor Anova test) shows that the probability that the reproductive capacity differs between groups, owing to random variations, is negligible, $P < 10^{-8}$. Once again there was no temperature increases within the vials during the exposures.

The results show that the effect of mobile telephony radiation is maximum at zero distance (intensities higher than 200 μW/cm^2) and then becomes maximum at a distance of 20-30 cm from the antenna, depending on the intensity of radiation (GSM or DCS). This distance corresponds to an intensity around 10 μW/cm^2 for both types of radiation in regards to the RF components.

Table 5. Radiation and Field Intensities in the Microwave and ELF regions

Distance from Antenna (cm)	GSM Radiation Intensity at 900 MHz, (mW/cm^2)	GSM Electric Field Intensity at 217 Hz, (V/m)	GSM Magnetic Field Intensity at 217 Hz, (mG)	DCS Radiation Intensity at 1800 MHz, (mW/cm^2)	DCS Electric Field Intensity at 217 Hz, (V/m)	GSM Magnetic Field Intensity at 217 Hz, (mG)
0	0.380 ±0.058	19 ±2.5	0.9 ±0.15	0.250 ±0.048	13 ±2.1	0.6 ±0.08
1	0.260 ±0.047	12 ±1.7	0.7 ±0.13	0.068 ±0.015	6 ±0.8	0. 4 ±0.07
10	0.062 ±0.020	7 ±0.8	0.3 ±0.05	0.029 ±0.005	2.9 ±0.48	0. 2 ±0.05
20	0.032 ±0.008	2.8±0.4	0.2 ±0.04	0.012 ±0.002	0.7 ±0.12	0. 1±0.02
30	0.010 ±0.002	0.6 ±0.09	0.1 ±0.02	0.007 ±0.001	0.3 ±0.06	0.06 ±0.01
40	0.006 ±0.001	0.2 ±0.03	0.05 ±0.01	0.004 ±0.0007	0.1 ±0.04	0
50	0.003 ±0.0006	0.1 ±0.02	0	0.002 ±0.0003	0	0
60	0.002 ±0.0003	0	0	0.0016 ±0.0002	0	0
70	0.0017 ±0.0002	0	0	0.0014 ±0.0002	0	0
80	0.0012 ±0.0002	0	0	0.0008 ±0.0002	0	0
90	0.0010 ±0.0001	0	0	0.0005 ±0.0001	0	0
100	0.0004 ±0.0001	0	0	0.0002 ±0.0001	0	0

Table 6. Effect of Modulated GSM and DCS radiation-fields on the Reproductive Capacity at different Distances-Intensities from the antenna

Groups -Distance from mobile phone antenna, (cm)	Average Mean Number of F_1 Pupae per Maternal Fly, for GSM 900 MHz	Deviation from Sham Exposed Group	Average Mean Number of F_1 Pupae per Maternal Fly, for DCS 1800 MHz	Deviation from Sham Exposed Group
0	7.45 ± 0.72	-46.01 %	9.26 ± 0.68	-34.00 %
1	9.38 ± 0.61	-32.03 %	11.36 ± 0.54	-19.03 %
10	11.29 ± 0.80	-18.19 %	11.93 ± 0.71	-14.97 %
20	11.52 ± 0.79	-16.52 %	9.19 ± 0.62	-34.50 %
30	7.33 ± 0.58	-46.88 %	13.03 ± 0.83	-7.13 %
40	12.88 ± 0.98	-6.67 %	13.76 ± 0.85	-1.92 %
50	13.48 ± 0.81	-2.32 %	13.85 ± 0.74	-1.28 %
60	13.61 ± 0.84	-1.38 %	14.00 ± 0.91	-0.21 %
70	13.70 ± 0.91	-0.72 %	14.21 ± 0.89	+1.28 %
80	13.97 ± 0.77	+1.23 %	14.07 ± 0.79	+0.29 %
90	13.74 ± 0.96	-0.43 %	14.02 ± 1.03	-0.07 %
100	14.02 ± 1.01	+1.59 %	14.31 ± 1.08	+2.00 %

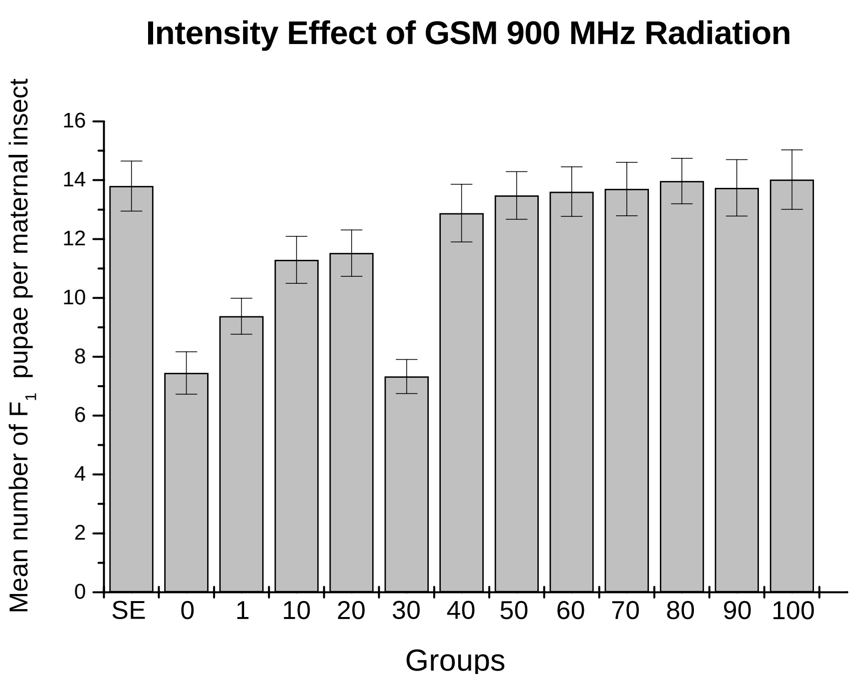


Figure 5. Reproductive Capacity in relation to the Distance from a GSM 900 MHz mobile phone antenna. The decrease in reproductive capacity is maximum at zero distance and at 30 cm distance from the antenna, corresponding to RF intensities 380μW/cm^2 and 10μW/cm^2 (Table 5).

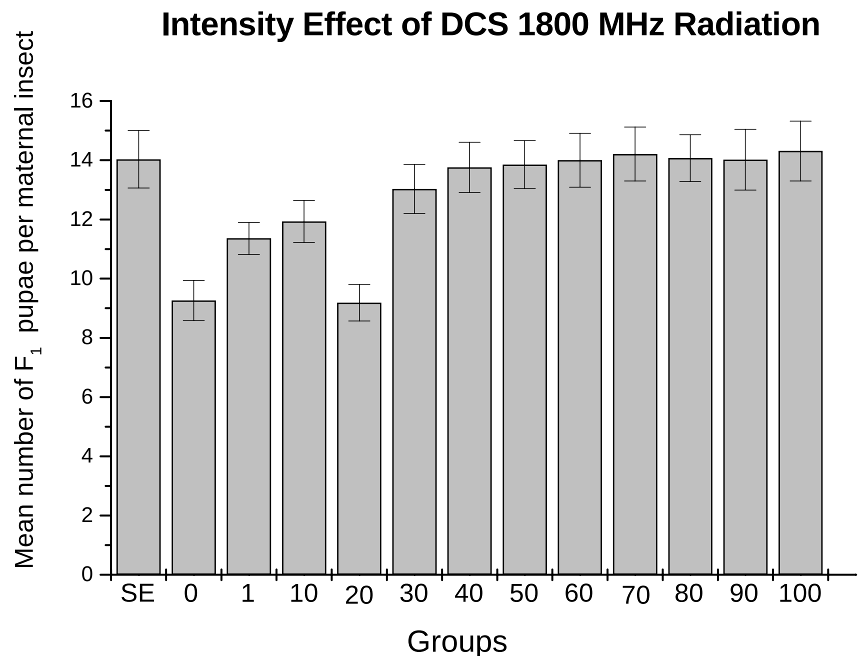


Figure 6. Reproductive Capacity in relation to the Distance from a DCS 1800 MHz mobile phone antenna. The decrease in reproductive capacity is maximum at zero distance and at 20 cm distance from the antenna, corresponding to RF intensities 250 μW/cm^2 and 12 μW/cm^2 (Table 5).

The effect on the reproductive capacity diminishes considerably for distances longer than 50 cm from the mobile phone antenna and disappears for distances longer than 80-90 cm, corresponding to radiation intensities smaller than 1 μW/cm^2. For distances longer than 50 cm where the ELF components fall within the background, the decrease in reproductive capacity is within the standard deviation. This might suggest that the ELF components of digital mobile telephony signals, play a key role in their bio-activity, alone or in conjunction with the RF carrier wave.

We have recorded the existence of an "intensity window" around 10 μW/cm^2 (in regards to the RF intensity) where the bio-effect becomes even more intense than at intensities higher than 200 μW/cm^2. This intensity window appears at a distance of 20-30 cm from a mobile phone antenna, which corresponds to a distance of about 20-30 meters from a base station antenna. Since mobile telephony base station antennas are usually located within residential areas, at distances 20-30 m from such antennas there are often houses and work places where people are exposed up to 24 hours per day.

Although intensity windows on the bio-effects of RF radiations have been recorded since many years, (Bawin et al 1975; 1978; Blackman et al, 1980), there is still no widely accepted explanation for their existence.

6. The Decrease in Reproductive Capacity is due to Cell Death in the Gonads

In each experiment of this final sixth set, we separated the collected insects into five groups. The first four groups were the same just as in the No 4 experiments: The first group (named

"900") was exposed to GSM 900 MHz field with the mobile phone antenna in contact with the glass vial containing the flies. The second (named "900A"), was exposed to GSM 900 MHz at 1cm distance from the mobile phone antenna. The third group (named "1800") was exposed to DCS 1800 MHz field with the mobile phone antenna in contact with the glass vial. The fourth group (named "SE") was sham-exposed. Finally there was an additional fifth group (named "C") which was the control. While sham-exposed animals were treated exactly as the exposed ones except that the mobile phone was turned off during the "exposures", control animals were never exposed in any way or even taken out of the culture room. Each group consisted as always of ten male and ten female insects.

In this set of experiments, there was an additional 6 min exposure in the morning of the sixth day, and one hour later female insects from each group were dissected and prepared for TUNEL assay. This additional exposure time was the only difference in the exposure procedure from the previous sets of experiments. Since we were studying the effect on early and mid oogenesis during which the egg chambers develop from one stage to the next within few hours, (King, 1970), an additional exposure, one hour before dissection and fixation of the ovarioles, was proven to be important in recording immediate effects on DNA fragmentation.

The most anterior region of the ovariole is called the germarium. The most sensitive developmental stages during oogenesis for stress-induced apoptosis, are region 2 within the germarium referred to as "germarium checkpoint" and stages 7-8 just before the onset of vitellogenesis, referred to as "mid-oogenesis checkpoint", (Drummond-Barbosa and Spradling, 2001; McCall 2004). The nurse cells (NC) and follicle cells (FC) of both checkpoints, were found to be very sensitive to stress factors like poor nutrition, (Drummond-Barbosa and Spradling, 2001; Smith et al., 2002), or exposure to cytotoxic chemicals like etoposide or staurosporine, (Nezis et al., 2000). Apart from these two check points, egg chambers were not observed before to degenerate during other provitellogenic or vitellogenic stages, (germarium to stage 10), (Drummond-Barbosa and Spradling, 2001; McCall 2004).

To determine the ability of GSM and DCS radiation to act as possible stress factors able to induce cell death during early and mid oogenesis, we used TUNEL assay, as described above. The samples from different experimental groups were blindly observed under the fluorescence microscope (i.e. the observer did not know the origin of the sample) and the percentage of egg chambers with TUNEL positive signal was scored in each sample. Statistical analysis was made by single factor Analysis of Variance test.

In Table 7 the summarised data from 8 separate experiments are listed. The data reveal that both GSM 900 and DCS 1800 mobile telephony radiations strongly induce cell death, (DNA fragmentation) in ovarian egg chambers of the exposed groups, (63.01% in 900, 45.08% in 900A and 39.43% in 1800), while in the SE and C groups the corresponding percentage of cell death was only 7.78% and 7.75% respectively.

Ovarian cell death between the control group and the sham exposed group did not differ significantly, (differences were within standard deviation) and this is why the data from the C group are omitted in Table 7.

Electromagnetic stress from mobile telephony radiations was found in our experiments to be much more bioactive than previously known stress factors like poor nutrition or cytotoxic chemicals, inducing cell death to a higher degree not only to the above check points but to all developmental stages of early and mid oogenesis and moreover to all types of egg chamber cells, i.e. nurse cells, follicle cells and the oocyte (OC), (Panagopoulos et al, 2007a).

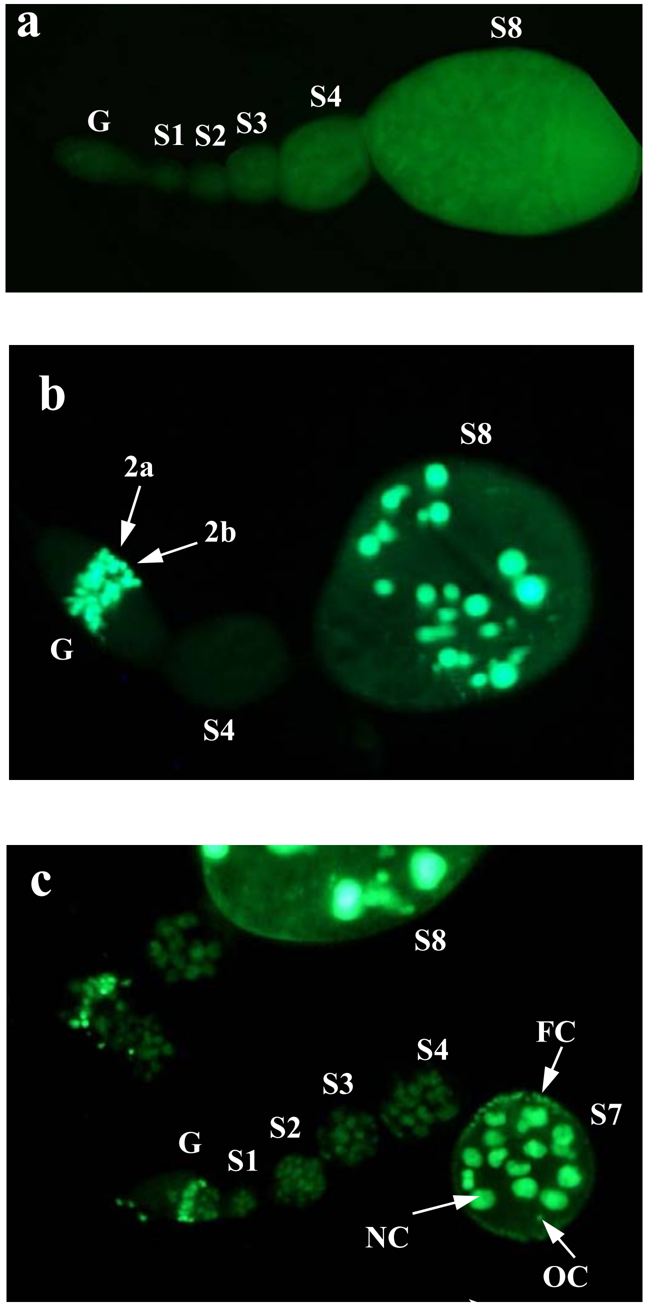


Figure 7. a) Ovariole of a sham exposed female insect with TUNEL negative egg chambers at all the developmental stages from germarium (G) to stage 8. b) Ovariole of exposed female insect with TUNEL positive signal at both check-points, germarium and stage 8 and TUNEL negative signal at the intermediate stages. c) Ovarioles of exposed female insects with TUNEL positive signals at all the developmental stages and in all types of egg chamber cells, nurse cells (NC), follicle cells (FC) and the oocyte (OC).

Table 7. Effect of GSM, DCS fields on Ovarian Cell Death

Groups	Dev. Stages	Ratio of TUNEL Positive to Total Number of Egg-chambers of each dev. stage	Sum Ratio of TUNEL Positive to Total Number of Egg-chambers of all stages	Percentage of TUNEL Positive Egg chambers	Deviation from Sham Exposed Groups
SE	Germarium 1-6 7-8 9-10	37/186 32/1148 78/364 7/282	154/1980	7.78%	0%
900	Germarium 1-6 7-8 9-10	165/189 675/1252 310/384 165/262	1315/2087	63.01%	+55.23%
900A	Germarium 1-6 7-8 9-10	116/184 484/1248 213/374 117/257	930/2063	45.08%	+37.30%
1800	Germarium 1-6 7-8 9-10	101/169 388/1202 196/358 91/239	776/1968	39.43%	+31.65%

Figure 7a, shows an ovariole from a sham exposed female insect, containing egg chambers from germarium to stage 8, all TUNEL negative. This was the typical picture in the vast majority of ovarioles and separate egg chambers from female insects of the sham exposed and control groups. In the SE groups, only 154 egg chambers (including germaria) out of a total of 1980 in 8 replicate experiments (7.78%), were TUNEL positive (Table 7), a result that is in full agreement with the rate of spontaneously degenerated egg chambers normally observed during *Drosophila* oogenesis, (Nezis et al., 2000; Baum et al., 2005).

Figure 7b shows an ovariole of exposed female insect (group 900A), with a TUNEL positive signal in the nurse cells at both checkpoints, germarium and stage 8, while egg chambers of intermediate stages are TUNEL negative. Corresponding pictures from 900 and 1800 (data not shown) had identical characteristics. The two checkpoints in all groups (exposed and SE/C) had the highest percentages of cell death compared to the other developmental stages 1-6 and 9-10, (Table 7). While in the SE groups the sum ratio of TUNEL positive to total number of egg chambers was slightly higher in stages 7-8 (78/364) than in the germarium (37/186), in all three exposed groups this ratio was higher in the germarium than in stages 7-8, (Table 7).

Figure 7c, shows ovarioles of exposed female insects (group 900A), with a TUNEL positive signal at all developmental stages from germarium to 7-8 and in all the cell types of the egg chamber, (nurse cells, follicle cells and the oocyte).

Although in most pictures the TUNEL positive signal was most evident in the nurse cells, in the majority of the egg chambers in all the exposed groups, a TUNEL positive signal was detected in all three kinds of egg chamber cells, (figures 1c).

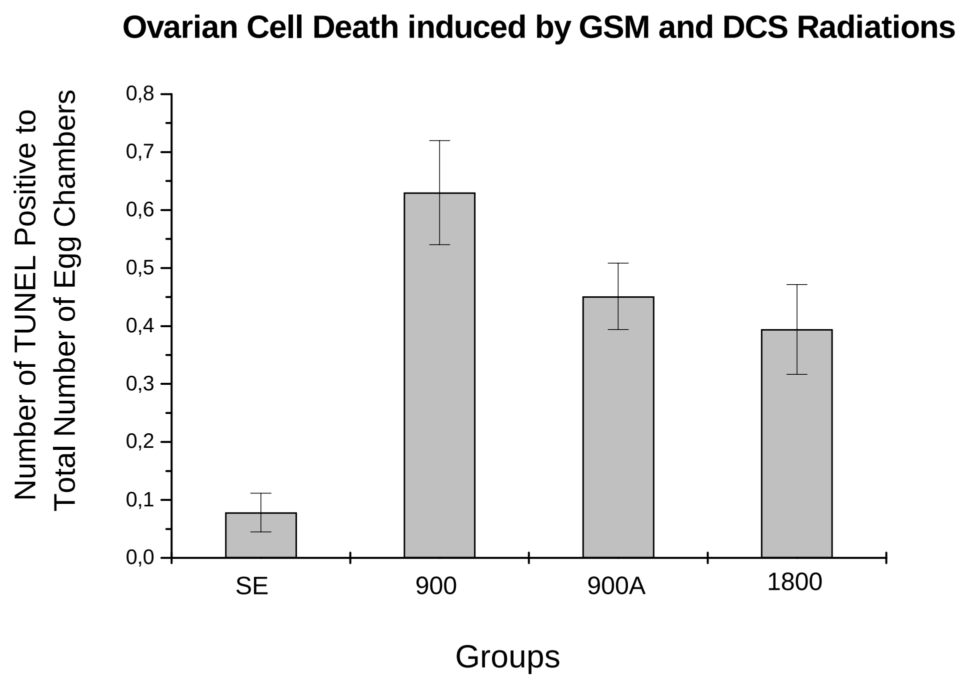


Figure 8. Mean ratio of Ovarian Cell Death (Number of TUNEL Positive to Total Number of Egg Chambers), in each experimental group ± SD, (0.078± 0.0335 in SE, 0.630± 0.0898 in 900, 0.451± 0.0574 in 900A and 0.394± 0.0777 in 1800).

In the SE groups the ratio of TUNEL positive egg chambers of stages 9-10 was very small (7/282). In contrast, the corresponding ratio in all three exposed groups was significantly higher, (165/262 in 900, 117/257 in 900A and 91/239 in 1800).

The summarised data of Table 7 are represented in Fig.8.

The statistical analysis, (single factor Analysis of Variance test), showed that the probability that groups differ between them because of random variations, is negligible, $P<10^{13}$.

Our experiments and the statistical analysis show that genomic DNA fragmentation of the egg chambers cells is induced by the mobile telephony radiation. Both types of radiation, GSM 900MHz and DCS 1800MHz induce cell death in a large number (up to 55% in relation to control), of ovarian egg chambers in the exposed insects with only 6 min exposure per day for a limited period of 6 days.

DNA fragmentation is induced in all cases predominantly at the two developmental stages named checkpoints, germarium and stages 7-8. Since the above check points were already known to be the most sensitive stages in response to other stress factors, (Chao and Nagoshi 1999; De Lorenzo et al., 1999; Nezis et al., 2000; Drummond-Barbosa and Spradling 2001; McCall 2004), such an observation could be expected. Our results show that these two checkpoints are the most sensitive stages also in response to electromagnetic stress. However the germarium checkpoint was found to be even more sensitive than stages 7-8 in response to this particular stress. Thereby the two check points are not equally responsive to distinct types of stress and may therefore also respond differentially to other types of stress stimuli. A possible explanation for the more sensitive germarium stage is that it may be more effective in evolutionary terms for the animal to block development of any defective egg chamber at the beginning rather than at later stages, in order to prevent the waste of precious nutrients.

In the sham exposed/control groups, induced DNA fragmentation was observed almost exclusively at the two developmental stages named check-points (37/186 in the germarium and 78/364 in stage 7-8) and only in few cases at the other provitellogenic and vitellogenic stages, 1-6 (32/1148) and 9-10 (7/282), correspondingly. In contrast, ovarian egg chambers of animals from all three exposed groups, were found to be TUNEL positive to a high degree at all developmental stages from germarium to stage 10, (Table 7).

In all cases (both in the sham exposed/control and also in the exposed groups), the TUNEL positive signal was more intense at the two check points, germarium and stages 7-8, than at the other developmental stages.

There was no detectable temperature increase within the vials during the exposures, therefore the effects are considered as non-thermal.

In this set of experiments, cell death was detected for the first time during all the developmental stages of early and mid oogenesis in *Drosophila*, from germarium to stage 10 and in all types of egg chamber cells, (nurse cells, follicle cells, oocyte). A possible explanation for these effects is that the electromagnetic stress induced in the ovarian cells by the GSM and DCS fields, is a new and probably more intense type of external stress, against which ovarian cells do not have adequate defence mechanisms like they do in the case of poor nutrition or chemical stress.

It is important to emphasize that the recorded effect in the oocyte which undergoes meiosis during the last stages of oogenesis, may result in heritable mutations upon DNA damage induction and repair, if not in cell death.

The results of this set of experiments reveal that the large decrease of reproductive capacity found in the previous sets of experiments is due to elimination of large numbers of egg chambers during early and mid oogenesis, either via stress induced apoptosis or necrosis of their constituent cells, caused by the mobile telephony radiation.

Our present results are in agreement with results of other experimenters reporting DNA damage in other cell types, assessed by different methods than ours, after *in vivo* or *in vitro* exposure to GSM radiation, (Diem et al., 2005; Markova et al., 2005; Salford et al., 2003; Lai and Singh 1995; 1996).

We do not know if the ovarian cell death found in our experiments to be induced by mobile telephony radiation is due to apoptosis, i.e. caused by the organism in response to the electromagnetic stress, or the result of necrosis caused directly by the electromagnetic radiation. This important issue remains to be uncovered.

A Plausible Mechanism for Mobile Telephony Radiation Bioeffects

As we have previously reported, (Panagopoulos et al. 2000b; 2002; Panagopoulos and Margaritis 2003b), any external oscillating electromagnetic field can induce a forced-vibration on the free ions that exist in large concentrations inside and outside all living cells in biological tissue playing a key role in all cellular functions initiating or accompanying all cellular biochemical processes.

The forced-vibrational movement of the free ions is described by the equation,

$$m_i \frac{d^2x}{dt^2} + \lambda \frac{dx}{dt} + m_i \omega_o{}^2 x = E_o z q_e \sin\omega t \qquad [1]$$

in the case of an external harmonically oscillating electric field: $E = E_o \sin\omega t$ with circular frequency: $\omega = 2\pi\nu$, (ν, the frequency), where: z is the ion's valence, $q_e = 1.6\times10^{-19}$ Cb, the electron's charge, $F_2 = - m_i \omega_o{}^2 x$, a restoration force proportional to the displacement distance x of the free ion, m_i the ion's mass and $\omega_o = 2\pi\nu_o$, with ν_o the ion's oscillation self - frequency if the ion were left free after its displacement x. In our case, this restoration force is found to be very small compared to the other forces and thus does not play any important role. $F_3 = -\lambda u$ is the damping force, where $u = \frac{dx}{dt}$, is the ion's velocity and λ, is the attenuation coefficient for the ion's movement, which for the cytoplasm or the extracellular medium is calculated to be $\lambda \cong 10^{-12}$ Kg/sec, while for ions moving inside channel proteins, is calculated to have a value: $\lambda \cong 6.4\times10^{-12}$ Kg/sec, (in the case of Na^+ ions, moving through open Na^+ channels), (Panagopoulos et al 2000b).

We have shown that the general solution of equation [1], is:

$$x = \frac{E_o z q_e}{\lambda\omega} \cos\omega t - \frac{E_o z q_e}{\lambda\omega} \qquad [2]$$

Since the second term of [2] is constant, the vibrational movement is described by the equation:

$$x = \frac{E_o z q_e}{\lambda\omega} \cos\omega t \qquad [3]$$

Eq. [3] shows that the forced - vibration is in phase with the external force.The amplitude of the free ions forced vibration is,

$$A = \frac{E_o z q_e}{\lambda\omega} \qquad [4]$$

Thus, the amplitude is proportional to the intensity and inversely proportional to the frequency of the external oscillating field.

Once this amplitude exceeds some critical value the coherent forces that the ions exert on the voltage sensors of voltage-gated membrane channels can trigger the irregular opening or closing of these channels, thus disrupting cell's electrochemical balance and function.

We have shown that in the most bioactive case of pulsed fields and for double valence cations (i.e. Ca^{+2}) interacting with the channel sensor, the condition for irregular gating of the channel becomes:

$$E_o \geq \nu \times 0.625 \times 10^{-4} \qquad [5]$$

(ν in Hz, E_o in V/m). Whenever [5] is satisfied, the external field E can irregularly gate the ion channel.

Relation [5] declares that external ELF electric fields with intensities less than tenths of a mV/m should theoretically be able to disrupt cell function by irregular gating of ion channels (!)

According to this mechanism, lower frequency fields are the most bioactive ones and additionally pulsed fields are shown to be more bioactive than continuous, (uninterrupted), ones, (Panagopoulos et al., 2002).

Thereby, the ELF components of the mobile telephony signals are certainly within the criteria of this theory and thus able to produce the reported effects on living organisms.

Somebody may wonder, how could be possible that irregular gating of ionic channels on a cell membrane could lead to cell death.

Let us consider the irregular gating of ion channels on a cell's plasma membrane. If the electrochemical balance is destroyed by irregular increase of intracellular ion concentration, then water molecules may enter the cell driven by osmotic forces, proportional to the concentration increase. Such an effect could be able to cause the cell to swell out and the plasma membrane to get ruptured, resulting to cell necrosis.

It is known that perturbations of intracellular Ca^{+2} concentrations are responsible for apoptotic triggering, (Zhou et al., 1998; Sheikh and Huang, 2004; Santini et al. 2005). Therefore, another scenario of cell death, caused by irregular gating of ion channels, could be that due to altered intracellular Ca^{+2} concentrations, a false signal may be given to initiate apoptosis.

A common event leading to both apoptosis and necrosis is mitochondrial membrane permeabilization, (Armstrong 2006). This can also be done by direct action of an external EMF on mitochondrial membrane Ca^{+2} channels. Apoptosis is connected with increased mitochondrial concentration of Ca^{+2} ions, released from the endoplasmic reticulum, (Santini et al., 2005). A false uptake of Ca^{+2} ions by mitochondria can be due to irregular opening of mitochondrial Ca^{+2} channels, or due to increased cytosolic Ca^{+2} concentration, caused by irregular release either through the membrane of endoplasmic reticulum or through the plasma membrane. In all cases this could be done by irregular gating of electrosensitive Ca^{+2} channels which exist in all cell membranes.

We have just described few of the many hypothetical but very possible biochemical scenarios which could very explain by means of the above described biophysical theory, the effects of DNA damage recorded in our experiments as well as in other labs experiments, (Diem et al., 2005; Markova et al., 2005; Salford et al., 2003; Lai and Singh 1995; 1996).

Conclusions

As shown by increasing number of biological, clinical and epidemiological studies, the radiations emitted by mobile telephony, at levels that people are daily exposed, are highly bioactive producing a variety of effects on living organisms.

Our studies regarding the effects of mobile telephony radiations on a biological model, the reproductive capacity of the insect *Drosophila melanogaster*, have investigated different physical parameters of these radiations, like intensity, carrier frequency, pulse repetition frequency, distance from the antenna, e.t.c.

Our experiments have shown a large decrease in reproductive capacity caused by the GSM and DCS fiels-radiation. The recorded effect is due to extensive DNA fragmentation on reproductive cells of the experimental animal, induced by these fields-radiation.

Thus, digital mobile telephony radiations nowadays exert an intense biological action able to kill cells, damage DNA, or decrease dramatically the reproductive capacity of living organisms. Diminishes of bird and insect populations can be explained according to reproduction decreases. Phenomena like headaches, fatigue, sleep disturbances, memory loss e.t.c. reported as "microwave syndrome" can possibly be explained by cell death on a number of brain cells during daily exposures from mobile telephony antennas.

Our experiments show that radiation intensities higher than 1 $\mu W/cm^2$ are able to decrease reproduction of living organisms by killing reproductive cells. Our opinion is that the international exposure limits for these radiations should be set not higher than 1 $\mu W/cm^2$. Since short term exposures for few minutes per day are able to produce so intense effects on living organisms, the criteria should not be set according to average values but according to maximum values during the exposure periods.

Our experiments reveal that exposure at a distance of 20-30 cm from a mobile phone can be even more bioactive than exposure in contact with the antenna, due to the existence of an "intensity window" around 10 $\mu W/cm^2$. This intensity, in the case of a usual base station antenna corresponds to a distance of about 20-30 m from the antenna.

Although both types of radiation examined are found to be highly bioactive, GSM 900 MHz seems to be even more bioactive than DCS 1800 MHz, mainly due to higher intensity, but also even when it is emitted at almost the same intensity. Since differences in bioactivity between the two types of radiation under the same intensity are within standard deviation, it seems that RF carrier frequency plays a minimal role in the bioactivity of this radiation, in contrast to the ELF pulse repetition frequencies and the radiation and field intensities that seem to be of great importance in regards to bioactivity.

The ELF components of the mobile telephony signals, seem to play a key role on their bio-effects, since the recorded effects are considerably diminished at distances that these components fall within the background of stray 50 Hz electric and magnetic fields. This supports that lower frequency fields are more bioactive than higher frequency ones with the same rest characteristics, as it is predicted by our theory, (Panagopoulos et al 2000b; 2002), and supported by other experimental evidence, (Lin Liu and Adey 1982; Penafiel et al 1997).

A plausible explanation of the effects of mobile telephony radiations on living organisms is given by the biophysical mechanism that we have proposed, (Panagopoulos et al. 2000b; 2002; Panagopoulos and Margaritis 2003b). According to this mechanism, altered intracellular ionic concentrations due to irregular gating of ion channels on the cell membranes by an external electromagnetic field can initiate cell death through apoptosis or necrosis.

Similar effects on humans with those recorded in our experiments on insects, are considered to be possible because first, insects are found to be more resistant to radiations than mammals, (Koval and Kazmar 1988, Koval et al 1979, 1977, Abrahamson et al 1973) and second, our results are in agreement with reported effects on mammals, (Lai and Singh 1995; 1996; Aitken et al., 2005; Salford et al., 2003).

Scientific evidence implies the need of reconsideration of the current exposure criteria to account for non-thermal effects which constitute the large majority of the recorded biological and health effects. Since Mobile Telephony has become part of our daily life, a better design of base station antenna networks towards the least exposure of residential areas and a very cautious use of mobile phones, is necessary.

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Volume 5

NON-THERMAL EFFECTS AND MECHANISMS OF INTERACTION BETWEEN ELECTROMAGNETIC FIELDS AND LIVING MATTER

An ICEMS Monograph

Edited by
Livio Giuliani and Morando Soffritti

National Institute for the Study and Control of Cancer and
Environmental Diseases "Bernardino Ramazzini"
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Preface

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Electromagnetic fields are waves that transport energy through space. They are characterized by wavelength and frequency, the two of which are inversely correlated. The shorter the wavelength, the greater the frequency.

Electromagnetic fields include the following (in order of decreasing wavelength and increasing frequency): electromagnetic fields of extremely low frequency (from electric sources), electromagnetic fields of low frequency, electromagnetic fields of radiofrequency and microwaves (from mobile telephones, television antennas etc), ultrasounds, infrared rays, ultraviolet rays, X rays and gamma rays. Gamma rays, given their energy charge, are also defined as ionizing radiation, and are capable of altering genetic cellular material. Indeed, the carcinogenic effects of ionizing radiation have been known for decades.

Scientific data regarding the long-term effects, in particular carcinogenic risk,of the exposure to non-ionizing electromagnetic fields were not reported in the literature until the 1970s. In 1979 two American researchers, Wertheimer e Leeper, published for the first time the results of an epidemiological study that demonstrated an increased carcinogenic risk, specifically leukemic, in children residing in close proximity to electric installations and therefore exposed to non-ionizing electromagnetic fields from electrical current at extremely low frequency.

As was to be expected, concern about the possible carcinogenic risks of non-ionizing radiation has now expanded beyond electricity to include other types of non-ionizing radiation, such as electromagnetic fields of radiofrequency and microwaves from cellular telephones and other wireless technologies such as cordless telephones, computers etc.

The expansion of mobile telephone technologies in the last 10 years is without precedent. In 1996 the number of cellular telephones in Italy was circa 4 million, today this figure is estimated to be 40 million. In the US, cellular telephones in the 1990s numbered 9 million, today more than 150 million Americans use cell phones, including children. It is estimated than more than 2 billion people use cell phones worldwide. In addition, many citizens are exposed to electromagnetic fields originating from the antennas of radio base stations that transmit cellular signals. Indeed, exposure to electromagnetic fields of radiofrequency and microwave, in both the work and general environment, has never before experienced this type of growth. For this reason it is fundamentally important to address the issue of safety, using all available tools to evaluate the potential risks of exposure. These tools include both epidemiological and experimental laboratory studies, as well as basic research.

This book provide updated information concerning mechanism of interaction between non ionising radiation fields and living matter, with particular reference to potential non-thermal toxic effects.

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The scientific knowledge available today regarding electromagnetic fields remains limited. Nevertheless, on the basis of recent epidemiological studies, and while awaiting new experimental data, it is advisable to limit exposure to electromagnetic fields as much as possible. This is especially true for children and adolescents, the most vulnerable segments of the population, and has been recommended by both the Swedish and UK health authorities.

Why investigate the non thermal mechanisms and effects of electromagnetic fields on living systems? An introduction

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A Fairy Tale

Protection against Non Ionizing Radiation is based on a paradigmatic assumption:

"*We know very well the interaction between electromagnetic fields and living organisms: it is a* thermal *interaction; thus the standards internationally accepted are adequate to protect people and workers*"[1].

This is a fairy tale.

Since the 1970s the *non thermal* effects of electromagnetic fields on living organisms have been well known and also the *non thermal* mechanisms have been investigated[2, 3]. Nevertheless, until today, we have been condemned to listen to representatives from international institutions repeating the old refrain above. Furthermore when scientists participating in the ICEMS agreed to edit a monograph – the present one - with the aim of illustrating the non thermal mechanisms and effects due to the electromagnetic interaction with living organisms - mechanisms that are well known today - some of us withdrew their contribution because they did not share the locution "*non thermal*" in the title. The following discussion, which many ICEMS scientists and the coauthors of this monograph took part in, focused on some basic points, maybe obvious but not infrequently forgotten.

To be able to speak about a thermal effect on a *system*, we must first observe a variation in the *temperature* of the *system*.

Temperature

In order to define the temperature of a system it is necessary to include the philosophical concept of ensemble: in extension a collection of independent and indistinguishable particles each having a well defined velocity. In such a picture the temperature will emerge as an average property of the system as the average kinetic energy defined on the ensemble. In the case of a biochemical system made up of many *non*-independent particles the very basic concept of temperature has to be defined through an oversimplification of the system description (useful in most applications): we assume that each molecule can be labelled with a mean velocity energy which, in turn, defines an average energy associated with each degree of freedom of the molecule itself. In such

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a picture a perturbation is termed "thermal" if it is able to change the average kinetic energy associated to each degree of freedom, in such a way that the average of the energies on the ensemble is changed.

The rotating motion of water molecules induced by microwaves is the most evident achievement of such a thermal effect, but we need not think it is unique. In our monograph we focus on an effect – the coupling of RF/MW with cancerous tissues – discovered by E.H. Frick and S. Morse (1924) and re-discovered by C. Vedruccio, as reported in this monograph.

The Energy transfer mechanism described by the classical or semi-classical model of biological matter is based on "hopping" along discrete energy levels. However, as is widely known in the literature, such a model cannot account for the energy transfer process in biological systems such as photo-synthesis, where the light-absorbing molecules can funnel energy with a near-unit quantum efficiency across mesoscopic distances. Such a conundrum implies a deeper re-thinking of the molecular biology model based upon independent and indistinguishable particles. The solution implies a high degree of correlation among a great number of molecules and the entry in play of quantum phenomena. Quantum mechanics teaches us that energy transfer can happen in a quantum-correlated system without entailing kinetic knocks.

Non Thermal effects

In such a picture it is paramount to distinguish between "thermal" and "non-thermal" effects. In fact, the existence of the latter implies a model of biological matter well beyond the classical or semi-classical representation. Hence the deep meaning of the thermal-non thermal *querelle* : to minimize this distinction could lead us to underestimate what is probably the watershed of modern biology.

However, because we are concerned with biology or biophysics - not atomic physics - we may be focused on much more complex systems than atoms and we may fail to monitor the variation of energy of single electrons or single atoms. Even an aqueous solution of aminoacids, in a quantity such as in the electrolytic cell of Zhadin described in this monograph, has millions of billions of billions of molecules, as Avogadro taught us. Thus we should not be deceived by the fact that a certain molecule receives energy during a reaction into concluding that this reaction is based on a thermal mechanism of interaction. We must look at the temperature of the system. We must observe the system and the average of the energies of all components involved.

For instance, in the aqueous solution of the Zhadin experiment, we witnesss an ion current peak - that can be detected in the order of 10-100 nA - when we apply a suitable combination of DC-AC magnetic fields. But the AC field is very weak: in the order of 10nT! And the DC field is like the geomagnetic one: there is no transfer of energy able to induce an alteration in the system temperature. It is not only a non thermal effect; it is an *athermal* effect!

Thermal/Non thermal in EMF risk assessment

Lastly, let us consider the current meaning of 'thermal effects' in RF/MW risk assessment. According to ANSI (1981), interactions inducing a temperature increase lower than 0.5 °C in the human body are commonly accepted, even by the WHO. The corresponding value in terms of of WHOLE BODY AVERAGE SPECIFIC ABSORBTION RATE (WBASAR) is 4 W/kg. Furthermore, the absorption of 0.4 W/kg – corresponding to a temperature increase equal to a 0.05°C in the body – is considered negligible for workers and the absorption of 0.08 W/kg – corresponding to a 0.01 °C increase – seems to be negligible. WHO, IEEE and ICNIRP assure us that under such a threshold we can be protected against all health effects due to RF/MWs. On this view, biological non thermal effects are only to be considered as reversible effects. But non-reversible effects are detected under the same threshold by epidemiologists –see the assay by Lennart Hardell in this monograph -: such effects can be considered '*non thermal'* effects in this context. What about mechanisms inducing temperature increases lower than 0.001 °C (corresponding to 0.008 W/kg SAR)? They can be considered '*non thermal'* in the same context, in accordance with the usual convention that perturbation of a system, when the parameters are lower by three orders of magnitude than the corresponding parameters of the system, can be considered not related to such parameters.

Perhaps we should specify the meaning of the terms thermal/non thermal in the present monograph. With reference to the usual meaning adopted in the context of *protection against radiation*, we can consider as *non thermal* all mechanisms that are not able to induce an increase in temperature higher than 0.01°C, when we are considering a system like a living organism, or lower than 0.001 °C when a system like a cell is considered, or again lower than 0.0005 °C when a sub-cellular system is studied.

Several mechanisms and effects are considered in this monograph with the collaboration of many scientists who have joined this ICEMS initiative.

Our book does also include thermal mechanisms and effects as well as macroscopic phenomena (see the various sections of the book).

The point is, *protection against non ionizing radiation*, based on parameters adopted by international standards organizations, seems not to be adequate, despite the statement of Ms Van Deventer, nor able to protect people and workers. This is convincingly shown in the paper by Devra Davis, Om Ghandi and colleagues in this monograph.

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On mechanism of combined extremely weak magnetic field action on aqueous solution of amino acid

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Abstract

The fundamental Physical mechanisms of the resonant action of an extremely weak (40 *nanoT*) alternating magnetic field at the cyclotron frequency combined with a weak (40 *mcT*) static magnetic field, on living systems are analyzed in the present article. The experimental effects of such sort of magnetic fields were described in different articles: the very narrow resonant peaks in electrical conductivity of the aqueous solutions in the *in vitro* experiments and the Biomedical *in vivo* effects on living animals of magnetic fields with frequencies tuned to some amino acids. The existing experimental *in vitro* data had a good repeatability in different laboratories and countries. Unfortunately, for free ions such sort of effects are absolutely impossible because the dimensions of an ion rotation radius should be measured by meters at room temperature and at very low static magnetic fields used in all the above experiments. Even for bound ions these effects should be also absolutely impossible from the positions of Classic Physics because of rather high viscosity of biological liquid media. Only modern Quantum ElectroDynamics of condensed media opens the new ways for solving these problems. The proposed article is devoted to detailed analysis of Quantum mechanisms of these effects.

Key words: **extremely weak magnetic fields, aqueous solution, amino acids, cyclotron resonance, coherence domain**

Introduction

About 25 years ago Profs Abraham Liboff[1] and Carl Blackman[2] in the USA discovered that weak (several tens of *mcT*) combined alternating and static magnetic fields resonantly affect different biological objects when the alternating magnetic field frequency was equal to the cyclotron frequency of some biologically active metal (calcium, potassium, magnesium) ions. The cyclotron frequency is determined by the following way:

$$\nu_{CF} = \frac{qB_s}{2\pi m}, \qquad (1)$$

where q is an ion charge, m is its mass, and B_s is the static magnetic field. After some

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discussions and theoretical analysis[1, 2] it was accepted that such sort of effect is impossible for free ions, because the dimensions of an ion rotation radius should be measured by meters at room temperature and at very low static magnetic fields used in all the above experiments. But they could arise for ions bound in molecules[3-6].

However, in 90s after discovering[7, 8] the resonant effects in aqueous solutions of alpha amino acids the situation became much more complicated. The static magnetic field was of 40 *mcT,* which is close to the natural geomagnetic field as earlier, but the alternating magnetic field of about 40 *nanoT* was thousand times less than in Liboff's[1, 9] and Blackman's[2] experiments. The two difficulties befogged the understanding of Physical mechanisms of these effects. The first one was the fact that in this case the ions were free, and the second one was connected with that the alternating field was thousand times less than in Liboff's effect[1], not counting even the fact that amino acids are not metals at all. The editorial staff of Bioelectromagnetics journal firstly delayed the publication of our submitted manuscript and asked to give some kind of Physical explanation of such unusual effect. This theoretical analysis was given by us four years later, when we pointed that similar effect could arise in solutions containing microcrystals of dissolved matter. But situation with the extremely weak alternating magnetic field nevertheless stayed unclear. Fortunately, both our articles[8, 10], experimental and theoretical ones, were published[5, 8] in this journal. Later, our experiments were successfully replicated in Italy[11-13] and in Germany[14], and now the different articles appeared in international scientific press[15-17] [and others], which were experimentally developing the investigations of Biological effects of the extremely weak alternating magnetic fields *in vivo* on animals. However, till 2002 an obstacle in understanding such sort of the ionic cyclotron resonance effect remained insuperable. It was the impossibility of essential acceleration of an ion at the real viscosity of an aqueous solution under the influence of extremely weak combined magnetic fields. The Classical Physics was giving the well defined negative answer to the possibility of such effect. This problem was solved by Quantum ElectroDynamics of condensed matter.

Physical mechanisms of extremely weak combined magnetic fields action

At the end of 20th century in the famous Institute of Nuclear Physics (Italy) Prof. Giuliano Preparata and his colleagues elaborated a new branch of Quantum ElectroDynamics – the theory of condensed matter[18-21]. Among different liquid media the specific attention was drawn to water with its multitude of unsolved problems which now are successfully solved by this new branch of Quantum Physics. Quantum ElectroDynamics of water convincingly evidenced that the liquid water consists of two components: coherent and incoherent ones. The coherent component is contained within spherical structures, the so called "coherence domains", where all molecules have the wave functions, oscillating synchronously with the same mutual phase. Coherence domains are surrounded by the incoherent component where the molecular wave functions are oscillating with casual phases relative to each other. As a matter of fact, the incoherent component is the water from the point of view of Classical Physics. Diameters of coherence domains are measured by tenths of a micron, and at room temperature the total volume of the domains is about 40% of the whole water volume. Within a domain, the features of coherent water sharply differ from ones of incoherent water and from the water as a whole. Within domains the water viscosity and oscillation damping are about ten times less than viscosity and damping in the whole water. The fluidity in the domain is essentially increased, and the diffusion rate of foreign inclusions is much higher than within the incoherent water. The theoretical estimates of all electrical constants of the whole water, being earlier inexplicable by Classical Physics, for the first time turned out to be close to the experimental values, being analyzed by Quantum ElectroDynamics of water. And the unusual dependence of water density on temperature was explained too. The stability of coherence domains is rather high, because the bond energy of water molecules within coherence domains is much more than the thermal noise energy.

In our recent work[22] we considered the amino acid ionic exchange between incoherent medium and coherence domains (using a glutamic acid ion as an example) under the influence of weak combined magnetic fields. (In this work we name the aqueous coherence domain containing one or more foreign molecules or ions as a "mixed domain" for brevity. We'll use this term further for the same purpose). In the above article we studied the formation of mixed coherence domains in aqueous solutions of some amino acids and revealed the mechanisms of capture of some amino acid ions in zwitterion forms. Far from all soluble matters are able to form the mixed domains, but only ones which have the main spectral lines, common with the lines in water spectrum. In the present article we'll analyze in detail the mechanism of escape of amino acid ion from the mixed coherence domains under the action of resonant combined magnetic fields.

In our analysis of magnetic field effect on ion motion within coherence domains we shall consider the domain wall without traditional easy-to-use approximation of a vertical potential well because the resonant increase in kinetic energy of an ion is impossible at this very rough approximation. Here we shall consider the domain wall as a layer with the finite thickness, in the range of which the density and viscosity have the same values as within the whole domain**.** Earlier we[5] derived, analyzed and solved the equation of the ion motion in the centrally symmetric potential field under the influence of parallel combined static and alternating magnetic fields. Here we'll use some important achievements of the above work. The equation will have the following form:

$$\frac{d^2\mathbf{r}_o}{dt^2} = -\gamma\frac{d\mathbf{r}_o}{dt} - \omega_o^2\mathbf{r}_o + \frac{q}{m}\left[\frac{d\mathbf{r}_o}{dt}\times\mathbf{B}\right] + \frac{q}{2m}\left[\mathbf{r}_o\times\frac{d\mathbf{B}}{dt}\right] + \mathbf{F} \tag{2}$$

The equation (2) is given in the vector form. Here is the radius-vector of the ion position originating at the equilibrium point of the ion; t is the time; q and m are the charge and mass of the ion; **B** is the total static and alternating magnetic fields; γ is the damping coefficient inhibiting ion circulation around the center ω_O; is the natural frequency of the ion oscillation in a coherence domain; **F** is the total force of an action of surrounding particles on the ion that causes the thermal motion of the ion near its equilibrium point; the bold letters denote vectors; the square brackets symbolize vector products. On the left the general form of a potential well inside a coherence domain is shown. On the right the first term takes into account the passive friction, and the second one is determined by the force of the intradomain potential field restoring the ion to its equilibrium point; the third term is the Lorentz force of the magnetic field action on the moving ion which manifests itself in the rotation of the trajectory of the ion thermal motion around the magnetic field line; the fourth one results from the force made by the curl field generated by the time-varying magnetic field. In the following, we considered the parallel magnetic fields algebraically summed: the static field, $\mathbf{B_o}$, and the alternating field, $\mathbf{B_{AC}}$, harmonically varying.

On fig. 1A the drawing of the approximate form of the potential well inside a coherent domain is shown. In the center of a domain the potential slow nonlinearly increases, step by step enlarging the rate of its rise. Within the peripheral region (between two vertical dotted lines R_i and R_e) its rising becomes especially sharp – it is the before mentioned domain border of finite thickness. In the area with $R_e > R_i$ the incoherent medium is located. On the right-hand the drawing of the coherence domain is shown, where the incoherent component outside the coherence domain border is shown too.

When the combined magnetic fields with a cyclotron frequency, corresponding to dissolved amino acid, become switched on, the dissolved amino acid ions can be located in arbitrary points, others than the domain center. All these ions started their comparatively slow rotation around different centers, other than the domain center. But these centers will begin to slide automatically step-by-step toward the domain center, because the minimal potential energy is located there. In some time, all the amino acid ions will gather on concentric orbits around domain center, forming the stable configuration with minimal potential energy. After that they become their rotation along the concentric orbits inside the domain, increasing their kinetic energy. It is rather effective because it will be not only due to the increase in the radius elongation, but especially because the kinetic energy will be especially grow within the high potential gradient in the layer $R_e > R_i$ of high nonlinearity in its potential growth. The group of ions leaves the coherence domain at the border R_i and enters into the incoherent medium, creating its contribution into formation of the prominent peak of the current through the solution. The viscosity of the coherent water inside the domains is about an order lower than in the incoherent media. It permits to increase the ion energy (which is proportional to squared ion velocity) to one or even two orders that is quite enough for leaving the ion from the domain. These processes would not practically influence on the total temperature of the domain and the total solution because of low mass of the total amino acid ions compared to the total mass of the surrounding water. Of course, the effectiveness of such sort of accelerator is extremely low, but it is quite enough for ion leaving a domain.

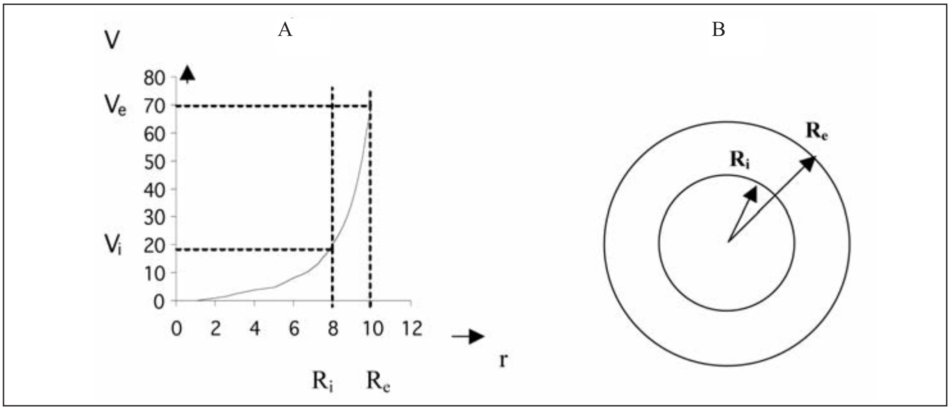

Fig. 1. A) The general form of a potential well inside a coherence domain. B) The coherence domain with the part of incoherent component $R_e > R_i$ area are shown. (Details are explained in the text of this article)

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Immunotropic effects of low-level microwave exposures *in vitro*

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Abstract

The reasons are presented for which the interest of many investigators is directed to the possible immunotropic influences of low energy microwave (MW) electromagnetic fields (EMFs), in terms of their potential harmful effects and also in the perspective of possible therapeutic applications. The available literature data on the influence of MWs on the immune system are up to now fragmentary, describing the changes of a few immune functions, mainly phagocytosis, lymphocyte proliferation, or antibody production, and are frequently controversial or not confirmed by the results of repeated experiments. On the grounds of results of the two series of own experiments the authors indicate which methodological elements, including precise dosimetric circumstances and the timing of exposure in relation to the cell cycle and the initial functional state of exposed cells may be decisive for the final effect of exposure in vitro.

Key words: **microwave immunotropic effects, sensitivity of immune cells to MWs, cell cycle, functional state of exposed cells.**

Introduction

Rapid development of radiocommunication and radiolocation, and widespread use of different electronic devices (mobile phones, radar and microwave broadcast stations) increase the environmental level of electromagnetic radiation. This, in turn, increased the interest of many investigators on possible pathogenic influences of electromagnetic emitters and, on the other hand, on the potential of their therapeutical applications.

After 30 years of research into this area, there is still insufficient information on the specific biological influence of nonthermal intensity of electromagnetic fields (EMFs)[1]. According to WHO Environmental Health Criteria WHO[2], nonthermal inten-

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sities of microwaves (MW) are presently recognized as a "weak factor of biological influence". This imprecise description has initiated searches for biological detectors sensitive enough to measure "weak biological influence" of MWs, and one of main candidates is the immune system, which is able to react in a measurable way to discrete environmental stimuli. As an important part of homeostatic neuroendocrine-immune network of the organism, the immune system is responsible for efficient defense against infections, regenerative support for injured tissues, and maintenance of immune tolerance toward self or foreign but neutral elements[3-5]. These different reactions of the immune system can be investigated using *in vitro* or *in vivo* tests to evaluate possible influences of external stimuli (e.g., drugs or physicochemical factors). Available data on the influence of MWs on the immune system are fragmentary, report on changes of few immune functions, mainly phagocytosis, lymphocyte proliferation, or antibody production, and are frequently controversial or not confirmed by the results of repeated experiments[6-9].

Some authors[10] conclude that studies of MW-exposed immune cells have shown no damage or change until the cells were heated, while others[11-13] report immunosuppressive or immunostimulatory phenomena in animals with long-term exposure to low-level MW fields.

Depending on conditions of exposure, frequency and modulation of the radiation, as well as on animal species used in the experiments, various symptoms of either stimulation or inhibition of certain immune reactions have been reported. Guy *et al.*[14] in the lifetime exposure of rats to MWs (pulsed 2450 MHz, SAR 0.15 - 0.4 W/kg) found lowered response of blood lymphocytes to mitogen phytohaemagglutinin (PHA), while Śmiałowicz[15] after exposure at the same wave frequency, although at higher power intensities (SAR 1 – 5 W/kg) reported increased mitogenic response of lymphocytes. Investigating the humoral immune response in mice exposed to 9.4 GHz at SAR 0.015 W/kg, depending on the carrier wave modulation, Vayert et al[9] found enhancement or lowering the response.

Even the epidemiological investigations of workers exposed to MW radiation did not confirm the existence of measurable shift in the immune status of the investigated populations, despite some observations on abnormalities in single immune parameters in several individuals (e.g. changed number of blood lymphocytes, lowered level of serum immunoglobulins or weaker response of lymphocytes to mitogens). In the available literature no reports exist on the complex assessment of immune phenomena under EMF influence, all investigatons were aimed to evaluate only selected, fragmentaric reactions of the system or selected types of immune cells. At the present state of knowledge it is, therefore, not possible to conclude about the specific immunotropic potencies of MW radiation, as the assessment of the immunotropic potency requires a general insight into the whole complex immune network, taking in advance the determination of immune status of the host or the investigated cellular population prior to the MW exposure.

The final effect of exposition of biological material to MW radiation depends on the physical properties of applied electromagnetic field on the one side, and on the functional state of exposed living target on the other. The EMFs used in different experiments may differ in countless dosimetric elements, including wave length and frequency, pulse modulation, intensity of EMF influencing the degree of specific absorption rate (SAR) and duration of the exposure. The functional characteristics of biological material, e.g. blood mononuclear cells mainly used for *in vitro* studies, is even more complex. The EMF exposure may affect the cell at different levels of its structure: the surface receptors changing their distribution and conformation, the cellular membrane changing its rigidity and permeability, mitochondrial metabolic activity, transcription and translation processes or several of these elements at different intensities.

The mononuclear cells isolated from peripheral blood remain in their most stable and inert metabolic state, the G0 phase of cell cycle, in which the cell represents low sensitivity to external influence[16,17] . When the cell cultured in vitro enter more active phases of cell cycle (G1, S, G2, M), its sensitivity to EMF influence may change significantly. In these circumstances the cells exposed to EMF after isolation from the blood, like in the most published studies in vitro, and after that cultured, specifically stimulated and tested for their different activities, may not display any significant changes. The exposition to EMF during the culture, of already activated cells, although methodically much more difficult, may deliver better insight into the potential immunotropic effects of the exposition.

One of the best methods of evaluation of immunotropic influences of EMF administered in vitro is the system of microcultures of mononuclear cells isolated from the blood (PBMC), representing in vitro the abilities of the immune system in vivo. The advantages of the method are accessibility of human cells, donor safety, and wide repertoire of immune tests which can be performed.

Recently, using these methods, we investigated the behavior of PBMC in a microculture system after exposure to pulsed (5 µsec pulses) 1300MHz microwaves ($10W/m^2$, SAR 0.18W/kg)[18]. The exposure resulted in the increased immunoregulatory activity of T cells, increased production of IL-10, increased IL-1 production by monocytes, and decreased concentration of IL-1ra in culture medium. We concluded that MW may support the inductive phase of immune response, increasing the activity of monocytes and T cells. The special feature of this experiment was that cells were exposed to EMF before the culture, indicating that at the time of exposure they remained metabolically neutral (G^o phase of cell cycle), which is normal for lymphocytes freshly isolated from blood.

In the in vivo situation, the accidental or deliberate exposure of the individual to MW may influence neutral or active immune cells, both normally present in the body. We have questioned how the active cells, e.g., stimulated in vitro with mitogens and entering G1 and S phases, will react to the subsequent exposure to MW. To evaluate the problem, a special anechoic chamber was constructed and technically tested in the Department of Microwave Safety, Military Institute of Hygiene and Epidemiology in Warsaw, Poland[19]. The chamber, containing the microplate with cultured cells and MW-emitting antenna, was installed inside the ASSAB CO2 incubator so the PBMC could be exposed to MW at different periods of culturing without removing them from the incubator.

The miniature anechoic chamber (MAC) was a cube of 40 × 40 × 40cm of external dimensions. The internal walls of the chamber were covered by pyramid absorbers to guarantee the absorption of incident field only by the samples. MW reflected from absorbers could be neglected. The absorbers also protected the test samples from the radiation reflected from metal walls of incubator and maintained the homogeneity of MW field around the samples inside the chamber. The plate with cultured cells was located in the middle part of chamber, while the mobile handset used as a MW-emitting antenna was placed on the floor of chamber. The internal dimensions of the chamber were 23 × 23 × 23 cm.

Experiment I. Immunotropic influence of 900 MHz microwave GSM signal on human blood immune cells activated in vitro

Blood samples were collected by vein puncture from healthy donors. PBMC were isolated on Ficol-Paque gradient, and after determination of cell viability (usually no less than 80% viable cells), the microcultures were set up in triplicates (10^5 cells/0.2 ml RPMI + 15% autologous inactivated serum) in Nuncoln microplates. Respective triplicates were left without stimulation or stimulated with phytohemagglutinin (PHA, HA16, Murex Biotech Ltd Dartford U.K., 0.4 µg/cult.) or with concanavalin A (Con A, Sigma, 8 µg/cult.). The plates were placed inside the anechoic chamber in the ASSAB incubator at 37°C and 5% CO_2. An identical plate of control cultures was also set up and placed in the ASSAB incubator beyond the chamber. At 24h of incubation, rearrangements of the cultures were performed as described elsewhere[18,20,21].

As a result of rearrangements of cultures performed at 24 h, the following parameters of T cell and monocyte activities were measured at the end of cultures: T lymphocyte response to PHA and to Con A, saturation of IL-2 receptors, T cell suppressive activity (SAT index), and the index of monocyte immunogenic activity (LM) related to the ratio of produced monokines (IL-1β versus IL-1ra)[20].

For the last 18h of incubation, ^{3}H-labelled-thymidine (^{3}HTdR), Amersham, U.K., spec act. 5 Ci/mM) was added into the cultures in a dose of 0.4 µCi/cult.

At the beginning of each of the three consecutive days of incubation, the cultures placed in the anechoic chamber were exposed to MW (900MHz, 20V/m, SAR 0.024W/kg) for 15 min. Control cultures were not exposed to MW.

At 72h the cultures were harvested and incorporation of 3HTdR was measured in Packard Tri carb 2100 TR scintillation counter. The results were calculated as a mean value of dpm (desintegrations per minute) per triplicate of cultures ± SD. The experiments were repeated 10 times, and the results observed in the exposed cultures were compared with those obtained in the control cultures. The data were analyzed with STATGRAPHICS PLUS 4.0 version (Nr. 471000349). The differences between the mean values were assumed statistically significant if the p values, calculated with the use of U Mann-Whitney's test, were lower than 0.05.

Results and discussion

The relatively short time of exposure of cultured cells to MW (15 min, administered repeatedly at the beginning of each of the three consecutive days of culturing) was chosen deliberately. First, our intention was to check the effects of exposure similar in duration to the average use of a mobile phone. Second, the cells, stimulated with mitogens, were exposed immediately after entering the G1 phase of cell cycle (first day exposure), again when the majority of cells responding to mitogen entered the S phase (second day exposure), and finally when the responding cells, after replication of DNA, reached stage G2 and mitosis (third day exposure). In this way the repeated exposures to MW covered the main periods of metabolic activity during the cell cycle of cultured cells[16,19].

The results of 10 experiments are presented in Table 1. The data obtained indicate that activity of lymphocytes and monocytes tested in vitro increased significantly under the influence of MW administered during the culture. The proliferative response of T lymphocytes exposed to MW increased from the value of 60.7 to 82.8 dpm in response to PHA ($p < 0.001$) and from the value of 55.9 to 73.8 dpm in response to Con A

Table 1 - Influence of MW (900 MHz) on the activity of T lymphocytes and monocytes in microcultures

Cultures (N = 10)	Tested parameter				
	Response to PHA dpm x 10^3/cult	Response to Con A dpm x 10^3/cult	Saturation of IL-2 receptors (%)	T cell suppressive T activity SAT (%)	LM index
Control	60.7 ± 18.7	55.9 ± 18.3	85 ± 3	36 ± 2	8 ± 2
Exposed to MW	↑ 82.8 ± 26.2	↑ 73.8 ± 25.7	84 ± 2	34 ± 2	↑ 18 ± 3
Statistical significance	p< 0.001	p< 0.001	p = 0.3920	p = 0.0964	p < 0.001

(p < 0.001). The exposure to MW also increased the immunogenic activity of monocytes. The value of LM index, which depends on the ratio of IL-1β to IL-1ra[20], (both monokines produced by monocytes), increased from the value 8.0 to the value 18.0 (p < 0.001). In contrast to the suppressive activity index (SAT), which represents regulatory function of T cells, the saturation of T lymphocyte receptors with interleukin 2 did not change under the influence of exposure to 900 MHz MWs.

The experiments presented here show for the first time that human lymphocytes and monocytes, induced in culture into active phases of their cell cycle (G1 in terms of monocytes and G1 and S in terms of T cells), further accelerate their metabolic activity under additional stimulus created by the exposure to 900 MHz GMS signal.

In contrast to the in vitro conditions, where freshly isolated PBMC remain in G0 phase, the immune cells of living organism represent all possible stages of cell cycle. To mimic in vitro the in vivo situation, we have used for our experiments the anechoic chamber installed in the ASSAB incubator. This technique opens the way to evaluate the possible influence of EMF on different phases of the cell cycle of immune cells. Our observations suggest that a 900 MHz GSM signal is immunostimulatory and may increase the immune reaction of lymphocytes and monocytes already participating in the immune response.

Testing possible immunotropic influences of 900 MHz GSM signal on human blood lymphocytes Scarfi *et al.*[22] did not found any changes in proliferative rate of cells exposed for 24 hour before setting up the cultures. Similar timing of exposure (irradiation before the culturing) was applied for human lymphocytes by Tuschi *et al.*[23]. They found no changes in several cytokine production and cytotoxic potential of lymphocytes exposed to 1950 MHz, SAR 1 mW/g. The both groups of authors conclude that tested radiofrequencies did not evoke any adverse influences on human immune cells. Nevertheless, in the light of cited above our experiments, the improper timing of irradiation could be responsible for observed negative results.

Experiment II. Immunotropic influence of 1300 MHz MW on cultures of blood mononuclear cells derived from normal donors or patients suffering from chronic virus B hepatitis.

The effect of irradiation may also be dependent on the initial immune state of the donor of blood lymphocytes. Two groups of blood donors, one of healthy individuals

(HD) and the other of patients suffering from chronic virus B hepatitis (HV) were enrolled into our experiments in which blood lymphocytes were exposed to 1300 MHz pulse modulated microwaves at 330 pps with 5 µs pulse width, or left without irradiation[24]. The specific absorption rate (SAR) was measured and the value of SAR = 0.18 W/kg was recorded. The microcultures of PBMC were subsequently set up to determine several parameters characterizing the T cell immunocompetence and monocyte immunogenic activity, including: proliferative response to mitogens (PHA, Con A), saturation of IL-2 receptors, T cell suppressive activity (SAT index), monocyte immunogenic activity (LM index) and production of chosen cytokines.

Results

The same power density of 1 mW/cm^2 reduced response to PHA in HD cultures and significantly increased this response in HV cultures, increased values of SAT and saturation of IL-2 receptors in the both HD and HV cultures (Table 2) and significantly increased production of interferon gamma (IFNγ) and production of tumor necrosis factor alpha (TNFγ) in the HV cultures but not in the HD cultures (Table 3). The results suggest that microwave irradiation (1300 MHz, pulse modulated) may exert distinct immunotropic influence and may enhance the effector immune response in patients with chronic virus B hepatitis, including considerable stimulation of the production IFNγ by immune cells.

Conclusion

The presented data suggest, that exposition in vitro of human blood mononuclear cells to different radiofrequencies of low energy MW (e.g. 900 and 1300 MHz) is potent to modulate the immune activity of lymphocytes and monocytes. The range of affected

Table 2 - Immunomodulatory effects in PBMC cultures exposed to EMF

Test	HD cultures		HV cultures		Statistical significance
	control	EMF exposed	control	EMF exposed	
Spontaneous ^{3}HTdR incorp.(dpm x 10^3)	1.9 ± 0.6	1.6 ± 0.2	2.9 ± 0.7	↓ 1.8 ± 0.3	HDc/HVc p< 0.01 HVc/e p< 0.01
Response to PHA (dpm x 10^3)	67.1 ± 8.7	↓ 45.8 ± 13.7	75.8 ± 9.8	↑ 98.2 ± 13.7	HDc/e p< 0.01 HVc/e p<0.05
Response to Con A (dpm x 10^3)	37.2 ± 11.7	46.9 ± 2.8	40.2 ± 16.8	47.7 ± 2.4	HDc/e NS HVc/e NS
SAT index	11.7 ± 9.4	↑ 29.7 ± 7.3	19.8 ± 11.4	↑ 28.9 ± 11.8	HDc/e p< 0.01 HVc/e p< 0.05
Saturation of IL-2 receptors	72.3 ± 4.6	↑ 91.1 ± 11.1	72.1 ± 7.6	↑ 87.1 ± 10.4	HDc/e p< 0.01 HVc/e p< 0.01
LM index	5.7 ± 3.1	7.6 ± 4.2	9.7 ± 4.2	↑ 19.7 ± 8.2	HDc/e NS HVc/e p< 0.01

HD: cultures of PBMC from healthy donors, HV: cultures of PBMC from patients with chronic virus B hepatitis.

Table 3 - Cytokine production in control and EMF exposed PBMC cultures (pg/ml)

Cytokines	HD cultures		HV cultures		Statistical significance
	control	EMF exposed	control	EMF exposed	
IL-1β	287 ± 120	298 ± 189	510 ± 212	741 ± 259	HDc/e NS HVc/e p< 0.05
IL-1ra	1312 ± 692	↓ 670 ± 256	2312 ± 672	2670 ± 1456	HDc/e p< 0.01 HVc/e NS
IFNγ	630 ± 92	510 ± 118	673 ± 92	↑ 1367 ± 847	HDc/e NS HVc/e p< 0.01
TNFα	1987 ± 986	2421 ± 475	1983 ± 936	↑ 3425 ± 875	HDc/e NS HVc/e p< 0.01
IL-10	311 ± 123	↑ 623 ± 193	471 ± 149	↓ 166 ± 59	HDc/e p< 0.01 HVc/e p< 0.01

HD: cultures of PBMC from healthy donors, HV: cultures of PBMC from patients with chronic virus B hepatitis

immune parameters depend not only on the wave length, frequency and intensity of EMF but also on the timing of exposures (before or during the culture) and on the initial immune status of the donor of immune cell.

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