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The Collision between Wireless and Biology

Héroux P. The Collision between Wireless and Biology. *Heliyon*, 2025. doi: 10.1016/j.heliyon.2025.e42267.

Abstract

This article examines the historical development of the concept of energy of activation, which has been used in the past to frame the belief that non-ionizing electromagnetic radiation is harmless at non-thermal levels. The power and telecommunications industries have used two arguments to support their view that human exposures to non-thermal non-ionizing radiation is inoffensive. First, the radiation is non-ionizing. Second, the energy quanta of the radiation are too weak to overcome the competing energy of thermal motion. Those arguments rest on the Arrhenius equation (1889) and on the concept of energy of activation. Later scientific developments such as the Eyring equation (1935) and the Bennett-Chandler (1977-1978) equation on reaction rates, and the Second Law of Thermodynamics, recognized in living systems by Schrödinger as “negentropy”, all undermine these arguments. The Second Law of Thermodynamics supplies the ionization claimed to be lacking, while some biological processes are independent of thermal motion. We contribute a new view of the physics and biology of non-ionizing electromagnetic radiation hygiene which explains many epidemiological, toxicological and scientific observations. The health effects of non-thermal non-ionizing radiation presently observed are in fact completely supported by physics. Furthermore, the expansion of wireless data rates is in direct conflict with preservation of a healthy environment.

Conclusion

Modeling living tissues as sugar/water/salt, or as separate bio-molecular components such as protein, biopolymers and solvated biomolecules excludes the most essential element of the living process, which is the continuous traffic of electrons and protons maintained by metabolism.

These currents are required by the Second Law of Thermodynamics, and their vulnerability to NTER [non-thermal electromagnetic radiation] is enhanced by the anatomy of OXPHOS [oxidative phosphorylation].

In a more complete model, and from the principle of superposition, oscillating electric or magnetic fields penetrating from the environment will alter the tissue's electron and proton currents. These can be far more easily disturbed by external electromagnetic fields than ionic species. To be biologically active, NTER does not need to produce ionized targets or electronic currents itself, but only to disturb those already provided by biology.

The present environmental perspective is sad given that a substantial engineering toolbox is available to mitigate NTER exposures: optical fiber, wire twisting, earthing practices, DC power. But a reversal of exposure tendencies will be difficult, as industry has long enjoyed the support of a critical actor, the military.

The same wireless communication techniques used to enable maneuverability in war theaters can also be used for high data rate access in civilian environments. Innovations such as 5G are useful to the military. Consequently, the military supports these developments with the goal of achieving superiority over their adversaries in a theater of war (Department of Defense 2020).

The alliance between industry and the military certainly has some practical advantages, but it has one major drawback.

If your environment is made to mimic a theater of war, it will not be a theater of health.

This paper addresses aspects of electron and proton dynamics in living systems. While it raises the subject of telecommunications signals crest factors, it ignores characteristics of common carrier modulations such as GSM and LTE, believed to be of importance in determining health impacts (NTP 2019). Refinement of modulations may minimize biological impacts, with the ultimate goal of controlling enough of those impacts to uncover new modulation schemes capable of reducing major health effects.

Open access paper: https://www.sciencedirect.com/science/article/pii/S2405844025006474

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Two letters attacking WHO-sponsored Systematic Review on RF-EMF Exposure and Cancer by Karipidis et al. (2024) and Authors' (Inadequate) Responses

Karipidis K, Baaken D, Loney T, Blettner M, Brzozek C, Elwood M, Narh C, Orsini N, Röösli M, Paulo MS, Lagorio S. The effect of exposure to radiofrequency fields on cancer risk in the general and working population: A systematic review of human observational studies - Part I: Most researched outcomes. Environ Int. 2024 Sep;191:108983. doi: 10.1016/j.envint.2024.108983. https://www.sciencedirect.com/science/article/pii/S0160412024005695

Frank JW, Moskowitz JM, Melnick RL, Hardell L, Philips A, Héroux P, Kelley E. The Systematic Review on RF-EMF Exposure and Cancer by Karipidis et al. (2024) has Serious Flaws that Undermine the Validity of the Study's Conclusions. Environment International, 2024. doi: 10.1016/j.envint.2024.109200. Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024007876

Karipidis K, Baaken D, Loney T, Blettner M, Mate R, Brzozek C, Elwood M, Narh C, Orsini N, Röösli M, Paulo MS, Lagorio S. Response to the letter from members of the ICBE-EMF. Environment International, 2024. doi: 10.1016/j.envint.2024.109201. Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024007888

ICBE-EMF. Scientific rebuttal to the misleading responses from Karipidis et al. on the ICBE-EMF critique of their systematic review on exposure to RF-EMF and human cancer. Jan. 15, 2025. Open access response: https://icbe-emf.org/scientific-response-to-the-rebuttal-of-karipidis-et-al-to-the-icbe-emfs-criticisms-of-the-who-cell-phone-radiation-cancer-review.

Di Ciaula A, Petronio MG, Bersani F, Belpoggi F. Exposure to radiofrequency electromagnetic fields and risk of cancer: Epidemiology is not enough! Environment International, 2025. doi: 10.1016/j.envint.2025.109275. https://www.sciencedirect.com/science/article/pii/S0160412025000261

Karipidis K, Baaken D, Loney T, Blettner M, Mate R, Brzozek C, Elwood M, Narh C, Orsini N, Röösli M, Paulo MS, Lagorio S. Response to the letter from Di Ciaula et al. Environment International, 2025. doi: 10.1016/j.envint.2025.109276. https://www.sciencedirect.com/science/article/pii/S0160412025000273

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The effect of exposure to radiofrequency fields on cancer risk in the general and working population: A systematic review of human observational studies – Part II: Less researched outcomes

Karipidis K, Baaken D, Loney T, Blettner M, Mate R, Brzozek C, Elwood M, Narh C, Orsini N, Röösli M, Paulo MS, Lagorio S. The effect of exposure to radiofrequency fields on cancer risk in the general and working population: A systematic review of human observational studies – Part II: Less researched outcomes. Environment International, 2025. doi: 10.1016/j.envint.2025.109274.

Abstract

Background

In the framework of the World Health Organization assessment of health effects of exposure to radiofrequency electromagnetic fields (RF-EMF), we have conducted a systematic review of human observational studies on the association between exposure to RF-EMF and risk of neoplastic diseases. Due to the extremely large number of included exposure types/settings and neoplasm combinations, we decided to present the review findings in two separate papers. In the first one we addressed the most investigated exposure-outcome pairs (e.g. glioma, meningioma, acoustic neuroma in relation to mobile phone use, or risk childhood leukemia in relation to environmental exposure from fixed-site transmitters) (Karipidis et al., 2024). Here, we report on less researched neoplasms, which include lymphohematopoietic system tumours, thyroid cancer and oral cavity/pharynx cancer, in relation to wireless phone use, or occupational RF exposure.

Methods

Eligibility criteria: We included cohort and case-control studies of neoplasia risks in relation to three types of exposure to RF-EMF: 1. exposure from wireless phone use; 2. environmental exposure from fixed-site transmitters; 3. occupational exposures. In the current paper, we focus on less researched

neoplasms including leukaemia, non-Hodgkin's lymphoma and thyroid cancer in mobile phone users; lymphohematopoietic system tumours and oral cavity/pharynx cancer in exposed workers. We focussed on investigations of specific neoplasms in relation to specific exposure sources (termed exposure-outcome pair, abbreviated E-O pairs), noting that a single article may address multiple E-O pairs. Information sources: Eligible studies were identified by predefined literature searches through Medline, Embase, and EMF-Portal. Risk-of-bias (RoB) assessment: We used a tailored version of the Office of Health Assessment and Translation (OHAT) RoB tool to evaluate each study's internal validity. Then, the studies were classified into three tiers according to their overall potential for bias (low, moderate and high) in selected, predefined and relevant bias domains. Data synthesis: We synthesized the study results using random effects restricted maximum likelihood (REML) models. Evidence assessment: Confidence in evidence was assessed according to the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) approach.

Results

We included 26 articles, which were published between 1988 and 2019, with participants from 10 countries, reporting on 143 different E-O pairs, including 65 different types of neoplasms. Of these, 19 E-O pairs satisfied the criteria for inclusion in quantitative syntheses of the evidence regarding the risks of leukaemia, non-Hodgkin's lymphoma or thyroid cancer in relation to mobile phone use, and the risks of lymphohematopoietic system tumours or oral cavity/pharynx cancer following occupational exposure to RF-EMF. RF-EMF exposure from mobile phones (ever or regular use vs no or non-regular use) was not associated with an increased risk of leukaemia [meta-estimate of the relative risk (mRR) = 0.99, 95 % CI 0.91–1.07, 4 studies), non-Hodgkin's lymphoma (mRR = 0.99, 95 % CI = 0.92–1.06, 5 studies), or thyroid cancer (mRR = 1.05, 95 % CI = 0.88–1.26, 3 studies). Long-term (10 + years) mobile phone use was also not associated with risk of leukaemia (mRR = 1.03, 95 % CI 0.85–1.24, 3 studies), non-Hodgkin lymphoma (mRR = 0.99, 95 % CI 0.86–1.15, 3 studies), or thyroid cancer (no pooled estimate given the small number of studies). There were not sufficient studies of any specific neoplasms to perform dose–response meta-analyses for either cumulative call time or cumulative number of calls; individual studies did not show statistically significant associations between lifetime intensity of mobile phone use and any specific neoplasm. Occupational RF-EMF exposure (exposed vs unexposed) was not associated with an increased risk of lymphohematopoietic system tumours (mRR = 1.03, 95 % CI = 0.87–1.28, 4 studies) or oral cavity/pharynx cancer (mRR = 0.68, 95 % CI 0.42–1.11, 3 studies). There were not sufficient studies of any specific neoplasms to perform meta-analysis on the intensity or duration of occupational RF-EMF exposure; individual studies did not show statistically significant associations with either of those exposure metrics and any specific neoplasms. The small number of studies, and of exposed cases in some instances, hampered the assessment of the statistical heterogeneity in findings across studies in the meta-analyses. Based on the summary risk of bias, most studies included in the quantitative evidence syntheses were classified at moderate risk of bias. The most critical issue was exposure information bias, especially for occupational studies where the exposure characterization was rated at high risk of bias for all included studies. Outcome information bias was an issue in mortality-based occupational cohort studies investigating non-rapidly fatal neoplasms. Further, the healthy subscriber effect, and (at a lesser extent) the healthy worker effect, were identified as plausible explanations of the decreased risks observed in some studies. The association of RF-EMF exposure from wireless phone use, or workplace equipment/devices, with other important neoplasms was reported by only one or two studies per tumour, so no quantitative evidence syntheses were conducted on these outcomes. It is

noted that there were generally no statistically significant exposure-outcome associations for any combinations, independently of the exposure metric and level, with a few studies reporting decreased risks (especially for smoking-related cancers). There was only one study which assessed the effect of RF-EMF exposure from fixed-site transmitters on less researched neoplasms and it reported no statistically significant associations between exposure from base stations and risk of lymphomas overall, lymphoma subtypes, or chronic lymphatic leukaemia in adults.

Conclusions

For near field RF-EMF exposure to the head from mobile phones, there was low certainty of evidence that it does not increase the risk of leukaemia, non-Hodgkin's lymphoma or thyroid cancer. For occupational RF-EMF exposure, there was very low certainty of evidence that it does not increase the risk of lymphohematopoietic system tumours or oral cavity/pharynx cancer. There was not sufficient evidence to assess the effect of whole-body far-field RF-EMF exposure from fixed-site transmitters (broadcasting antennas or base stations), or the effect of RF-EMF from any source on any other important neoplasms.

Other

This project was commissioned and partially funded by the World Health Organization (WHO). Co-financing was provided by the New Zealand Ministry of Health; the Istituto Superiore di Sanità in its capacity as a WHO Collaborating Centre for Radiation and Health; and ARPANSA as a WHO Collaborating Centre for Radiation Protection. Registration: PROSPERO CRD42021236798. Published protocol: [(Lagorio et al., 2021) DOI https://doi.org/10.1016/j.envint.2021.106828].

Excerpts

"Our conclusive statements, formulated in accordance with the GRADE guidelines 26 (Santesso et al., 2020), are provided below.

- For near field RF-EMF exposure to the head from mobile phones, there was low certainty of evidence that it does not increase the risk of leukaemia, non-Hodgkin's lymphoma or thyroid cancer.
- For occupational RF-EMF exposure, there was very low certainty of evidence that it does not increase the risk of lymphohematopoietic system tumours or risk of oral cavity/pharynx cancer.
- There was not sufficient evidence to assess whole-body far-field RF-EMF exposure from fixed-site transmitters (broadcasting antennas or base stations) or the effect of exposure to RF-EMF (from any source) on any other *important* neoplasms."

"The main limitation in this second paper on findings from our systematic review was the small number of studies per tumour type (which in some ways is inherent to this paper, that is dedicated to less researched neoplasms). A formal synthesis of the evidence was only possible for a few types of neoplasms, mainly different types of lymphohematopoietic system tumours, as well as thyroid and oral cavity/pharynx cancers. There were 54 types of neoplasms which were investigated in only one or two studies and did not satisfy the criteria for a quantitative synthesis of the evidence, but none of these showed evidence of an effect of RF EMF."

"Looking at specific sources of RF-EMF exposure, the majority of the evidence was on mobile phone use. There was only sufficient evidence to assess the effect of ever (or regular) use *vs* no (or non-regular) use, as well as of long-term (10 + years) use. There was not sufficient evidence on lifetime intensity of mobile phone use, including cumulative call time and cumulative number of calls, so we could not conduct a dose–response analysis."

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Mark Elwood has given expert advice on topics in electromagnetic fields and health, and on the objective interpretation of epidemiological and other scientific information, over many years to individuals and groups, including government ministries, environmental regulators, community groups, commercial organisations, and formal inquiries by government and professional groups including parliamentary and legal proceedings. Some of this work has been financially supported, by universities, health care organisations, research bodies, or by government, professional or commercial groups. Some work has been reported 'blind', with the client being unidentified. Susanna Lagorio was principal investigator (April 2019 – March 2020) of the research project "BRiC 2018/06 – Systematic reviews of exposure to radiofrequency fields and cancer", supported by the Italian Workers' Compensation Authority, a public no-profit entity (grant code I85B19000120005). Her employment duties involved provision of advice on health hazards from exposure to RF-EMF to the Italian Ministry of Health and Higher Health Council (she retired on August 1st, 2023). Martin Röösli's research is entirely funded by public entities or not for profit foundations. He has served as advisor on potential health effects of exposure to non-ionizing radiation to several national and international public advisory and research steering groups, including the World Health Organization, the International Agency for Research on Cancer, the International Commission on Non-Ionizing Radiation Protection, the Swiss Government (member of the working group "Mobile phone and radiation" and chair of the expert group BERENIS), the German Radiation Protection Commission (member of the committee Non-ionizing Radiation (A6) and member of the working group 5G (A630)) and the Independent Expert Group of the Swedish Radiation Safety Authority. From 2011 to 2018, M.R. was an unpaid member of the foundation board of the Swiss Research Foundation for Electricity and Mobile Communication, a non-profit research foundation at ETH Zurich. Neither industry nor nongovernmental organizations are represented on the scientific board of the foundation. Chris Brzozek and Rohan Mate as part of their employment are involved in the provision of advice to the Australian Commonwealth Government, Australian States and Territories and the general public on the risks and health effects of exposure to ionising and non-ionising radiation.

The other authors declare that they have no known conflicts of interest.

Open access paper: https://www.sciencedirect.com/science/article/pii/S016041202500025X

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Histopathologic effects of mobile phone radiation exposure on the testes and sperm parameters: a systematic literature review of animal studies

Assefa EM, Abdu SM. Histopathologic effects of mobile phone radiation exposure on the testes and sperm parameters: a systematic literature review of animal studies. Front Reprod Health. 2025 Jan 17;6:1515166. doi: 10.3389/frph.2024.1515166.

Abstract

Introduction: Male infertility, often attributed to insufficient production of healthy and active sperm, can be exacerbated by electromagnetic radiation emitted from mobile phones, which disrupts normal spermatogenesis and leads to a notable decline in sperm quality. The main targets of mobile phone-induced damage in the testes are Leydig cells, seminiferous tubules, and sperm cells. The aim of this systematic literature review is to identify histopathological changes in the testes due to mobile phone radiation exposure and to examine its effects on sperm parameters in experimental animals.

Methods: In this systematic review, an extensive literature search was conducted across databases such as PubMed, ScienceDirect, Hinari, and Google scholar.

Results: A total of 752 studies were identified for screening, and 18 studies were deemed eligible for data extraction. Studies have identified histopathological alterations in testicular tissue caused by mobile phone radiation, such as reduced seminiferous tubule diameter, tunica albuginea and germinal epithelial thickness, Leydig cell hypoplasia, and increased intertubular space. Consistent exposure to mobile phone radiation has been shown to significantly reduce sperm count, motility, and viability, while also increasing abnormal sperm morphology in male rats, mice, and rabbits.

Conclusion: Animal studies indicate that electromagnetic radiation from mobile phones can negatively impact testicular tissue and sperm parameters, including sperm count, motility, viability, and morphology. As a precaution, preventive measures are recommended to minimize potential risks from mobile phone exposure, and further research is needed to fully understand its effects on human reproductive health.

Open access paper: https://www.frontiersin.org/journals/reproductive-health/articles/10.3389/frph.2024.1515166

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Laptop and tablet use and their influence on total motile sperm count parameters: are laptops linked to infertility in Jamaican men?

Sterling L, Carroll K, Harris LR. Laptop and tablet use and their influence on total motile sperm count parameters: are laptops linked to infertility in Jamaican men? Rev Int Androl. 2024 Dec;22(4):25-32. doi: 10.22514/j.androl.2024.027.

Abstract

Background: This study aims to determine the impact of laptop and tablet use on total motile sperm count (TMSC) in men being investigated for assisted reproduction.

Methods: A cross-sectional study was conducted on 156 men attending a fertility clinic in Jamaica.

Routine semen analyses were performed and parameters specific to TMSC assessed. All data analyses were performed using SPSS Version 26. Logistic regression analyses were performed to independently predict the impact of quantifiable measures of laptop and tablet use. The main outcome measures were the parameters associated with TMSC.

Results: Overall, 64% of the participants reported using laptops and 36% reported using tablets. There was a significant relationship seen with time spent on laptops and time trying to conceive (p = 0.015). Regression analyses showed that persons who used their laptops for 2 to 5 h daily were approximately 16 times (adjusted Odds Ratio (aOR) = 15.9; 95% Confidence Interval (CI), 2.5-103.3, p = 0.004) more likely to be diagnosed with low semen volume (hypospermia). Although no significant association was found between total motile sperm count (TMSC) and laptop use, a trend towards significance was observed with high laptop use (p = 0.052), suggesting potential implications for TMSC as a predictor of pregnancy outcomes.

Conclusions: Our findings highlight the need for clinicians to take into consideration wireless device usage in men undergoing fertility investigations.

Open access paper: https://files.intandro.com/files/article/20241230-28/pdf/RIA20240615001.pdf

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A review of effects of electromagnetic fields on ageing and ageing dependent bioeffects of electromagnetic fields

Wei X, Huang Y, Sun C. A review of effects of electromagnetic fields on ageing and ageing dependent bioeffects of electromagnetic fields. Sci Total Environ. 2025 Jan 15;963:178491. doi: 10.1016/j.scitotenv.2025.178491.

Abstract

Thanks to the progress of science and technology, human life expectancy has dramatically increased in the past few decades, but accompanied by rapid ageing of population, resulting in increased burden on society. At the same time, the living environment, especially the electromagnetic environment, has also greatly changed due to science and technology advances. The effect of artificial electromagnetic fields (EMFs) emitted from power lines, mobile phones, wireless equipment, and other devices on ageing and ageing-related diseases are receiving increasing attention. However, the information on the relationship between EMFs and ageing and ageing related susceptibility to EMFs is fragmentary, a review is needed. Only few studies directly investigate the effect of EMFs on ageing, and we reviewed the impact of EMFs on lifespan and cellular senescence to pry whether EMFs have an effect on ageing, and reviewed the age-dependent bioeffects and health impacts of EMFs to see whether ageing would affect biological susceptibility to EMFs. The results indicated that EMFs may have an effect on longevity and cellular senescence, but the results were inconsistent which may depend on EMF types (frequency, intensity, wave shape, etc.), species, and cell lines. Ageing has an impact on the biological or health effects of EMFs; however, the results differ depending on the EMF type and the endpoint or health outcome. Age-dependent changes in free radical metabolism, ion homeostasis, gene expression, enzyme activity, and tissue biophysical properties may be the reason; however, the underlying mechanisms are not fully elucidated.

Highlights

- Electromagnetic fields (EMF) exposure has an effect on lifespan, but the effect may vary with type of EMF and animal model.
- Extremely-low-frequency EMFs exposure can affect cellular senescence in a wave shape- and/or magnetic density-dependent manner.
- Radio-frequency EMFs promotes cellular senescence in a frequency- and intensity-dependent manner.
- The influence of EMFs on cellular, animal, and human health exhibits a degree of age-dependency.

https://pubmed.ncbi.nlm.nih.gov/39818160/

Conclusion

With the intensification of ageing and the variety of EMFs in the environment continues to increase, the effects of EMFs on ageing and ageing-dependent effects of EMFs will get constant attention. Although current research is insufficient to answer this question, some important information can be gleaned. The ageing state of the cell or body plays a role in determining the biological or health effects of EMF exposure, but the exact effect depends on the specific conditions, and further investigation of the underlying mechanism is needed.

6.1. The effect of EMFs on ageing

Ageing is a complex and expanding concept (López-Otín et al., 2023); therefore, understanding the effects of EMFs on ageing is not to be done in a short time, but we can gain insights into this mystery from the study of lifespan and cellular senescence. SMFs have an effect on delaying cellular senescence (Fig. 3) and extending the lifespan of C. elegans and mice (Fig. 2); however, SMFs at high flux intensity had negative effects on C. elegans (Fig. 2). RMFs have both beneficial effects on anti-cellular senescence and prolong the lifespan of C. elegans (Fig. 2, Fig. 3). The impact of ELF-EMFs on lifespan and cellular senescence had been found to be inconsistent, potentially dependent on wave shape and/or magnetic flux density (Fig. 2, Fig. 3). Exposure to RF-EMFs in the wireless communication bands (1800 MHz–2480 MHz) appears to have no significant impact on lifespan (Fig. 2). However, these RF-EMFs may influence cellular senescence in a frequency- and intensity-dependent manner (Fig. 3).

6.2. Ageing-dependent effect of EMFs

With the global ageing of the population, it is very meaningful to understand the age-dependent health effects of EMFs. Although the current research is still in the preliminary stage, the biological effects of SMFs, ELF-EMFs, and RF-EMFs have been reported to be age dependent (Fig. 4). SMFs have an age-dependent effect on cell apoptosis, calcium signalling and tissue hydration. ELF-EMFs have an age-dependent effect on human-derived primary cells and brain oxidative stress in animals, and

epidemiological studies have shown that the relationship between ELF-EMFs and the risk of neurodegenerative disease is greater in older individuals and that the risk of carcinogenesis is greater in young individuals. RF-EMFs have an age-dependent effect on immune cells, tissue development, and brain activity but do not interfere with sleep. Importantly, RF-EMFs are more strongly related to the risk of carcinogenesis in younger age groups.

6.3. Possible mechanisms for the age-dependent effect of EMFs

Cellular senescence is the basis of ageing, so the age-dependent effect may be fundamentally due to cellular senescence (van Deursen, 2014). A deeper understanding of the molecular mechanism underlying the interactions between EMFs and cells may lead to new findings. Free radical metabolism and calcium signalling have mostly been studied for their ability to mediate the bioeffects of EMFs; thus, age-related functional changes in these two aspects might be the cause of age-dependent effects (Falone et al., 2008; Selakovic et al., 2013). Existing studies have shown that other possible mechanisms, such as age-dependent Na+/K+ pump dysfunction (Deghoyan et al., 2014) and decreased expression levels of high-affinity ouabain receptors (Narinyan et al., 2013), play important roles in the age-dependent effect of SMFs on tissue hydration. The effect of EMFs is also dependent on the biophysical properties of tissues or cells, and ageing-related differences in the biophysical properties that result in different responses to EMFs may also be the cause of age-dependent effects.

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Effects of radiofrequency electromagnetic radiation with a focus on hematology parameters: a brief review and future research needs

N. Žura, I. Žura Žaja*, P. Perić, K. Malarić, S. Milinković Tur, N. Poljičak Milas, V. Rimac, J. Pejaković Hlede, S. Kunštek, M. Pećin, M. Vili. Effects of radiofrequency electromagnetic radiation with a focus on haematology parameters: a brief review and future research needs. Veterinarska Stanica, 56(3):375-387. 2025. doi: 10.46419/vs.56.3.6.

Abstract

The use of radiofrequency electromagnetic radiation (RF-EMR) has steadily increased since the 1950s. RF-EMR is used in medicine, industry, household appliances, security and navigation, and especially in wireless tele- communications and animal husbandry. The widespread use of RF-EMR, especially with the introduction of 5G networks, raises concerns about potential adverse effects on human and animal health. The effects and mechanisms of RF-EMR impacts of 5G network frequencies on human and animal health are still unknown or poorly understood. Current research findings include the biological effects of RF-EMR on genotoxicity, cell proliferation, gene expression, cell signalling, cell membrane function, and the function of immune, hematopoietic, and reproductive systems. Exposure of humans and laboratory animals to RF-EMR emitted from cell phones and many other electronic devices of 4G and older technologies has been shown to have detrimental effects on blood cells and to cause changes in the complete blood count. This depends on the type of organisms exposed, sources, frequency, electric field level and duration of exposure. There is sparse data in the available literature on the effects of RF-EMR on haematology indicators and erythrocyte morphometry in domestic animals. Therefore, the aim of this scientific review is to highlight the effects of RF-EMR on haematology indicators, erythrocyte morphometry, and platelet activation in humans and animals, taking into account the

findings on the effects of 5G electromagnetic radiation on these indicators. Considering the ubiquitous electromagnetic pollution, it is important to gain knowledge about the effects of RF-EMR on human and animal health. In addition, it is necessary to determine the effects following in vitro exposure of blood to RF-EMR, especially due to the storage and use of blood and blood products in transfusion medicine.

Open access paper: https://hrcak.srce.hr/file/462530

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Waveforms of 4G and 5G Radiofrequency Signals: Are Differences Relevant to Biology or Health?

My note: Studies of **4G** and **5G** exposure have found adverse effects as well as exposure to **millimeter waves**.

Foster KR, Maxson D, Zollman PM. Waveforms of 4G and 5G Radiofrequency Signals: Are Differences Relevant to Biology or Health?. Health Physics. November 20, 2024. doi: 10.1097/HP.0000000000001895.

Abstract

This Note briefly reviews, at a level that is intended to be accessible to non-specialists, the similarities and differences between waveforms of 4G Long-Term Evolution (4G LTE) and 5G New Radio (5G NR) transmitted by cellular base stations, as a resource for health physicists and others who are engaged in public communication about cellular telephone technologies. Despite the difference in levels of controversy presently existing between 4G LTE (introduced in 2008) and 5G NR (introduced in 2019), the differences in waveform as represented by the baseband waveform are minimal, although 5G NR offers system designers a much wider choice of parameters. Transmitted radiofrequency signals in both technologies appear noise-like, in a frequency range that is narrowly contained in the assigned channel. It is concluded that the modulation differences between 4G LTE and 5G NR are unlikely to have any biological relevance, but the greater range of accessible frequencies in 5G NR suggests the need for further health research, particularly in the 5G FR2 millimeter-wave band.

Conclusion

In closing, it is noted that the topic of 5G NR and health extends beyond the technical considerations concerning modulation, waveform, and frequency, to include population exposure assessment, risk perception and risk communication, and other topics. One factor contributing to public concerns about 5G NR cell sites is the use of small wireless facilities ("small cells") along city streets, sometimes close to residences (network operators have deployed 4G LTE and 5G NR small cells in some localities). To address this broader range of issues, in 2022, the European Union funded a large set of studies called CLUE-H that combines efforts of "more than 70 European research organizations in four research consortia" (https://emf-health-cluster.eu) to study the risks and perceived risks of 5G technology.

As communications technology continues to develop, the authors hope that high-quality targeted research will resolve the remaining gaps in our knowledge.

https://journals.lww.com/health-physics/abstract/9900/waveforms_of_4g_and_5g_radiofrequency_signals__are.200.aspx

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Auto-induced uplink 4G and 5G RF-EMF exposure assessment using a network monitoring application in different microenvironments across seven European countries

Stroobandt B, Van Bladel H, Veludo AF, Deprez K, Aerts S, Verloock L, Thuróczy G, Politanski P, Polanska K, Tognola G, Parazzini M, Wiart J, Guxens M, Röösli M, Joseph W. Auto-induced uplink 4G and 5G RF-EMF exposure assessment using a network monitoring application in different microenvironments across seven European countries. Environmental Research, 2025, doi: 10.1016/j.envres.2025.121029.

Highlights

Assessment of uplink 4G and 5G microenvironmental RF-EMF exposure in Europe

Novel methodology using network monitoring application QualiPoc for 4G and 5G

Transmit powers were higher in villages than in big cities, with 5G lower than 4G

Base station density was suggested as key predictor of auto-induced uplink exposure

Transmit powers are related to uplink duty cycles and frequency band usage

Abstract

The auto-induced uplink (a-UL) radio-frequency electromagnetic field (RF-EMF), often the dominant part of the total RF-EMF exposure, has not been included in previous microenvironmental studies. As 5G exposure depends more on mobile phone usage, monitoring typical transmit power levels is crucial towards more accurate personal exposure assessment. This study describes spatial differences in average mobile phone transmit power and investigates the influence of uplink duty cycles and frequency band usage. A novel methodology using the network monitoring application QualiPoc in fourth-generation (4G) and non-standalone fifth-generation (5G) networks was presented. For the first time, the assessment of 4G and 5G a-UL RF-EMF exposure was conducted simultaneously in a large-scale microenvironmental study in Europe. Measurements were performed along predefined routes in 282 different microenvironments (e.g., parks, residential areas) across seven European countries, during a maximum uplink usage scenario. The Netherlands had the highest average transmit powers per microenvironment (median 20.6 dBm). Transmit powers in villages were 0.6 to 2.1 dB higher than in big cities. The study suggested that base station density is a key predictor of a-UL exposure. Comparing technologies and frequency bands, average transmit powers for 5G were about 3.3 dB lower than for 4G and lowest for frequency bands with a time division duplexing (TDD) scheme due to the low uplink duty cycle (below 20%). This study provides crucial measurement data for epidemiologists and governments to enhance the understanding of the a-UL component of personal RF-EMF exposure.

https://www.sciencedirect.com/science/article/pii/S0013935125002804

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Electromagnetic Field-Aware Radio Resource Management for 5G and Beyond: A Survey (Review)

Salem MA, Lim HS, Diong KS, Alaghbari KA, Zarakovitis CC, Chien SF. Electromagnetic Field-Aware Radio Resource Management for 5G and Beyond: A Survey. *Computers*. 2025; 14(2):51. doi: 10.3390/computers14020051.

Abstract

The expansion of 5G infrastructure and the deployment of large antenna arrays are set to substantially influence electromagnetic field (EMF) exposure levels within mobile networks. As a result, the accurate measurement of EMF exposure and the integration of EMF exposure constraints into radio resource management are expected to become increasingly important in future mobile communication systems. This paper provides a comprehensive review of EMF exposure evaluation frameworks for 5G networks, considering the impacts of high-energy beams, the millimeter wave spectrum, network densification and reconfigurable intelligent surfaces (RISs), while also examining EMF-aware radio resource management strategies for 5G networks and beyond, with RIS technology as an assistive factor. Furthermore, challenges and open research topics in the EMF evaluation framework and EMF-aware resource management for 5G mobile networks and beyond are highlighted. Despite the growing importance of RIS technology in enhancing mobile networks, a research gap remains in addressing specific EMF exposure considerations associated with RIS deployments. Additionally, the impact of EMF-aware radio resource allocation approaches on RIS-assisted 5G networks is still not fully understood.

Open access paper: https://www.mdpi.com/2073-431X/14/2/51

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Measurement of Ambient Millimeter Wave Exposure Levels around Small Base Stations

My note: Averaging exposure over time, 30 minutes in this study, ensures very low power densities for 5G millimeter waves (MMW) especially when few (or no) 5G cell phones are downloading files using the MMW band. Assessing MMW exposure from a 5G base station is both a costly and tricky endeavor especially if one is concerned about peak exposures: "... when a UE was used to attract the beam toward the measurement location, the maximum instantaneous exposure measured was -60 dBm (0.8% public MPE)." This was 381 times the 30-min average maximum exposure at that location.

Bushberg JT, Butcher MJ. Measurement of Ambient Millimeter Wave Exposure Levels around Small Base Stations. Health Phys. 2025 Jan 13. doi: 10.1097/HP.0000000000001935.

Abstract

This study investigated the implementation and impact of fifth-generation (5G) wireless millimeter wave (mmW) technology. 5G offers significant advancements over previous generations and supports additional frequency bands, including mmW, to enhance mobile broadband with ultra-reliable, low-latency communications, supporting a high volume of diverse communications. This technology is expected to enable billions of new connections in the Internet of Things (IoT), fostering innovations in various sectors including healthcare, manufacturing, and education. This research contributes to the understanding and safe implementation of this transformative technology. Global adoption of 5G is rapidly increasing, with over 1.5 billion subscriptions as of 2024, projected to reach 58% of all wireless subscriptions by 2029. Despite its benefits, 5G mmW installations have raised concerns regarding exposure to electromagnetic fields. This study was conducted using a dual-polarized horn antenna and relatively inexpensive spectrum analyzers to measure typical ambient mmW radiofrequency field power densities near operational radio base stations (RBS) in urban and suburban environments. The measurements were taken at various times of the day and in different weather conditions to ensure a comprehensive understanding of the ambient mmW exposure. The study's results provide reassuring

evidence that the ambient mmW exposure from RBSs is significantly lower than the safety limits set by the Federal Communications Commission (FCC) and other international standards. The exposure levels ranged from 0.0003% to 0.0082% of the public maximum permissible exposure (MPE), with the highest levels being more than 25,000 times lower than the allowed continuous public exposure. This study concludes that typical mmW exposure from 5G RBSs is minimal and substantially below established safety limits.

https://pubmed.ncbi.nlm.nih.gov/39804717/

Excerpts

Table 1 - RF hardware.

Device	**Description**	**Manufacturer/Part Number**
Spectrum Analyzer #1	Spectrum Analyzer 24-43 GHz v.2	SAF/J0GSAP541B
Spectrum Analyzer #2	Spectrum Compact 24-40 GHz v.2	SAF/J0GSAP741B
Antenna	18.0-40.0GHz Dual Polarization Horn Antenna	A-Info/LB-SJ-180400-KF
RF Cable Assembly (x2)	Sucoflex 102 500 mm Cable with 2.92 mm Connectors	HUBER+SUHNER/SF102/11SK/11SK/500 mm
Right Angle Adapter (x2)	2.92 mm Plug to 2.92 mm Jack Right Angle Adapter	Dynawave/1101-9495-6200

Thirty-minute (30 min) measurements were made at three distance intervals (3-15, 15-30, and 35+ m) from the base of the RBS support structure as measured with a laser rangefinder (Fig. 3). These distance intervals were selected to highlight the fact that exposure levels can vary with distance and angle relative to the BTS. Locations were selected for alignment with the RBS antenna panels, line of sight to the antenna, and critically in a location that allowed for 30-min uninterrupted measurements. All the criteria could not be met for all locations. As seen in Fig. 4, the middle and far locations were selected off-boresight to avoid vehicle traffic and achieve line-of-sight. Following the 30-min measurement at each location, four additional 2-min measurements were made with the horn oriented at 0°, 90°, 180°, and 270° relative to the direction of the 30-min measurement to assess the presence of reflections and mmW signals from other RBSs in the area. An example is shown in Fig. 5. The first 2 min are oriented at the RBS, and the remaining time is at the other azimuths before returning to the RBS.

At most of the measured RBSs, a 1-min sample acquisition was obtained with a mobile phone (UE) behind the horn antenna assembly. High-definition/large file-size video downloads were performed to attract the beam toward the measurement location. The increase in signal strength over the RBS signal bandwidth was used to confirm that the measurement equipment and RBS were operating as expected and to estimate the maximum exposure corresponding to the RBS operating close to full capacity. It was

noted that some RBS operated at 800, 400, and 300 MHz, corresponding to eight, four, and three 100-MHz channels.

The spectrum analyzers display and record received signal power in units of decibels relative to a milliwatt (dBm). The analyzers required a little over 10 s to scan the entire 1 GHz spectrum, using overlapping 100 kHz bins spaced every 30 kHz. SAF settings are listed in Table 2. Before measurements, the spectrum analyzers, the horn antenna, and the feedlines were checked with an RF source at mmW frequencies and found to agree with the expected levels. Each frequency bin was averaged throughout the measurement, and the bin with the highest received averaged power was selected to represent the highest time-average exposure at the base station. Extrapolating from the highest received averaged power bin provides a very conservative assessment of power over the entire spectrum based on the measurements. The highest received averaged power bin was converted to power received over the operating bandwidth, considering the ratio of the bin bandwidth to the observed bandwidth of the signal and the loss of the transmission lines.

The power density for both polarizations was summed to determine the time-averaged total exposure and compared with the exposure limit. This result is presented for three distances for each RBS. RBSs in four geographic areas—Los Angeles, CA; Arlington, VA; Washington, DC; and Providence, RI—were selected. All have deployed different manufacturers' equipment by different operators, including T-Mobile and AT&T. Locations included urban commercial and residential areas.

Table 3 shows data of 30-min measurement results at different distance intervals, indicating the maximum average bin over that 30-min expressed as a percent of the General Public exposure limit. The ambient mmW measurements ranged from −77 dBm down to −94 dBm, which, when polarizations are combined, correspond to total exposure levels of 0.0082% to 0.0003% of the public maximum permissible exposure (MPE). The noise floor adjacent to the measured signal was −98 dBm (Fig. 6). By comparison, **when a UE was used to attract the beam toward the measurement location, the maximum instantaneous exposure measured was -60 dBm (0.8% public MPE) (Fig. 7)**. At the same location, the 30-min average maximum 100 kHz bin is −83 dBm (0.0021% GP). The figures show only one polarization at RBS CYLA4-7 and include the 100 MHz channel average.

Conclusions

One of the distinguishing characteristics of 5G mmW base stations is dynamic beamforming using a multi-element antenna. When the scanning beams detect a UE in its service environment, the RBS creates a narrow beam directed toward UEs requesting service. Even when an obstacle in its direct path blocks the beam, the system will use multiple directed beams for spatial multiplexing. Spectral analysis of mmW signals typically requires expensive portable spectrum analyzer equipment, costing upwards of $70,000. Substantially less expensive equipment (approximately $20,000) can be used. This report demonstrates that a cross-polarized horn and two spectrum analyzers can make power density measurements of orthogonal polarization and capture the total mmW exposure from an RBS.

RF surveys were conducted in the United States in various urban environments, using different frequency bands, operators, and equipment manufacturers. Measurements at several distances from operational radio base stations (RBS) indicate that the typical exposure from an mmW RBS at ground level was an exceedingly small fraction of the FCC public safety limit. The overall measurements of

ambient mmW exposure ranged from 0.0003% to 0.0044% of the FCC public MPE. Even the highest exposure level was more than 25,000 times lower than allowed for continuous public exposure.

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Explainable Machine Learning-Based Electric Field Strength Mapping for Urban Environmental Monitoring

Kiouvrekis Y, Psomadakis I, Vavouranakis K, Zikas S, Katis I, Tsilikas I, Panagiotakopoulos T, Filippopoulos I. Explainable Machine Learning-Based Electric Field Strength Mapping for Urban Environmental Monitoring: A Case Study in Paris Integrating Geographical Features and Explainable AI. *Electronics*. 2025; 14(2):254. https://doi.org/10.3390/electronics14020254

Abstract

The objective of this study is to determine the optimal machine learning model for constructing electric field strength maps across urban areas, advancing the field of environmental monitoring. These models are unique because they use a detailed dataset that goes beyond electromagnetic readings, incorporating information like population density, urbanization levels, and building characteristics. This novel approach, combined with explainable AI, helps identify the key factors affecting electromagnetic exposure. The models enable the creation of highly detailed and dynamic maps of electromagnetic pollution. These maps are not just static snapshots, they can track changes over time, evaluate the success of mitigation efforts, and provide deeper insights into how electromagnetic fields are distributed in urban areas. To construct a detailed electric field strength map, we conducted an extensive analysis using 410 machine learning models across the urban area of Paris, incorporating three fundamental approaches: k-nearest neighbors, neural networks, and decision trees. This comprehensive exploration allowed us to evaluate and optimize various model configurations, ensuring robust and accurate predictions of electric field strength across diverse urban environments. The kNN model exhibited the most consistent performance, with an RMSE of 1.63 and an SD of 0.20. The analysis indicates that kNN outperforms simple neural networks and decision trees in terms of both RMSE and performance stability. From the SHAP analysis, we conclude that the feature representing the total volume of buildings in the area around each antenna (V) is the most significant in predicting electromagnetic field strength in the kNN regression model, consistently showing a high impact across predictions. The population density feature (POP) also demonstrates considerable influence.

Open access paper: https://www.mdpi.com/2079-9292/14/2/254

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Effects of 5G mobile phone network electromagnetic field exposure on testicular endoplasmic reticulum stress and the protective role of coenzyme Q10 (CoQ10)

Yilmaz H, Tümkaya L, Mercantepe T, Yılmaz A, Gül F, Suzan ZT. Effects of 5G mobile phone network electromagnetic field exposure on testicular endoplasmic reticulum stress and the protective role of coenzyme Q10. Arch Med Res. 2025 Jan 6;56(4):103157. doi: 10.1016/j.arcmed.2024.103157.

Abstract

Aim: Nowadays, the electromagnetic field (EMF) has become an issue of electromagnetic pollution. This study aimed to determine the effect of 5 G Fr1 frequency band EMF waves on endoplasmic reticulum (ER) stress in testicular tissue and to demonstrate the efficacy of coenzyme Q10 (CoQ10) in suppressing the potential situation.

Materials and methods: Three groups of eight male Sprague-Dawley rats were established. In group I (control) received only saline solution by oral gavage. In group II (EMF), saline solution was administered by oral gavage and the rats were exposed to 5.9 GHz EMF for 2 h/d (09:00-11:00). In group III (EMF+ CoQ10), the EMF exposure was created in the same way as in group II and CoQ10 was given daily at 10 mg/kg (CoQ10), 2 mg/kg dissolved in corn oil and administered by oral gavage for the experimental period (30 days).

Results: Histopathological damage, including edematous regions, vascular congestion, and neutrophil inflammation accompanied by loss of spermatogenic cells, particularly spermatozoa, and spermatids, increased thiobarbituric acid (TBARS) and decreased total thiol (TT) levels were observed in the seminiferous tubules in the EMF group. Furthermore, germinal epithelial cells showing intense GRP-78 immunopositivity and spermatogenic cells indicating C/EBP homologous protein (CHOP) immunopositivity were increased in the seminiferous tubules. On the other hand, in the EMF+CoQ10 group, both histopathological and biochemical findings were observed in the opposite direction.

Conclusion: Due to its antioxidant properties and its ability to suppress oxidative stress and apoptosis, CoQ10 may be a promising candidate against 5 G EMF-induced testicular ER damage.

https://pubmed.ncbi.nlm.nih.gov/39765017/

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Short-term exposure of 2.4 GHz electromagnetic radiation on cellular ROS generation and apoptosis in SH-SY5Y cell line and impact on developing chick embryo brain tissue

Deena K, Maadurshni GB, Manivannan J, Sivasamy R. Short-term exposure of 2.4 GHz electromagnetic radiation on cellular ROS generation and apoptosis in SH-SY5Y cell line and impact on developing chick embryo brain tissue. Mol Biol Rep. 2025 Jan 21;52(1):144. doi: 10.1007/s11033-025-10217-8.

Abstract

Background: Electromagnetic radiation (EMR) from wireless technology and mobile phones, operates at various frequencies. The present study analyses the major impact of short-term exposure to 2.4 GHz frequency EMR, using the two model systems chick embryos and SH-SY5Y cell lines. We hypothesized that exposure to this frequency would induce oxidative stress and apoptosis in neurons.

Methods and results: Chick embryos were exposed continuously to 2.4 GHz EMR for 4 h each day over a 5-day period, and comparisons were made with a control group. At the end of the exposure, brain tissues were dissected for histopathological analysis, antioxidant assays, and reactive oxygen species (ROS) detection. Additionally, SH-SY5Y cells were exposed to 2.4 GHz EMR to assess cell viability, DNA

damage, and apoptosis. Our results showed that exposure to 2.4 GHz EMR induces oxidative stress in both chick embryos and the SH-SY5Y cells, though no significant tissue-level impact was observed. In SH-SY5Y cells, ROS production increased after 4 h of exposure, accompanied by moderate DNA damage and early markers of apoptosis, such as upregulation of the Bax gene. Furthermore, we observed that antioxidants, such as NAC and Mito-TEMPO, helped mitigate the cytotoxic effects of EMR in both the study models.

Conclusion: In conclusion, short-term exposure (4 h) to 2.4 GHz EMR induced moderate cellular and molecular changes, primarily oxidative stress. The oxidative stress was reduced by antioxidants, which suggests potential benefits in preventing EMR-induced cytotoxicity. Extended exposure to EMR beyond 4 h may pose adverse health risks to humans, endorsing further investigation.

https://pubmed.ncbi.nlm.nih.gov/39836269/

Conclusion

This study demonstrates the intricacy of the influential impacts of short-term exposure to 2.4 GHz electromagnetic radiation (EMR) at the cellular and tissue levels, thus shedding light on its potential biological implications. Even though there were no significant structural changes detected in histopathological studies of chick embryo brain tissues, results of scanning electron microscopy revealed micro-impacts after short-term exposure of 2.4 GHz, which induced moderate surface modifications. Similarly, antioxidant enzyme activities displayed differential responses where the levels of SOD increased, and on the other hand, CAT activity remained the same. These observations thus emphasise the tight regulation of oxidative stress responses to EMR exposure. In neuronal cell, SH-SY5Y, a marked increase in ROS generation was accompanied by DNA damage and upregulation of apoptotic markers, especially the Bax gene. These findings show that EMR causes oxidative stress and triggers the activation of apoptosis-related pathways stating that mitochondria have a role in these events. Interestingly, the antioxidant protection by NAC and Mito-TEMPO shows a potential area of intervention for the abrogation of oxidative stress due to EMR.

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Compound exposure of 2.8 GHz and 9.3 GHz microwave causes learning and memory impairment in rats

Sun L, Wang X, Ren K, Yao C, Wang H, Xu X, Wang H, Dong J, Zhang J, Yao B, Wei X, Peng R, Zhao L. Compound exposure of 2.8 GHz and 9.3 GHz microwave causes learning and memory impairment in rats. Heliyon. 2025 Jan 3;11(1):e41626. doi: 10.1016/j.heliyon.2025.e41626.

Abstract

The anxieties and concerns about health hazards caused by microwave has been growing recently. Previous studies have reported microwave induced structural and functional injuries to brain. However, the biological effects caused by compound microwave were largely unexplored. In this study, we investigated the biological effects on rat's hippocampus after sequentially exposure to 2.8 GHz and 9.3 GHz at **average power density of 10 mW/cm^2**. Morris water maze (MWM) navigation tests showed that microwave exposure significantly extended the average escape latency (AEL) at 1d and 3d after exposure, suggesting reduced learning and memory ability. Importantly, compound microwave

produced strongest responses at 3 d after exposure. Moreover, microwave also could induce abnormal electroencephalogram (EEG), such as increasing the power of θ wave and δ wave, suggesting brain damage or dysfunction. Histopathological analysis suggested that microwave resulted in obvious structural injuries in hippocampus at 7 d after exposure, and most serious injuries were observed in compound microwave exposed rats. Moreover, disorder of mitochondria and reduced Nissl bodies in hippocampus might contribute to the decrease of cognitive function. However, both the cognitive function and hippocampal structure restored to normal at 28 d after exposure, which might be attributed to self-recovery mechanisms. Gene ontology (GO) and Protein-protein interaction (PPI) analyses of differential expressed genes (DEGs) in peripheral blood suggested that Htt and Bdnf might be potential indicators to predict microwave. In conclusion, compound microwave of 2.8 GHz and 9.3 GHz could elicit reversible structural injuries to hippocampus, which could decrease the cognitive function of rats.

Conclusion

The composite microwave of 2.8 GHz and 9.3 GHz can cause damage to rat hippocampal tissue, inhibit brain activity, and reduce the metabolism of hippocampal neurons through inducing mitochondrial disorder and decreasing Nissl bodies, and ultimately impaired the learning and memory abilities of rats. Notably, compound microwave can reduce the learning and memory ability of rats more than single frequency microwave. Through a combination of GO and PPI analyses, we have also identified Htt, Htra, Psen1, Tp73, and Bdnf as potential predictive indicators of microwave-induced neuronal damage in the nervous system.

Open access paper: https://pmc.ncbi.nlm.nih.gov/articles/PMC11760294/

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Measurement of non-ionizing radiation (NIR) from Wi-Fi access points and microwave ovens in residential environments

Silva, J. da L. A., Rodrigues, M. E. C., Pinheiro, F. S. R., Silva, G. S. da, Mendonça, H. B., Silva, R. Q. de F. H., … Sousa, V. A. de, Jr. (2025). Measurement of non-ionizing radiation (NIR) from Wi-Fi access points and microwave ovens in residential environments. *Journal of Electromagnetic Waves and Applications*, 1–22. doi: 10.1080/09205071.2024.2449120.

Abstract

It is essential to monitor the radiation levels to which the general population may be exposed and compare them to limits established by national and international standards. This is especially true in residential environments, where there is a consolidated use of microwave ovens and Wi-Fi access points, in addition to the short distances devices can be from the user, as well as prolonged periods of user exposure. The objective of this work is to measure the exposure levels for daily Wi-Fi and microwave oven use scenarios in residential environments, to compare measured levels with the standards and to verify possible relation with the characteristics of the equipment under analysis. We use the Narda NBM-520 to support our measurements, the same equipment the National Telecommunication Agency (ANATEL) uses for Brazil's Non-ionizing Radiation (NIR) inspection. This work presents measurements in 40 Wi-Fi access points in which the highest exposure level was 4.66V/m (7.64 % of the limit), verified for the 2.4 GHz network (the so-called Situation 1). This work also presents

measurements in 50 microwave ovens. It was observed that 72% of them had the highest level of exposure for the position in front of the door.

Conclusion

This work evaluates the level of exposure to NIR in homes, mainly from technologies commonly found in residences: Wi-Fi and microwave ovens. For this, measurements were performed on 40 Wi-Fi access points and 50 microwave ovens following measurement methodologies from suitable governmental agencies.

For Wi-Fi case study, the influence of electric field levels was investigated in four measurement situations, by equipment brand, and by time of use. The highest level of exposure was verified for the 2.4 GHz loaded network (Situation 1), at a value of 4.66V/m (7.64% of limit). As for the influence of the brand, the variation of the equipment model between the samples impacts the dispersion of the data; so Brand 4, which has the highest dispersion, has four different models and only two samples of identical models, while Brands 1 and 2 had the lowest dispersion and contain most of the samples belonging to the same model. Thus, no clear relation was observed regarding the year of acquisition of Wi-FI APs and the NIR leakage.

The microwave oven case study targets the relation between power density level and position, brand, time of use, and conservation. We observe that 72% of the samples had the highest level of exposure in front of the door, followed by 18% on the left side (considering the observer facing the microwave oven as a reference). We speculate that the ventilation outlet located at the left side is responsible for some NIR leakage, since 2 of 3 samples that presented the worst point at the top of the oven, the ventilation outlet is located in this local

Our results do not show the influence of the brand on the power density levels. However, regarding the time of use, there is a tendency for microwave ovens to reach higher levels of power density with age, since microwave ovens with year of acquisition <2016 (oldest) present the highest levels. Likewise, the state of conservation of the equipment restrained the levels of power density so that all microwave ovens that reached an average power density above 0.6W/m2 showed signs of use. In addition, only two of the nine ovens that obtained peak power above 1W/m2 did not show signs of use.

https://www.tandfonline.com/doi/full/10.1080/09205071.2024.2449120

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Evaluation of Population Exposure to Radiofrequency Fields in Microenvironments in the Cities of Lima, Cusco and Pucallpa in Perú, Using a Personal Exposimeter

Cruz V, Quispe M. Evaluation of Population Exposure to Radiofrequency Fields in Microenvironments in the Cities of Lima, Cusco and Pucallpa in Perú, Using a Personal Exposimeter. 2024 IEEE XXXI International Conference on Electronics, Electrical Engineering and Computing (INTERCON), Lima, Peru, 2024, pp. 1-8, doi: 10.1109/INTERCON63140.2024.10833492.

Abstract

The objective of this study was to make an evaluation of radiofrequency fields in microenvironments of Cuzco, Lima and Pucallpa using personal exposimeters. To carried it out a literature review was first made, then the urban environ-ments were defined, and 95 microenvironments were selected in the three cities. Subsequently, the exposimeter including the proprietary software for data processing was tested. In total, 1900 measurements of the main telecommunications services were carried out. The electric field was measured for each environment, with a maximum of 2.531 V/m, a minimum of 0.063 V/m and an average of 0.521 V/m for all measurements combined. Based on the ICNIRP 1998 limits, exposure quotients were also obtained for all the measurements combined and for the measurements in each city considering outdoor and indoor measurements, different types of environments and by main frequency bands. For all measurements combined, the maximum exposure quotient was 0.747% and the average was 0.033%. All measurements made were well below international limits, the largest contributors to total exposure were mobile phone base stations, the second largest were broadcasting services, and mobile phone handsets exposure was well below that of mobile phone base stations.

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=10833492&isnumber=10833229

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Wireless radiation and health: making the case for proteomics research of individual sensitivity

Leszczynski D. Wireless radiation and health: making the case for proteomics research of individual sensitivity. Front. Public Health. Volume 12 doi: 10.3389/fpubh.2024.1543818.

No abstract

Excerpts

"According to the WHO definition of health, just a belief in having EHS and experiencing non-specific symptoms, physiological and/or psychological, is experiencing the health effects of wireless technology. Hence, it is correct to claim that wireless radiation causes health effects."

"Puzzlingly, the frequent observation that the self-declared EHS person can't feel the wireless radiation and can't recognize when the wireless transmitter emits radiation and when it is not transmitting, is considered ultimate proof that the form of individual sensitivity to wireless radiation called EHS is not caused by wireless radiation exposures. This is questionable as no person, sensitive or not, could feel the ionizing radiation or other non-ionizing radiation like ultraviolet in their environment."

"...logically and per analogiam with other environmental factors, individual sensitivity to wireless radiation, which includes EHS, exists as indicated below, and should be studied using biochemical methods."

"Search for sensitive individuals, most commonly using provocation studies where experimentally controlled exposures are followed by inquiries about acutely occurring symptoms and feelings, has failed to detect any sensitivity to wireless radiation. The reason might be that provocation exposures combined with psychological inquiries might be not sensitive enough to detect individual sensitivity to a single agent present in a mix of other environmental agents..."

"There is a need for human volunteer studies where the already proposed, and other potentially useful biomarkers, would be examined in groups of sensitive and non-sensitive persons, ethically exposed to wireless radiation."

"The way forward in EHS research is to discover biomarkers of EHS, molecules that are affected by wireless radiation exposure, by research using high-throughput screening techniques of proteomics, transcriptomics, and metabolomics [...]. For the start, proteomics might be the most promising of these methods."

"The reasons why proteomics is not used to study the physiological effects of wireless radiation exposures in humans are difficult to understand and comprehend. Despite the advantages of research using proteomics methodology, over the last 20 years, only a few proteomics studies have examined proteome changes in response to wireless radiation exposures."

"In conclusion, it is logical to conclude that the individual sensitivity to wireless radiation emitted by wireless communication devices and networks exists and impacts the health of sensitive persons. Clearly, the to-date unsuccessfully used methods of provocation studies were either too crude or too much affected by the perceptions and preexisting opinions of study volunteers."

Open access paper: https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2024.1543818/full

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Amelioration and Immuno-modulation by Ashwagandha on Wi-fi Induced Oxidative Stress in Regulating Reproduction Via Estrogen Receptor Alpha in Male Japanese Quail

Gupta V, Srivastava R. Amelioration and Immuno-modulation by Ashwagandha on Wi-fi Induced Oxidative Stress in Regulating Reproduction Via Estrogen Receptor Alpha in Male Japanese Quail. Reprod Sci. 2025 Jan 13. doi: 10.1007/s43032-024-01774-7.

Abstract

As global change threatens avian biodiversity, understanding species responses to environmental perturbations due to radiation emitted by enormous increase in the application of wireless communication is very urgent. The study investigates the effect of MW radiation on redox balance, stress level, male fertility and the efficacy of Withania somnifera (WS) root extract (100 mg/kg body weight) orally administered in 8 weeks old mature male Japanese quail exposed to 2.4 GHz MW radiation for 2 h/day for 30 days with power density = 0.1264 mw/cm^2 and SAR = 0.9978 W/Kg. Wi-fi exposure induces a decrease in testicular weight, volume, density and gonado-somatic index (GSI) while Ashwagandha increases them. Oxidative stress parameters increased and activity of SOD, catalase, GSH was reduced in testes of exposed quail while Ashwagandha treatment reinstates the redox balance. Exposure to Wi-fi alters quail reproduction by increase in corticosterone and decreased testosterone with reduced expression of estrogen receptor alpha (ERα) in testis. Wi-fi exposure increases IL1β and reduces IL10 in testis. IL-1β inhibits testicular cell function and promotes apoptosis by increasing NF-κB and decreasing sperm count in exposed quails. Ashwagandha increases expression of ERα, sperm count and immunity in quail testis. Further, decrease in IL1β, NF-κB and increase in IL-10 after administration of Ashwagandha in Wi-fi exposed quail prevents inflammatory damages and enhances gonadal function.

Thus, exposure to Wi-fi increases oxidative stress, activates apoptosis, modulates immunity in testis while Ashwagandha reverses them via enhanced ERα expression, increase in sperm count thereby enhancing fertility in male Japanese quail.

https://pubmed.ncbi.nlm.nih.gov/39806168/

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The Development of a Reverberation Chamber for the Assessment of Biological Effects of Electromagnetic Energy Absorption in Mice

Iskra S, McIntosh RL, McKenzie RJ, Frankland JV, Deng C, Sylvester E, Wood AW, Croft RJ. The Development of a Reverberation Chamber for the Assessment of Biological Effects of Electromagnetic Energy Absorption in Mice. Bioelectromagnetics. 2025 Jan;46(1):e22539. doi: 10.1002/bem.22539.

Abstract

In this paper, we present the design, RF-EMF performance, and a comprehensive uncertainty analysis of the reverberation chamber (RC) exposure systems that have been developed for the use of researchers at the University of Wollongong Bioelectromagnetics Laboratory, Australia, for the purpose of investigating the biological effects of RF-EMF in rodents. Initial studies, at 1950 MHz, have focused on investigating thermophysiological effects of RF exposure, and replication studies related to RF-EMF exposure and progression of Alzheimer's disease (AD) in mice predisposed to AD. The RC exposure system was chosen as it allows relatively unconstrained movement of animals during exposures which can have the beneficial effect of minimizing stress-related, non-RF-induced biological and behavioral changes in the animals. The performance of the RCs was evaluated in terms of the uniformity of the Whole-Body Average-Specific Absorption Rate (WBA-SAR) in mice for a given RF input power level. The expanded uncertainty in WBA-SAR estimates was found to be 3.89 dB. Validation of WBA-SAR estimates based on a selected number of temperature measurements in phantom mice found that the maximum ratio of the temperature-derived WBA-SAR to the computed WBA-SAR was 1.1 dB, suggesting that actual WBA-SAR is likely to be well within the expanded uncertainties.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/bem.22539

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Continuous exposure to 60 Hz extremely low frequency magnetic field at 10-14 mT promotes various human cell proliferation by activating extracellular-signal-regulated kinase

Goh J, Suh D, Um DY, Chae SA, Park GS, Song K. Continuous exposure to 60 Hz extremely low frequency magnetic field at 10-14 mT promotes various human cell proliferation by activating extracellular-signal-regulated kinase. Biochem Biophys Res Commun. 2025 Jan 28;751:151414. doi: 10.1016/j.bbrc.2025.151414.

Abstract

We previously showed that 60 Hz extremely low-frequency magnetic fields (ELF-MF) at 6 mT promote various humancell proliferation. This study investigated the effects of 60 Hz ELF-MF at 10-16 mT on various mammalian cells, including human cervical carcinoma, rat neuroblastoma, liver cancer stem cells, immortalized normal hepatic cells, and normal fibroblasts. Using a revised ELF-MF-generating

device that increases magnetic flux density stably without thermal effects, we exposed cells to 10 and 16 mT ELF-MF for 72 h. All cell types exhibited an approximately 20 % or greater increase in proliferation compared to the sham exposure group at 14 mT, with no further increase observed at 16 mT. In cells with activated proliferation at 14 mT, we observed activation of the MEK-ERK pathway and NF-κB, but not Akt, and a slight increase in S phase population. Intracellular and mitochondrial ROS levels remained unchanged, and the proliferation-activating effects persisted when oxidative phosphorylation was interrupted. No changes in intracellular calcium levels were observed, and the proliferation-activating effects were maintained in the presence of a calcium chelator. These findings suggest that ROS and intracellular calcium do not mediate ELF-MF's proliferation-activating physiological effect. In conclusion, exposure to 60 Hz ELF-MF at 10-14 mT promotes cell proliferation by activating ERK1/2 without affecting intracellular ROS and calcium levels.

https://pubmed.ncbi.nlm.nih.gov/39903967/

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An amplification mechanism for weak ELF magnetic fields quantum-bio effects in cancer cells

Zandieh A, Shariatpanahi SP, Ravassipour AA, Azadipour J, Nezamtaheri MS, Habibi-Kelishomi Z, Ghanizadeh M, Same-Majandeh A, Majidzadeh-A K, Taheri A, Ansari AM, Javidi MA, Pirnia MM, Goliaei B. An amplification mechanism for weak ELF magnetic fields quantum-bio effects in cancer cells. Sci Rep. 2025 Jan 23;15(1):2964. doi: 10.1038/s41598-025-87235-w.

Abstract

Observing quantum mechanical characteristics in biological processes is a surprising and important discovery. One example, which is gaining more experimental evidence and practical applications, is the effect of weak magnetic fields with extremely low frequencies on cells, especially cancerous ones. In this study, we use a mathematical model of ROS dynamics in cancer cells to show how ROS oscillatory patterns can act as a resonator to amplify the small effects of the magnetic fields on the radical pair dynamics in mitochondrial Complex III. We suggest such a resonator can act in two modes for distinct states in cancer cells: (1) cells at the edge of mitochondrial oscillation and (2) cells with local oscillatory patches. When exposed to magnetic fields, the first group exhibits high-amplitude oscillations, while the second group synchronizes to reach a whole-cell oscillation. Both types of amplification are frequency-dependent in the range of hertz and sub-hertz. We use UV radiation as a positive control to observe the two states of cells in DU and HELA cell lines. Application of magnetic fields shows frequency-dependent results on both the ROS and mitochondrial potential which agree with the model for both type of cells. We also observe the oscillatory behavior in the time-lapse fluorescence microscopy for 0.02 and 0.04 Hz magnetic fields. Finally, we investigate the dependence of the results on the field strength and propose a quantum spin-forbidden mechanism for the effect of magnetic fields on superoxide production in Q_O site of mitochondrial Complex III.

Excerpts

In a nutshell, our proposed scheme acts in two distinct levels: [I] At the level of superoxide production in mitochondrial ETC where the applied magnetic field can alter production rate of superoxide by closing the energy gap between singlet and triplet state of a radical pair in Complex III. Here the applied magnetic field effectively acts as a static field. And [II] at the level of mitochondrial network, where

oscillation of the applied magnetic field (and thus oscillation in the production rate of superoxide) can resonate with the intrinsic frequency of RIRR in cancer cells. At this level, the minor effect of underlying RPM is amplified to affect the physiology of the cell in a frequency-dependent manner....

Conclusion

Our study proposed a quantum biological mechanism for the effect of varying small magnetic fields on cancer cells. The frequency dependent effect of magnetic field is here postulated to be the result of interaction of alternating field with the intrinsically oscillatory system of coupled mitochondria via a novel radical pair phenomenon.

Here the site of action of the field is suggested to be the semiquinone/FeS radical pair in Complex III of ETC. A magnetic field of the order of few hundreds of millitesla is predicted to populate the triplet state of the radical pair whose electron transfer onto oxygen molecule is restricted by a spin forbidden reaction in half of the cases. This leads to a mild decrease in superoxide production in the presence of such a magnetic field. An oscillatory field can amplify such an effect via a resonance phenomenon in a network of coupled mitochondria in many cell lines. This substantial change in ROS balance can potentially cause physiological effect in the cells, including apoptosis. Our simulations show the mentioned effect can be manifested in two resonance modes: Either triggering the oscillation in network or synchronizing the out of phase oscillatory mitochondria. Our experimental results confirm the suggested model which can explain the previous observations for the first time. The hypothesis was validated by the observation of the synchronization when cells were exposed to sudden UV irradiation.

Moreover, we observed a frequency-dependent variation of the ROS concentration and mitochondrial membrane potential under the effect of oscillatory magnetic field in frequencies and intensities suggested by our model.

Further in vitro investigation with higher resolution of microscopy and more extensive profile of magnetic field frequencies and intensities can shed light on the detailed components of the involved mechanism.

Open access paper: https://pmc.ncbi.nlm.nih.gov/articles/PMC11757740/

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Effect of terahertz radiation on cells and cellular structures (Review)

Rytik AP, Tuchin VV. Effect of terahertz radiation on cells and cellular structures. Front Optoelectron. 2025 Jan 27;18(1):2. doi: 10.1007/s12200-024-00146-y.

Abstract

The paper presents the results of modern research on the effects of electromagnetic terahertz radiation in the frequency range 0.5-100 THz at different levels of power density and exposure time on the viability of normal and cancer cells. As an accompanying tool for monitoring the effect of radiation on biological cells and tissues, spectroscopic research methods in the terahertz frequency range are described, and attention is focused on the possibility of using the spectra of interstitial water as a

marker of pathological processes. The problem of the safety of terahertz radiation for the human body from the point of view of its effect on the structures and systems of biological cells is also considered.

Conclusion

The presented data show that THz radiation has a variety of effects on cells, which are manifested in the disruption of the properties of cell membranes, the formation of pores, the activation of ion channels, and changes in their proliferation and viability [110]. Possible mechanisms that determine the reaction of cells to THz radiation may be the following:

- a change in the conformation of membrane proteins, which triggers an intracellular cascade of regulators of the genetic and enzymatic systems and the permeability of cell membranes for various substances;
- a change in the conformation of membrane proteins that perceive external regulatory signals;
- change in the conformation of membrane proteins that are pumps or channels for the transport of various substances into and out of the cell;
- redistribution of the electric charge on the cell membrane;
- excitation of resonant oscillations of macromolecules that make up the cell membrane and the cytoskeleton as a whole.

Thus, fundamentally, THz radiation does not cause the breaking or restoration of chemical covalent bonds, since the quantum energy is insufficient for this, 1 THz − 4.1 meV. However, this radiation, in its frequencies, falls into the region of vibrational–rotational movements of biological molecules and water and can excite energy levels of vibrational–rotational transitions of proteins and water, and thereby change the spatial conformation of proteins, which can affect various interactions between proteins, protein and water molecules.

It is generally accepted that there are several mechanisms that determine the effect of the response of living cells to THz radiation, in particular [1]:

- redistribution of electrical charge on the cell membrane, changing the ratio of concentrations of bound and free water;
- excitation of resonant vibrations of macromolecules that make up the cell membrane and the cytoskeleton as a whole;
- change in the conformation of membrane proteins.

Water molecules themselves can be considered as a universal marker in the THz frequency range, which is sensitive to various vital processes occurring in living tissues and cells. Compared to what is traditionally described in dielectric spectroscopy, in the THz frequency range water as a marker allows one to obtain new information about biological systems. Moving from the gigahertz (GHz) to the THz range, we are gradually approaching various vibrational–rotational processes that are determined by the interaction of water molecules with surrounding molecular systems [23]. Biomacromolecules, being excited, absorb part or all of the energy of electromagnetic waves, depending on the frequency of the incident radiation [26]. Since the generalized terahertz range (0.1–100 THz) partially overlaps with the

vibration spectrum of biomolecules, terahertz waves can greatly enhance vibrations of biomolecule bonds such as twisting, stretching, and bending through resonant excitation [111]. However, early studies of the biological effects induced by optical stimulation focused on the infrared region, which promotes the strong absorption of incoming energy by water and its conversion into heat [112, 113]. While heat alters transmembrane capacitance or ion channel activity and hence induces biological responses, it inevitably also causes a transient increase in local temperature. On the other hand, terahertz wave modulation is seen as a promising approach for interfering with biophysical processes without being damaged by electromagnetic radiation. The study of non-thermal biological effects of infrared radiation has attracted close attention from both opticians and biologists. In addition, THz waves with low photon energy are unlikely to cause ionizing effects, thus will not damage genome integrity as other radiation intervention approaches might [112].

It can be concluded that currently there is no full consensus in the scientific community as to whether THz radiation has a damaging effect on biological objects at various levels of organization [83, 114]. Therefore, an increase in studies using THz radiation to monitor the activity of uncontrolled dividing cells is expected in the near future. The development of new high-resolution THz diagnostic methods in combination with AI technologies will take cancer diagnosis and therapy to a new level. It is obvious that more and more new data will appear soon for THz diagnostics and therapy of tumor oncological processes. In addition, theranostics technologies, where THz radiation from the same source is used first for diagnosis and then at increased energy parameters for therapy within a single protocol, have not yet received proper development, but are undoubtedly promising.

Open access paper: https://link.springer.com/article/10.1007/s12200-024-00146-y

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Metabolomic and gene networks approaches reveal the role of mitochondrial membrane proteins in response of human melanoma cells to THz radiation

Butikova EA, Basov NV, Rogachev AD, Gaisler EV, Ivanisenko VA, Demenkov PS, Makarova AA, Ivanisenko TV, Razumov IA, Kolomeyets DA, Cheresiz SV, Solovieva OI, Larionov KP, Sotnikova YS, Patrushev YV, Kolchanov NA, Pokrovsky AG, Vinokurov NA, Kanygin VV, Popik VM, Shevchenko OA. Metabolomic and gene networks approaches reveal the role of mitochondrial membrane proteins in response of human melanoma cells to THz radiation. Biochim Biophys Acta Mol Cell Biol Lipids. 2025 Jan 20:159595. doi: 10.1016/j.bbalip.2025.159595.

This paper presents a study on the biological effects of terahertz irradiation with a frequency of 2.3 THz and a power of 0.056 W/cm^2 on SK-MEL-28 cells, using targeted metabolomic screening by liquid chromatography and tandem mass spectrometry (LC-MS/MS) and gene network analysis.

Highlights

• THz radiation exposure induced significant changes in the levels of 40 metabolites, especially those related to purine and pyrimidine pathways. Lipids, such as ceramides and phosphatidylcholines, were also affected by this exposure.
• Gene network reconstruction identified mitochondrial membrane proteins, including components of the respiratory chain complex, ATP synthase, and lipid rafts, as key regulators of the enzymes involved in

biosynthesis and degradation of the significantly altered metabolites.
• THz radiation induces reversible disruption of lipid raft macromolecular structure, altering mitochondrial molecule transport while maintaining protein integrity.
• Importantly, the metabolic effects observed were specific to THz radiation and were not due to heating, as evidenced by the distinct responses in control cells exposed to infrared radiation.

Abstract

Terahertz (THz) radiation has gained attention due to technological advancements, but its biological effects remain unclear. We investigated the impact of 2.3 THz radiation on SK-MEL-28 cells using metabolomic and gene network analysis. Forty metabolites, primarily related to purine, pyrimidine synthesis and breakdown pathways, were significantly altered post-irradiation. Lipids, such as ceramides and phosphatidylcholines, were also affected. Gene network reconstruction and analysis identified key regulators of the enzymes involved in biosynthesis and degradation of significantly altered metabolites. Mitochondrial membrane components, such as the respiratory chain complex, the proton-transporting ATP synthase complex, and components of lipid rafts, reacted to THz radiation. We propose that THz radiation induces reversible disruption of the lipid raft macromolecular structure, thereby altering mitochondrial molecule transport while maintaining protein integrity, which explains the high cell survival rate. Our findings enhance the understanding of THz biological effects and emphasize the role of membrane components in the cellular response to THz radiation.

https://www.sciencedirect.com/science/article/abs/pii/S1388198125000034

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Hidden route of protein damage through oxygen-confined photooxidation

Kim S, Kim E, Park M, Kim SH, Kim BG, Na S, Sadongo VW, Wijesinghe WCB, Eom YG, Yoon G, Jeong H, Hwang E, Lee C, Myung K, Kim CU, Choi JM, Min SK, Kwon TH, Min D. Hidden route of protein damage through oxygen-confined photooxidation. Nat Commun. 2024 Dec 30;15(1):10873. doi: 10.1038/s41467-024-55168-z.

Abstract

Oxidative modifications can disrupt protein folds and functions, and are strongly associated with human aging and diseases. Conventional oxidation pathways typically involve the free diffusion of reactive oxygen species (ROS), which primarily attack the protein surface. Yet, it remains unclear whether and how internal protein folds capable of trapping oxygen (O_2) contribute to oxidative damage. Here, we report a hidden pathway of protein damage, which we refer to as O_2-confined photooxidation. In this process, O_2 is captured in protein cavities and subsequently converted into multiple ROS, primarily mediated by tryptophan residues under blue light irradiation. The generated ROS then attack the protein interior through constrained diffusion, causing protein damage. The effects of this photooxidative reaction appear to be extensive, impacting a wide range of cellular proteins, as supported by whole-cell proteomic analysis. This photooxidative mechanism may represent a latent oxidation pathway in human tissues directly exposed to visible light, such as skin and eyes.

Open access paper: https://www.nature.com/articles/s41467-024-55168-z

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Structural Analysis of Plasma-Induced Oxidation and Electric Field Effect on the Heat Shock Protein (Hsp60) Structure

Attri P, Okumura T, Koga K, Shiratani M. Structural Analysis of Plasma-Induced Oxidation and Electric Field Effect on the Heat Shock Protein (Hsp60) Structure: A Computational Viewpoint. Chem Biodivers. 2025 Jan 5:e202401243. doi: 10.1002/cbdv.202401243.

Abstract

In recent years, there has been an increase in the study of the mechanisms behind plasma oncology. For this, many wet lab experiments and computational studies were conducted. Computational studies give an advantage in examining protein structures that are costly to extract in enough amounts to analyze the biophysical properties following plasma treatment. Therefore, in this work, we studied the effect of plasma oxidation and electric field on the human mitochondrial heat shock protein (mHsp60). Hsp60, alias chaperonin, is one of the most conserved proteins expressed across all species. Hence, we performed molecular dynamic simulations to calculate the root-mean-square deviation, root-mean-square fluctuation, and solvent-accessible surface area of mHsp60 with and without oxidation. In addition to the oxidation state, we also applied an electric field (0.003 and 2.0 V/nm) to check the changes in the mHsp60 protein. Through simulations, we observed that the electric field strongly affects the structure of mHsp60 protein compared with the oxidation. The combination of oxidation and electric field effect increases the destabilization of the mHsp60 structure compared with their respective control states.

https://pubmed.ncbi.nlm.nih.gov/39756028/

Conclusion

We can conclude that the mHsp60 structure is modified by possible plasma-assisted oxidation, particularly involving Trp, Try, and Met amino acids, resulting in noticeable structural changes. RMSD values reflect that mHsp60 structure flexibility slightly increases in OXID-2, whereas the structure becomes rigid in OXID-1. This suggests that the oxidation of Met amino acids plays a significant role in enhancing mHsp60 flexibility. On the other hand, applying an electric field (EF1 and EF2) to the control mHsp60 increases the RMSD value more than for oxidized mHsp60 (OXID-1 and OXID-2), indicating that the electric field has a more substantial effect on the mHsp60 structure than oxida- tion alone. Additionally, the RMSD values of OXID-1 and OXID-2 increased after electric field treatment (0.003 V/nm from the x, y, and z axes), demonstrating that the small electric field generated by DBD plasma can significantly influence protein conforma- tional changes in both native and oxidized states. HSPs, including Hsp60, play a vital role in maintaining protein homeostasis, which is crucial for cell integrity, survival, and metabolism. However, when chaperone-assisted protein quality control is compromised due to oxidation or exposure to electric effect, it may trigger the onset and progression of numerous diseases.

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World Health Organization's EMF Project's Systemic Reviews on the Association Between RF Exposure and Health Effects Encounter Challenges

In a newly-published paper, one of the world's most renowned scientists who has studied the effects of radio frequency (RF) radiation, Dr. James C. Lin, Professor Emeritus at the University of Illinois, Chicago and a former ICNIRP Commissioner, attacks the World Health Organization's systematic reviews of the research on RF radiation that dismiss the substantial evidence for adverse biological and health effects.

He concludes:

"The criticisms and challenges encountered by the published WHO-EMF systematic reviews are brutal, including calls for retraction. Rigorous examinations of the reviews reveal major concerns. In addition to the scientific quality, they appear to have a strong conviction of nothing but heat to worry about with RF radiation. The unsubtle message that cellular mobile phones do not pose a cancer risk is clear. The reviews exhibit a lack of serious concerns for conflicts of interest and display unequivocal support for the recently promulgated ICNIRP RF exposure guidelines for human safety.

From its inception, WHO-EMF had close ties with ICNIRP, a private organization, frequently referred to as the WHO-EMF project's scientific secretariat [18]. What may not be as apparent for the WHO-EMF systematic reviews is the lack of diversity of views. A large number of ICNIRP commissioners and committee members are listed as authors for the WHO-EMF systematic reviews; some also served as lead authors. These concerns advance issues of reviewer independence and potential for conflicts of interest."

Lin JC. World Health Organization's EMF Project's Systemic Reviews on the Association Between RF Exposure and Health Effects Encounter Challenges [Health Matters]. *IEEE Microwave Magazine*, 26(1): 13-15, Jan. 2025, doi: 10.1109/MMM.2024.3476748.

No abstract

Excerpts

1) Regarding "The WHO-EMF systematic review on the association between RF exposure and adverse health effects pertaining to reproductive health (pregnancy and birth outcome.... While the WHO-EMF systematic review presents itself as thorough, scientific, and relevant to human health, numerous issues were identified, suggesting the WHO-EMF review was severely flawed. The found flaws skewed the results in support of the review's conclusion that there is no conclusive evidence for effects other than RF-induced tissue heating. It showed that the underlying data, when relevant studies are cited correctly, support the opposite conclusion: "There are clear indications of detrimental nonthermal effects" from RF exposure. The authors identified a multitude of flaws in the methodology. To those scientists, the methodology and low quality of the systematic review were highly concerning "as it threatens to undermine the trustworthiness and professionalism of the WHO-EMF project in the area of human health hazards from man-made RF radiation."

2) Regarding "The WHO-EMF systematic review of human observational studies on the occurrence of migraine, headaches, tinnitus, sleep disturbances, and nonspecific symptoms in the general and working population .... An ensuing critical appraisal by three accomplished senior researchers documented major problems with the WHO-EMF-commissioned review and called for its retraction [8]. The meta-analysis

for the handful of very heterogeneous primary studies identified for each of the analyzed exposure and outcome combinations appeared fundamentally inappropriate. The number is very small, and the methodological quality of the relevant primary studies is low. In contrast, this peer-reviewed publication concluded that the body of evidence reviewed is inadequate to either support or refute the safety of current exposure limits.

3) "Some skepticism has been expressed regarding a third WHO-EMF systematic review on RF-induced oxidative stress [9]. The study identified 11,599 studies on oxidative stress in the frequency range 800–2,450 MHz and then eliminated 11,543 of them as not meeting the criteria for inclusion. Of the remaining 56 papers, there were 45 animal studies and 11 in vitro cellular studies....For many years, Henry Lai, a leading researcher in RF oxidative responses and professor emeritus at the University of Washington, Seattle, has maintained a bibliography of RF-oxidative stress papers. As of mid-August, his list includes 367 studies, published between 1997 and 2024. By his count, 89% showed significant effects. Lai's assessment of the WHO-EMF review is that it left out a large portion of RF-oxidative effect studies and appears to have only considered oxidative molecular reactions among the possible oxidative effects [10]. As reported, others have opined that "this systematic review methodically excluded most of the relevant research."

4) Regarding the WHO systematic review to assess the evidence provided by human epidemiological studies for the cancer risk from radiofrequency (RF): " This WHO-EMF review was picked up and reported on by many Western media outlets. Actually, there are truly few data that are new in this review. For sure, the assessment of scientific evidence in this subject has been controversial and less than uniform. The question is, "Is this review really the definitive word on the long-standing issue of whether cell phone radiations pose a cancer risk?" My answer is, far from it!"

"Microwave News [12] published a meticulously researched investigative report in the historical context of the latest WHO-EMF cancer review. Five years ago, the lead author [13] with some members of the same team made similar efforts to terminate the RF–cancer debate with basically the same no-risk message. However, "it was not well received" by the scientific community, since the analysis excluded some people older than 59 years of age, the largest segment of the brain cancer population."

"The WHO-IARC, NIH-NTP, and Ramazzini outcomes, under normal circumstances, would likely have provided the justification for raising WHO-IARC's current possible cancer risk designation to the probable cancer-causing classification, if not higher.

https://ieeexplore.ieee.org/document/10795296

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A mechanistic understanding of human magnetoreception validates the phenomenon of electromagnetic hypersensitivity (EHS)

Henshaw DL, Philips A. (2024). A mechanistic understanding of human magnetoreception validates the phenomenon of electromagnetic hypersensitivity (EHS). *International Journal of Radiation Biology*, 1–19. doi: 10.1080/09553002.2024.2435329.

Abstract

Background Human electromagnetic hypersensitivity (EHS) or electrosensitivity (ES) symptoms in response to anthropogenic electromagnetic fields (EMFs) at levels below current international safety standards are generally considered to be nocebo effects by conventional medical science. In the wider field of magnetoreception in biology, our understanding of mechanisms and processes of magnetic field (MF) interactions is more advanced.

Methods We consulted a range of publication databases to identify the key advances in understanding of magnetoreception across the wide animal kingdom of life.

Results We examined primary MF/EMF sensing and subsequent coupling to the nervous system and the brain. Magnetite particles in our brains and other tissues can transduce MFs/EMFs, including at microwave frequencies. The radical pair mechanism (RPM) is accepted as the main basis of the magnetic compass in birds and other species, acting via cryptochrome protein molecules in the eye. In some cases, extraordinary sensitivity is observed, several thousand times below that of the geomagnetic field. Bird compass disorientation by radio frequency (RF) EMFs is known.

Conclusions Interdisciplinary research has established that all forms of life can respond to MFs. Research shows that human cryptochromes exhibit magnetosensitivity. Most existing provocation studies have failed to confirm EHS as an environmental illness. We attribute this to a fundamental lack of understanding of the mechanisms and processes involved, which have resulted in the design of inappropriate and inadequate tests. We conclude that future research into EHS needs a quantum mechanistic approach on the basis of existing biological knowledge of the magnetosensitivity of living organisms.

Conclusions and recommendations

1. At the scientific level, researchers working in the field of *magnetoreception in biology* should be made aware of EHS as a human public health concern and funded to address the issue as part of their scientific research.

2. All interested parties, especially EHS sufferers and medical professionals, should be made aware of the considerable growth in understanding in recent decades of the mechanisms by which all forms of life sense MFs/EMFs, even at extremely low levels. EHS research to date has been significantly hindered by a fundamental lack of knowledge among many medical scientists and EHS researchers regarding the current scientific understanding of quantum biology mechanisms and processes. This has resulted in the design and analysis of inappropriate provocation tests.

3. Almost all existing epidemiological and provocation studies have failed adequately to determine and measure the necessary dependent and independent variables. In particular:

    1. to characterize in proper technical detail the EMF/RF exposures (including electric and MF levels; average and peak power-density levels; frequencies involved; and modulation characteristics).

    2. to triage participants effectively to remove ‘electrophobic’ and other volunteers self-reporting apparent EHS-related problems.

3. in provocation studies, to fail to recognize the nonlinear nature of EHS responses and the extremely low levels of exposure (<100 nT) that have effects and, instead, use relatively high exposures fairly close to the ICNIRP and IEEE guidance levels.

4. in provocation studies, to provide a participant-comfortable extremely low EMF/RF test location, screened from anthropogenic sources and allow adequate time (days rather than hours) for adverse effects to washout between exposures.

4. EHS studies should move away from current, nonforensic epidemiological approaches and human subjective provocation studies (Leszczynski 2022; Röösli et al. 2024). Instead, objective measurements of biological parameters, such as heart rate variability, brain wave activity (e.g. fMRI and wide-bandwidth EEG), and the immune response to oxidative stress should be investigated (Caswell et al. 2016; Gurfinkel et al. 2018; Pishchalnikova et al. 2019; Wang et al. 2019; Thoradit et al. 2024). We caution that these approaches require sophisticated design and analysis and advanced design personal exposure meters.

5. We recommend that the WHO properly reevaluates its understanding of EHS to align it with the substantial body of available scientific literature showing mechanistic evidence of interactions of all forms of life, including humans, with low levels of electric and magnetic fields.

Open access paper: https://www.tandfonline.com/doi/full/10.1080/09553002.2024.2435329

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Gaps in Knowledge Relevant to the "ICNIRP Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (100 kHz TO 300 GHz)"

International Commission on Non-Ionizing Radiation Protection (ICNIRP). Gaps in Knowledge Relevant to the "ICNIRP Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (100 kHz TO 300 GHz)". Health Phys. 2025 Feb 1;128(2):190-202. doi: 10.1097/HP.0000000000001944.

Abstract

In the last 30 y, observational as well as experimental studies have addressed possible health effects of exposure to radiofrequency electromagnetic fields (EMF) and investigated potential interaction mechanisms. The main goal of ICNIRP is to protect people and the environment from detrimental exposure to all forms of non-ionizing radiation (NIR), providing advice and guidance by developing and disseminating exposure guidelines based on the available scientific research on specific parts of the electromagnetic spectrum. During the development of International Commission on Non-Ionizing Radiation Protection's (ICNIRP's) 2020 radiofrequency EMF guidelines some gaps in the available data were identified. To encourage further research into knowledge gaps in research that would, if addressed, assist ICNIRP in further developing guidelines and setting revised recommendations on limiting exposure, data gaps that were identified during the development of the 2020 radiofrequency EMF guidelines, in conjunction with subsequent consideration of the literature, are described in this Statement. Note that this process and resultant recommendations were not intended to duplicate more traditional research agendas, whose focus is on extending knowledge in this area more generally but was tightly focused on identifying the highest data gap priorities for guidelines development more

specifically. The result of this distinction is that the present data gap recommendations do not include some gaps in the literature that in principle could be relevant to radiofrequency EMF health, but which were excluded because either the link between exposure and endpoint, or the link between endpoint and health, was not supported sufficiently by the literature. The evaluation of these research areas identified the following data gaps: (1) Issues concerning relations between radiofrequency EMF exposure and heat-induced pain; (2) Clarification of the relation between whole-body exposure and core temperature rise from 100 kHz to 300 GHz, as a function of exposure duration and combined EMF exposures; (3) Adverse effect thresholds and thermal dosimetry for a range of ocular structures; (4) Pain thresholds for contact currents under a range of exposure scenarios, including associated dosimetry; and (5) A range of additional dosimetry studies to both support future research, and also to improve the application of radiofrequency EMF exposure restrictions in future guidelines.

Open access paper:https://journals.lww.com/health-physics/fulltext/2025/02000/gaps_in_knowledge_relevant_to_the__icnirp.8.aspx

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Sensory Processing Sensitivity, and Not Gender, Drives Electromagnetic Hypersensitivity and Nature Connection

Watten RG, Volden F, Visnes H. Sensory Processing Sensitivity, and Not Gender, Drives Electromagnetic Hypersensitivity and Nature Connection. Ecopsychology. Nov 28, 2024. doi: 10.1089/eco.2024.0027

Abstract

Electromagnetic hypersensitivity (EHS) is a biomedical condition associated with exposure to man-made radio-frequency electromagnetic fields. Common sources are devices like mobile phones, wireless networks, base stations, computers, TVs, and more. Identifying individuals at risk of developing EHS is important. Those with heightened sensory processing sensitivity (SPS; the ability to perceive, process, and react to environmental stimuli, approximately 25% to 30% of the population) are of special interest. SPS could also be associated with connectedness to nature (CNS) and EHS. In the current gender-matched cross-sectional study (*n* = 450; 225 men and 225 women) we assessed gender differences in environmental sensitivity assessed as SPS, EHS, and CNS. Women had higher general EHS prevalence than men (13.3% vs. 5.3%), higher mean values on perceived sensitivity for 5 out of 9 categories of electromagnetic equipment (computers, electrical appliances, fluorescent lighting, mobile phones, and television) and they had higher scores on the three EHS Scales EHS General, EHS Scale, and EHS Index, in addition to higher SPS and CNS scores. The gender differences vanished when adjusting for SPS in the multivariate analyses of variance (MANOVA) analyses, suggesting that the differences in these scales were associated with SPS. The statistical equation modeling (SEM) results showed a significant positive direct effect of SPS on CNS, and a significant indirect effect mediated by EHS. The present study provides the first empirical evidence that highly sensitive individuals are capable of perceiving electromagnetic radiation. The results indicate that perceived EHS and CNS are driven by SPS and not by gender.

https://www.liebertpub.com/doi/10.1089/eco.2024.0027

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Effect of Exposure to Mobile Phones on Electrical Cardiac Measurements: Multivariate Analysis & Variable Selection Algorithm to Detect Relationship With Mean Changes

Alharbi N, Alassiri M. The Effect of Exposure to Mobile Phones on Electrical Cardiac Measurements: A Multivariate Analysis and a Variable Selection Algorithm to Detect the Relationship With Mean Changes. Int J Cell Biol. 2024 Oct 3;2024:7093771. doi: 10.1155/2024/7093771.

Abstract

Background: The exponential growth in mobile phone usage has raised concerns about electromagnetic field (EMF) exposure and its health risks. Blood pressure and BMI, which impair heart function due to decreased adrenoreceptor responsiveness, parasympathetic tone withdrawal, and increased sympathetic activity, may further exacerbate these risks. However, the effects of radiofrequency electromagnetic (RF-EM) exposure from mobile phones on electrocardiograms (ECGs) and heart rate variability (HRV) in individuals remain unclear.

Purpose: Building upon our previous findings on HRV changes due to mobile phone proximity, this study is aimed at significantly enhancing the analytical approach used to assess the effects of mobile phones on cardiac parameters. This study exploits data from a previous study but with a different purpose. The aim of this study is twofold: (a) to examine whether exposure to mobile phones changes the five variables (P-R, QRS, QT, ST, and HR) in a multivariate manner and (b) to examine whether the blood pressure and/or the body mass index (BMI), which acts as a proxy for obesity, have an effect on the change of these five variables. For both aspects of the study, four cycles are performed.

Method: We conducted multivariate analysis on previously collected electrical cardiac measurement data from 20 healthy male subjects exposed to mobile phone EMF, with the mobile phones placed at four different body locations. The one-sample Hotelling T^2 test on the mean vector of differences was utilised instead of multiple paired t-tests. This multivariate method comprehensively analyzes data features and accounts for variable correlations, unlike multiple univariate analyses. Given our small sample size, we employed the MMPC variable selection algorithm to identify predictor variables significantly related to mean changes.

Results: Significant alterations in ECG intervals and heart rate were noted in the subjects before and after the first EMF exposure cycle, independent of their BMI. Notably, heart rate, P-R, and QRS intervals fell postexposure while QT and ST intervals increased. These changes were influenced by variations in systolic blood pressure, with BMI showing no significant effect.

Conclusion: The observed modifications in cardiac electrical measurements due to mobile phone EMF exposure are attributed to the effects of EMF itself, with no impact from BMI on the extent of these changes.

Note: iPhone 5 Plus was used.

Conclusion

Given the evidence linking EMFs from mobile phones to adverse effects on heart health, it is crucial for regular users of such devices, especially those at risk of CVDs, to take steps towards reducing their

overall exposure. This can be achieved through measures such as limiting talk time or using hands-free headsets during calls. Additionally, ongoing research in this area is essential to deepen our understanding of how these potentially harmful frequencies impact our bodies over both short- and long-term periods.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1155/2024/7093771

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The Role of Excess Charge Mitigation in Electromagnetic Hygiene: An Integrative review

Jamieson IA, Bell JNB, Holdstock P. The Role of Excess Charge Mitigation in Electromagnetic Hygiene: An Integrative review. Biomedical Journal. 2024, doi: 10.1016/j.bj.2024.100801.

Abstract

The electromagnetic characteristics of many environments have changed significantly in recent decades. This is in large part due to the increased presence of equipment that emits electromagnetic radiation and materials that may often readily gain excess charge. The presence of excess charge can often increase risk of infection from pathogens, and likelihood of individuals experiencing compromised performance, respiratory problems and other adverse health issues from increased uptake of particulate matter. It is proposed that adopting improved electromagnetic hygiene measures, including optimized humidity levels, to reduce the presence of inappropriate levels of electric charge can help reduce the likelihood of ill health, infection and poor performance arising from contaminant inhalation and deposition, plus reduce the likelihood of medical devices and other electronic devices getting damaged and/or having their data compromised. It is suggested that such measures should be more widely adopted within clinical practice guidelines and water, sanitation and hygiene programs.

Highlights

Electric fields can increase localized deposition of pathogens.

High charge of either polarity increases contaminant deposition.

40-60% relative humidity reduces likelihood of infection.

Proper specification of materials reduces infection risks.

Electromagnetic hygiene can reduce risk of infection.

Open access paper: https://www.sciencedirect.com/science/article/pii/S2319417024001045

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5G RF-EMF Effects on the Human Sleep Electroencephalogram: A Randomized Controlled Study in Healthy Volunteers (pre-print, not peer-reviewed)

My note: Most studies to date that claim to evaluate the effects of 5G exposure did not employ a 5G signal generator. This study, however, used an exposure system (sXh5G) developed by the IT'IS Foundation that provides a controlled and well-characterized 5G EMF exposure at two different carrier frequencies.

Sousouri G, Eicher C, D'Angelo RM, Billecocq M, Fussinger T, Studler M, Capstick M, Kuster N, Achermann P, Huber R, Landolt H-P. 5G Radio-Frequency-Electromagnetic-Field Effects on the Human Sleep Electroencephalogram: A Randomized Controlled Study in CACNA1C Genotyped Healthy Volunteers. MedRxiv. Dec 26, 2024. doi: 10.1101/2024.12.16.24319082.

Abstract

Background: The introduction of 5G technology as the latest standard in mobile telecommunications has raised concerns about its potential health effects. Prior studies of earlier generations of radiofrequency electromagnetic fields (RF-EMF) demonstrated narrowband spectral increases in the electroencephalographic (EEG) spindle frequency range (11-16 Hz) in non-rapid-eye-movement (NREM) sleep. However, the impact of 5G RF-EMF on sleep remains unexplored. Additionally, RF-EMF can activate L-type voltage-gated calcium channels (LTCC), which have been linked to sleep quality and EEG oscillatory activity.

Objective: This study investigates whether the allelic variant rs7304986 in the CACNA1C gene, encoding the α1C subunit of LTCC, modulates 5G RF-EMF effects on EEG spindle activity during NREM sleep.

Methods: Thirty-four healthy, matched participants, genotyped for rs7304986 (15 T/C and 19 T/T carriers), underwent a double-blind, sham-controlled study with standardized left-hemisphere exposure to two 5G RF-EMF signals (3.6 GHz and 700 MHz) for 30 min before sleep. Sleep spindle activity was analyzed using high-density EEG and the Fitting Oscillations & One Over f (FOOOF) algorithm.

Results: T/C carriers reported longer sleep latency compared to T/T carriers. A significant interaction between RF-EMF exposure and rs7304986 genotype was observed, with 3.6 GHz exposure in T/C carriers inducing a faster spindle center frequency in the central, parietal, and occipital cortex compared to sham.

Conclusion: These findings suggest 3.6 GHz 5G RF-EMF modulates spindle center frequency during NREM sleep in a CACNA1C genotype-dependent manner, implicating LTCC in the physiological response to RF-EMF and underscoring the need for further research into 5G effects on brain health.

Excerpts

All participants completed three experimental nights with different, standardized exposure conditions according to a randomized, double-blind, cross-over design: 1) 30-min, pre-sleep exposure to an active 5G EMF at a carrier frequency of 700 MHz, 20 MHz bandwidth, and 12.5 Hz applied power control, 2) 30-min, pre-sleep exposure to an active 5G EMF at a carrier frequency of 3.6 GHz, 100 MHz bandwidth, and 12.5 Hz applied power control, and 3) a 30-min sham exposure without an active field....

All exposure conditions were administered with the same exposure system (sXh5G), provided by the IT'IS Foundation for Research on Information Technologies in Society (IT'IS Foundation, Zurich, Switzerland), which ensures controlled and well-characterized 5G EMF exposure. Following detailed simulated dosimetry (Figure 1), the signal intensity was calibrated to ensure the specific absorption rate (SAR) for the head (averaged over 10 g of tissue) did not exceed 2 W/kg. The active field remained within the SAR limit for the general population established by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and posed no known health risks. The two active fields administered are 5G uplink signals generated in the 5G frequency range. The lower frequency signal has

a carrier frequency of 700 MHz, 20 MHz bandwidth, Frequency Division Duplexing/Orthogonal Frequency-Division Multiplexing (FDD/OFDM) with 24 resource blocks, 16 time slots, 60 kHz sub-carrier spacing and Quadrature Phase Shift Keying (QPSK) modulation, with an output power of 4.28 W. The higher frequency signal has a carrier frequency of 3.6 GHz, 100 MHz bandwidth, Time Division Duplexing (TDD)/QPSK OFDM with 135 resource blocks, 16 time slots, 60 kHz sub-carrier spacing and QPSK modulation, with an output power of 1.63 W. In the signals used, only uplink communication is implemented, and all frames are identical with 16 time slots. Both signals have identical power control applied that introduces low frequency amplitude modulation at 12.5 Hz on top of the modulation due to the occupied time slots which have a dominant power modulation frequency of 200 Hz resulting in a 14.2 dB peak to average power ratio (PAPR) (Supp. Figure 1, 2 & 3). The exposure levels in grey and white matter, thalamus and all tissues in the brain averaged over 0.125 g which is a cube of side length ~5 mm are reported in Table 1 for both 700 MHz and 3.6 GHz....

... we found a significant interaction between exposure and the genetic variant in the center frequency of sleep spindles. Specifically, we demonstrated a topographically widespread acceleration of spindle center frequency in the T/C carriers after exposure to the 3.6 GHz RF-EMF in comparison to sham....

By leveraging the strengths of spectral parameterization, we demonstrated a widespread shift in the center frequency of sleep spindles towards faster oscillatory activity in T/C allele carriers after exposure to a 5G RF-EMF with a carrier frequency of 3.6 GHz. This effect was evident in central, parietal, and occipital cortical areas coinciding with areas that predominantly express faster spindles. A number of previous studies also reported enhanced EEG spectral power in the upper spindle range after exposure to RF-EMF of earlier generation (Huber et al., 2000, 2002; Schmid, Loughran, et al., 2012; Schmid, Murbach, et al., 2012)....

The discrepancy between the deeper penetration of the 700 MHz signal revealed by the simulated SAR distribution in the brain and the more pronounced effects on the EEG sleep spindles observed following exposure to the 3.6 GHz signal remains unclear. Notably, the pulse modulation, which has been identified as critical for the biological effects of RF-EMF (Huber et al., 2002), was identical at 12.5 Hz in both fields and the psSAR10gr was consistently set at 2 W/kg. The findings underscore the necessity for a comprehensive investigation into the complex characteristics of the new 5G signals. Furthermore, they may suggest that the dielectric and conductive properties of the tissues associated with the minor allele may not be adequately represented by the current simulation parameters. Alternatively, the observed effects may indicate a distinct mode of action that is unrelated to SAR distribution....

The differential effects observed between the 700 MHz and 3.6 GHz exposures highlight the importance of considering signal characteristics and tissue properties in understanding RF-EMF interactions. Overall, our results provide new insights into the genetic and biophysical factors underlying RF-EMF effects on sleep, emphasizing the need for more targeted studies to elucidate these mechanisms.

Open access pre-print: https://www.medrxiv.org/content/10.1101/2024.12.16.24319082v1

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RF-EMF Exposure near 5G NR Small Cells

Aerts S, Deprez K, Verloock L, Olsen RG, Martens L, Tran P, Joseph W. RF-EMF Exposure near 5G NR Small Cells. *Sensors*. 2023; 23(6):3145. doi: 10.3390/s23063145.

Abstract

Of particular interest within fifth generation (5G) cellular networks are the typical levels of radiofrequency (RF) electromagnetic fields (EMFs) emitted by 'small cells', low-power base stations, which are installed such that both workers and members of the general public can come in close proximity with them. In this study, RF-EMF measurements were performed near two 5G New Radio (NR) base stations, one with an Advanced Antenna System (AAS) capable of beamforming and the other a traditional microcell. At various positions near the base stations, with distances ranging between 0.5 m and 100 m, both the worst-case and time-averaged field levels under maximized downlink traffic load were assessed. Moreover, from these measurements, estimates were made of the typical exposures for various cases involving users and non-users. Comparison to the maximum permissible exposure limits issued by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) resulted in maximum exposure ratios of 0.15 (occupational, at 0.5 m) and 0.68 (general public, at 1.3 m). The exposure of non-users was potentially much lower, depending on the activity of other users serviced by the base station and its beamforming capabilities: 5 to 30 times lower in the case of an AAS base station compared to barely lower to 30 times lower for a traditional antenna.

Excerpt

Scaled to small-cell powers, the measured exposure levels in this study were below the MPE limits for both occupational (at distances between 0.5 m and 1 m from the base station) and general public exposure (>1 m) issued by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [17]: the maximum exposure ratios were 0.15 (occupational) and 0.68 (general public). These theoretical worst-case exposures were higher than the actual maxima measured in situ by maximizing the downlink traffic load, and both types of worst-case exposures were much higher (3–12 times) than the exposures of a typical user, which in turn were much higher (4–9 times) than the exposures without any users. Finally, the exposure of a non-user within a mature 5G NR network depends on the distribution of users, their usage, and the AAS capabilities of the base station radio.

Although adverse health effects at non-thermal exposure levels cannot be ruled out [20], the ICNIRP reference levels are still relevant to calculate exposure ratios against. The measurement values obtained in this study and reported in this paper can be directly compared to other reference or limit levels (e.g., from legislation or scientific literature), depending on the scope of the study.

For a 5G NR AAS base station, the actual exposure of a given user will generally be less than the theoretical maximum exposure E_{max} for several reasons. First, other users (the number may vary) may be in beams other than the one the given user is using. Hence, the RF energy directed toward these users will not add (much) to the exposure of the given user. Second, the usage by the given user will generally be less than the maximum assumed for which E_{max} was defined. Third, there may be dynamic power control to reduce base station power to the minimum needed for communication. This was not taken into account in this study. Finally, the base station beam may be narrower or wider than that used to measure E_{max}. Hence, the problem of determining actual RF exposure becomes a statistical one that depends on several different variables. However, the exposure will almost always be less than E_{max}.

Similarly, for the non-user, the difference lies in whether they are in a beam or not. Generally, the RF exposure from the base station for the non-user will be smaller than that for a user (here by at least a

factor of 5 for an AAS), unless there are many users around and the MaMIMO capabilities of the base station are limited (Table 4) [19].

Open access paper: https://www.mdpi.com/1424-8220/23/6/3145

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Improving Monitoring of Indoor RF-EMF Exposure Using IoT-Embedded Sensors and Kriging Techniques

Jabeur R, Alaerjan A. Improving Monitoring of Indoor RF-EMF Exposure Using IoT-Embedded Sensors and Kriging Techniques. *Sensors*. 2024; 24(23):7849. https://doi.org/10.3390/s24237849

Abstract

Distributed wireless sensor networks (WSNs) are widely used to enhance the quality and safety of various applications. These networks consist of numerous sensor nodes, often deployed in challenging terrains where maintenance is difficult. Efficient monitoring approaches are essential to maximize the functionality and lifespan of each sensor node, thereby improving the overall performance of the WSN. In this study, we propose a method to efficiently monitor radiofrequency electromagnetic fields (RF-EMF) exposure using WSNs. Our approach leverages sensor nodes to provide real-time measurements, ensuring accurate and timely data collection. With the increasing prevalence of wireless communication systems, assessing RF-EMF exposure has become crucial due to public health concerns. Since individuals spend over 70% of their time indoors, it is vital to evaluate indoor RF-EMF exposure. However, this task is complicated by the complex indoor environments, furniture arrangements, temporal variability of exposure, numerous obstructions with unknown dielectric properties, and uncontrolled factors such as people's movements and the random positioning of furniture and doors. To address these challenges, we employ a sensor network to monitor RF-EMF exposure limits using embedded sensors. By integrating Internet of Things-embedded sensors with advanced modeling techniques, such as kriging, we characterize and model indoor RF-EMF downlink (DL) exposure effectively. Measurements taken in several buildings within a few hundred meters of base stations equipped with multiple cellular antennas (2G, 3G, 4G, and 5G) demonstrate that the kriging technique using the spherical model provides superior RF-EMF prediction compared with the exponential model. Using the spherical model, we constructed a high-resolution coverage map for the entire corridor, showcasing the effectiveness of our approach.

Conclusions

This study proposes the use of WSN to monitor the indoor RF-EMF exposure induced by cellular networks. To this end, we first proposed a measurement system based on the Narda NBM-550 and Nucleo-F401RE microcontroller board. The aim is to characterize and model indoor RF-EMF DL exposure using the collected measurements and kriging technique. First, several indoor measurements are conducted in an area covered by various frequency bands, including those used for 5G. By comparing the spherical and exponential models, we demonstrated that the spherical model provides a superior fit for predicting RF-EMF exposure levels. The high-resolution coverage map constructed using the spherical model revealed that the maximum average RF-EMF DL exposure levels within the corridor are well below the limits established by the ICNIRP. These findings underscore the effectiveness of the

kriging technique in accurately modeling and predicting RF-EMF exposure in complex indoor environments.

For future work, several avenues can be explored to enhance the understanding and assessment of indoor RF-EMF exposure. Firstly, expanding the measurement campaign to include a wider variety of indoor environments, such as residential buildings, offices, and public transport, would provide a more comprehensive dataset. Additionally, incorporating temporal variations by conducting long-term measurements could offer insights into the fluctuations of RF-EMF exposure over time. Furthermore, integrating advanced machine learning algorithms with the kriging technique could improve the accuracy and efficiency of exposure predictions. Another important research axis involves the analysis of measurement uncertainty, which is planned for future investigation. For large-scale deployments, the Narda NBM-550 can be replaced with frequency-selective equipment such as the ExpoM-RF4, MVG EME Spy Evolution, or Narda SRM-3006. This substitution ensures that only downlink bands are considered and enables the reconstruction of RF-EMF exposure maps for each frequency band, facilitating a more detailed assessment by frequency band. Finally, investigating the impact of emerging wireless technologies, such as beyond 5G, on indoor RF-EMF exposure will be crucial as these technologies become more widespread. These future directions will contribute to a more thorough understanding of indoor RF-EMF exposure and help address public concerns regarding wireless communication systems.

Open access paper: https://www.mdpi.com/1424-8220/24/23/7849

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AI-based optimization of EM radiation estimates from GSM base stations using traffic data

Lal R, Singh RK, Nishad DK, *et al.* AI-based optimization of EM radiation estimates from GSM base stations using traffic data. *Discov Appl Sci* 6, 655 (2024). doi: 10.1007/s42452-024-06395-y

Abstract

The fast expansion of mobile networks has sparked worries regarding base station EM radiation's health impacts. Traffic load is commonly ignored when evaluating EM radiation levels using maximum power output. This study proposes utilizing AI and ML on real network traffic data to optimize GSM base station EM radiation estimations. We obtained EM radiation measurements and traffic data from selecting GSM base stations by location and configuration. To predict EM radiation levels, traffic patterns were used to train linear regression, random forests, and neural networks. Base stations were clustered by radiation profile using unsupervised learning. Considering regulatory restrictions and measurement feasibility, an optimization methodology was created to minimize EM radiation estimate inaccuracy. The results show better prediction accuracy than power-based estimations and high generalisability across base station types. Site-specific factors influenced daily EM radiation patterns after clustering. EM radiation levels can be monitored using traffic data and the optimized AI/ML model. This research helps telecom operators and regulators analyze EM radiation more accurately and efficiently. Future projects should include 5G and small cell network extensions and intelligent city platform integration. The suggested method develops data-driven, AI-powered Public Safety and mobile network trust solutions.

Open access paper: https://link.springer.com/article/10.1007/s42452-024-06395-y

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Advancements in electromagnetic microwave absorbers: Ferrites and carbonaceous materials

Mohapatra PP, Singh HK, Dobbidi P. Advancements in electromagnetic microwave absorbers: Ferrites and carbonaceous materials. Adv Colloid Interface Sci. 2024 Dec 14;337:103381. doi: 10.1016/j.cis.2024.103381.

Abstract

Heightened levels of electromagnetic (EM) radiation emitted by electronic devices, communication equipment, and information processing technologies have become a significant concern recently. So, substantial efforts have been devoted for developing novel materials having high EM absorption properties. This critical review article provides an overview of the advancements in understanding and developing such materials. It delves into the interaction between EM radiation and absorbing materials, focusing on phenomena like multiple reflections, scattering, and polarization. Additionally, the study discusses various types of losses that impact microwave absorber performance, like magnetic loss, and dielectric loss. Each of these losses has distinct implications for microwave absorbers' effectiveness. Furthermore, the review offers detailed insights into different microwave-absorbing materials, such as metal composites, magnetic materials, conducting polymers, and carbonaceous materials (composites with carbon fiber, porous carbon, carbon nanotube, graphene oxide, etc.). Overall, it highlights the progress achieved in microwave-absorbing materials and emphasizes optimizing various loss mechanisms for enhanced performance.

Conclusions

This study provides a comprehensive overview of recent advancements in magnetic and carbon-based dielectric composites, showcasing their potential as promising materials for microwave absorption. The examples underscore that a single dielectric or magnetic system alone cannot consistently achieve optimal microwave absorption performance, necessitating the formulation of composite mixtures that incorporate dielectric and magnetic fillers. These composites' exceptional microwave absorption capabilities can be attributed to several key factors: optimizing intrinsic properties: The amalgamation of a carbon-based material with dielectric components yields distinctive complementary responses in their intrinsic properties, resulting in optimized impedance matching. Inducing Interfacial Polarization: Ample heterogeneous interfaces between different components effectively induce strong interfacial polarization, enhancing the overall microwave absorption performance. Facilitating Conductive Networks: Integrating multiple components facilitates the formation of a conductive network, hopping electrons and fostering the migration and fortifying conductivity loss. Precision in Microstructure Design: Meticulously designed microstructures offer additional propagation paths for incident electromagnetic waves, stimulating multiple reflections and scatterings that efficiently consume electromagnetic energy.

Despite remarkable progress in carbon-based dielectric systems, persistent challenges warrant a strategic approach: In-Depth Exploration of EM Loss Characteristics: A meticulous exploration of the electromagnetic loss characteristics of each component is crucial. It emphasizes the need for a rational combination of elements rather than arbitrarily preparing multicomponent composites. Defect Engineering: While defects like grain boundaries, atom vacancies, and heteroatoms positively affect polarization and conductivity losses, the intricate relationship between defect sites and microwave

absorption performance necessitates further exploration. Defect engineering is pivotal in guiding the fabrication of high-performance magnetic and carbon-based dielectric composites. Expanding the Effective Frequency Range: The effective frequency range of most composites is confined to 8.0–18.0 GHz, limiting their applicability in the electronics industry, where many devices operate at frequencies lower than 8.0 GHz. A rational construction approach for multicomponent composites with well-designed microstructures holds the potential to overcome this limitation and enhance low-frequency attenuation capabilities. Simplified Preparation Methods: The preparation methods, especially for multicomponent composites, are often complicated, posing challenges for large-scale production. Streamlining these methods is crucial for overcoming production difficulties.

In conclusion, the future outlook for high-performance materials against electromagnetic pollution lies in developing novel carbon-based dielectric systems, magnetic fillers with well-balanced compositions, and intricate microstructures. Addressing the outlined challenges will contribute to realizing these materials' potential to mitigate electromagnetic interference.

https://pubmed.ncbi.nlm.nih.gov/39700971/

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Effect of radiation emitted from mobile phone on innate immunity in mice

Pei, Y., Gao, H., Zhang, M., Zhou, F., Zhu, Y., Wang, X., & Sun, J. (2024). Effect of radiation emitted from mobile phone on innate immunity in mice. *Radiation Effects and Defects in Solids*, *179*(11–12), 1585–1596. doi: 10.1080/10420150.2024.2352845

Abstract

This present study aims to explore the potential impact of cell phone radiation on innate immunity in mice. Ninety-six male BALB/C mice aged 2–3 weeks were randomly distributed into 4 groups as blank control, control, TD-SCDMA and LTE-Advanced respectively, with 32 mice in each group. Mice were designed to be exposed to cell phone radiation for 4–8 weeks. Eight mice in each group were taken out for measurement given exposure periods were 4, 6 and 8 weeks respectively. Cell biological technique was conducted to assess the chemotaxis of neutrophils, and a morphological method was performed for the detection of phagocytosis of neutrophil and macrophage, while microbiological means was carried out to test the relative activity of lysozyme in serum of mice. As a result, the chemotaxis ratio of neutrophils was with little statistical difference among the four groups given a shorter exposure period. However, the ratios in TD-SCDMA and LTE-Advanced groups were decreased significantly on the condition that the exposure period was more than 6 weeks. No statistical difference was observed among the four groups during the entire exposure period in terms of the chemotaxis index. Phagocytosis of the innate cells as neutrophil and macrophage showed little change in the two control groups during the whole experimental stages, while the percentage in the two treated groups decreased statistically, and this kind of reduction was prone to feature time dependence. The activities of lysozyme in TD-SCDMA and LTE-Advanced groups declined significantly, further to that, the impact was climbing paralleled with the prolonged duration. It could be deduced that radiation from cell phones could weaken innate immunity in experimental mice; moreover, this adverse effect was seemingly more severe as the radiation exposure continued.

https://www.tandfonline.com/doi/full/10.1080/10420150.2024.2352845

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Numerical dosimetry of specific absorption rate of insects exposed to far-field radiofrequency electromagnetic fields

Jeladze V, Nozadze T, Partsvania B, Thielens A, Shoshiashvili L, Gogoladze T (2025). Numerical dosimetry of specific absorption rate of insects exposed to far-field radiofrequency electromagnetic fields. *International Journal of Radiation Biology*, 1–14. doi: 10.1080/09553002.2024.2442693.

Abstract

Purpose This paper reports a study of electromagnetic field (EMF) exposure of several adult insects: a ladybug, a honey bee worker, a wasp, and a mantis at frequencies ranging from 2.5 to 100 GHz. The purpose was to estimate the specific absorption rate (SAR) in insect tissues, including the brain, in order to predict the possible biological effects caused by EMF energy absorption.

Method Numerical dosimetry was executed using the finite-difference time-domain (FDTD) method. Insects were modeled as 3-tissue heterogeneous dielectric objects, including the cuticle, the inner tissue, and the brain tissue. The EMF source was modeled as sinusoidal plane waves at a single frequency (far-field exposure).

Results The whole-body averaged, tissue averaged, and 1 milligram SAR values were determined in insects for all considered frequencies for 10 different incident plane waves. SAR values were normalized to the incident power density of 1 mW/cm2. Maximal EMF absorption in the inner and brain tissues was observed at 6, 12, and 25 GHz for the considered insects, except the brain tissue of a ladybug (max at 60 GHz).

Conclusion The paper presented the first estimation of the SAR for multiple insects over a wide range of RF frequencies using 3-tissue heterogenous insect 3D models created for this specific research. The selection of tissues' dielectric properties was validated. The obtained results showed that EMF energy absorption in insects highly depends on frequency, polarization, and insect morphology.

Conclusion

The paper presented a study of RF-EMF dosimetry of honeybee worker, wasp, mantis, and ladybug from 2.5 to 100 GHz, including frequencies that will be utilized in future 5 G technologies.

Discrete, 3-tissue heterogenous insect 3D models were created and used for FDTD modeling.

The whole-body averaged SAR values and tissue-averaged SAR values were estimated in insects' tissues for 9 considered frequencies and 10 polarizations of incident plane wave. For the first time, 1 mg SAR values were determined in insect tissues.

The obtained results showed SAR values in honeybee, wasp, ladybug, and mantis body tissues, which depend on the direction of the incident plane wave and polarization, frequency, and the insects' body sizes and peculiarities.

The highest values of the peak 1 mg SAR for the honeybee and wasp − 39.2 W/kg and 169.2 W/kg for an incident field strength of 1 mW/cm^2, were observed when E-field polarization was directed along the insect's length (pol. E3, E5, E9).

The obtained results showed maximal tissue-specific SAR values in the brain at 25 GHz for the honeybee (3.6 W/kg), 12 GHz for the wasp (5.4 W/kg), 25 GHz for the mantis (5.2 W/kg), and 60 GHz for the ladybug (10 W/kg), all for an incident power density of 1 mW/cm^2. Maximal EMF absorption in the inner tissue was observed at 12 GHz, 4.3 W/kg, 5.9 W/kg, 4.8 W/kg for the honey bee, wasp, and ladybug, respectively, and for the mantis 3.3 W/kg at 6 GHz for an incident power density of 1 mW/cm^2. The absorption in insects' cuticles increased proportionally with frequency. For example, for the ladybug, the tissue-specific SAR in the cuticle was 0.1 W/kg at 2.5 Ghz and 11.9 W/kg at 100 GHz for the same incident power density of 1 mW/cm^2.

Future studies will consider introducing insect models that will be obtained using micro-CT scanning, examining the effects of high-frequency electromagnetic fields on other insects of different forms and sizes, conducting thermal simulations along with EM simulations, and evaluating temperature rise in insect tissues.

Based on the present results, we expect this research to have an impact on (environmental) policymaking and standardization and regulation regarding RF-EMF emissions. We expect to contribute to the harmonization of 5G EMF safety and compliance doses and to the development of future recommendations about safe frequencies and doses of 5G-EMF on the organisms studied in the present research.

https://www.tandfonline.com/doi/full/10.1080/09553002.2024.2442693

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Emerging cancer therapies: targeting physiological networks and cellular bioelectrical differences with non-thermal systemic electromagnetic fields in the human body – a comprehensive review

Costa FP, Wiedenmann B, Schöll E, Tuszynski J. Emerging cancer therapies: targeting physiological networks and cellular bioelectrical differences with non-thermal systemic electromagnetic fields in the human body – a comprehensive review. Frontiers in Network Physiology. Vol. 4, 2024. doi: 10.3389/fnetp.2024.1483401.

Abstract

A steadily increasing number of publications support the concept of physiological networks, and how cellular bioelectrical properties drive cell proliferation and cell synchronization. All cells, especially cancer cells, are known to possess characteristic electrical properties critical for physiological behavior, with major differences between normal and cancer cell counterparts. This opportunity can be explored as a novel treatment modality in Oncology. Cancer cells exhibit autonomous oscillations, deviating from normal rhythms. In this context, a shift from a static view of cellular processes is required for a better understanding of the dynamic connections between cellular metabolism, gene expression, cell signaling and membrane polarization as states in constant flux in realistic human models. In oncology, radiofrequency electromagnetic fields have produced sustained responses and improved quality of life

in cancer patients with minimal side effects. This review aims to show how non-thermal systemic radiofrequency electromagnetic fields leads to promising therapeutic responses at cellular and tissue levels in humans, supporting this newly emerging cancer treatment modality with early favorable clinical experience specifically in advanced cancer.

Open access paper:

https://www.frontiersin.org/journals/network-physiology/articles/10.3389/fnetp.2024.1483401

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Effect of 6 GHz radiofrequency electromagnetic field on the development of fetal bones

Karamazı Y, Emre M, Uçar S, Aksoy G, Emre T, Tokuş M. (2024). Effect of 6 GHz radiofrequency electromagnetic field on the development of fetal bones. *Electromagnetic Biology and Medicine*, 1–9. doi: 10.1080/15368378.2024.2438608.

Abstract

This study examined the impact of 6 GHz (0.054 W/kg SAR) Radiofrequency-Electromagnetic Field (RF-EMF) on prenatal bone development. In this study, 20 female and 20 male Wistar Albino rats divided into four groups. The Control group received no treatment, while in Group-I, only male rats were exposed to RF-EMF, female rats had no exposure. Group-II, both male and female rats received RF-EMF treatment. While in Group-III, only female rats were exposed to RF-EMF, male rats had no exposure. The exposure lasted 4 hours per day for 6 weeks. The rats were then allowed to mate within the group. After pregnancy, pregnant rats (Group-II and III) were exposed 4 hours per day for 18 days. On the 18th day of gestation, fetuses were removed and their weight and various lengths were measured. The skeletal system development of fetuses was examined with double skeletal staining method and assessed ossification in the extremities. In the study, fetal weights, head-tail length, occipital-frontal and parietal-parietal lengths significantly increased in all exposure groups when compared to the control group ($p < 0.001$). Although occipital-frontal length was smallest in Group-I, Group-II and Group-III were more higher than the control group ($p < 0.001$). The bones of the anterior and posterior extremities showed significant increases in length, ossification zone length, and ossification percentage in all experimental groups compared to the control group ($p < 0.001$). Our study showed that rats exposed to 6 GHz (0.054 W/kg) RF-EMF during the prenatal period had significant increases in bone development.

Plain-Language Summary

Radiofrequency Electromagnetic Field (RF-EMF) sources are one of the most widely used technology systems in daily life. This study examined the impact of 6 GHz RF-EMF on prenatal bone development. In this study, 20 female and 20 male Wistar Albino rats divided into four groups. The control group rats received no treatment, while in Group-I, only male rats, Group-II, both male and female rats, while in Group-III, only female rats were exposed to RF-EMF. The exposure lasted 4 hours/day for 6 weeks. The rats were then allowed to mate within the group. After pregnancy, pregnant rats (Group-II and III) were exposed 4 hours/day for 18 days. On the 18th day of gestation, fetuses were removed 10 fetuses each group were randomly selected in each group and their weight and various lengths were measured. The skeletal system development of fetuses was examined with double skeletal staining method. The ImageJ program was used assess ossification in the extremities.

https://www.tandfonline.com/doi/full/10.1080/15368378.2024.2438608

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Effects of 4G Long-Term Evolution Electromagnetic Fields on Thyroid Hormone Dysfunction and Behavioral Changes in Adolescent Male Mice

Kim H-Y, Son Y, Jeong YJ, Lee S-H, Kim N, Ahn YH, Jeon SB, Choi H-D, Lee H-J. Effects of 4G Long-Term Evolution Electromagnetic Fields on Thyroid Hormone Dysfunction and Behavioral Changes in Adolescent Male Mice. *International Journal of Molecular Sciences*. 2024; 25(20):10875. doi: 10.3390/ijms252010875.

Abstract

Radiofrequency electromagnetic fields (RF-EMFs) can penetrate tissues and potentially influence endocrine and brain development. Despite increased mobile phone use among children and adolescents, the long-term effects of RF-EMF exposure on brain and endocrine development remain unclear. This study investigated the effects of long-term evolution band (LTE) EMF exposure on thyroid hormone levels, crucial for metabolism, growth, and development. Four-week-old male mice (C57BL/6) were exposed to LTE EMF (whole-body average specific absorption rate [SAR] 4 W/kg) or a positive control (lead; Pb, 300 ppm in drinking water) for 4 weeks. Subsequently, the mice underwent behavioral tests including open field, marble burying, and nest building. Blood pituitary and thyroid hormone levels, and thyroid hormone-regulating genes within the hypothalamus–pituitary–thyroid (HPT) axis were analyzed. LTE exposure increased T3 levels, while Pb exposure elevated T3 and T4 and decreased ACTH levels. The LTE EMF group showed no gene expression alterations in the thyroid and pituitary glands, but hypothalamic Dio2 and Dio3 expressions were significantly reduced compared to that in the sham-exposed group. Pb exposure altered the hypothalamic mRNA levels of Oatp1c1 and Trh, pituitary mRNA of Trhr, and Tpo and Tg expression in the thyroid. In conclusion, LTE EMF exposure altered hypothalamic Dio2 and Dio3 expression, potentially impacting the HPT axis function. Further research is needed to explore RF-EMF's impacts on the endocrine system.

Open access paper: https://www.mdpi.com/1422-0067/25/20/10875

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Evaluation of the Thyroids of Offsprings Exposed to 2450 MHz Radiofrequency Radiation During Pregnancy: A Sixth Month Data

Ozyilmaz C, Oktay MF, Dasdag S, Ulukaya E, Genel ME, Tansuker HD, Emre F, Yeğin K. Evaluation of the Thyroids of Offsprings Exposed to 2450 MHz Radiofrequency Radiation During Pregnancy: A Sixth Month Data. Journal of International Dental & Medical Research, 2024, 17(2): 925-930.

Abstract

This study aimed to determine whether the exposure to radiofrequency emitted by wireless internet providers (2450 MHz) throughout the day during rats' pregnancy causes a problem in the thyroid tissues of their offspring.

The pregnant rats in the experimental group were exposed to radiofrequency radiation (RFR) (24 hours/day) at a 2450 MHz frequency in pulse wave mode with 1 W output strength by a generator simulating Wi-Fi waves. The offspring in the control and experimental groups were randomized selected (n:8). At the end of the sixth month, the thyroid tissues were removed and evaluated histopathologically and biochemically. Mann–Whitney U-tests and T-tests were used for statistical analysis. The threshold for statistical significance was $p < 0.05$.

There was a significant difference in mononuclear cell infiltration ($p=0.03$) and vascular increase in congestion ($p<0.001$). There was no difference in the TUNEL-positive cell percentage ($p=0.62$) and H2A.X antibody levels ($p=0.68$) between the rats in the control and experimental groups. In this study, 2450 MHz RFR exposure during the prenatal period did not cause a statistically significant difference in terms of H2A.X levels and TUNEL-positive cell percentages in the thyroid tissue of rats.

Open access paper: http://www.jidmr.com/journal/wp-content/uploads/2024/06/71-M24_3112_Suleyman_DASDAG_Turkey-Exp-2.pdf

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Effects of extremely low frequency magnetic fields on animal cancer and DNA damage: a systematic review and meta-analysis

Brabant C, Honvo G, Demonceau C, Tirelli E, Léonard F, Bruyère O. Effects of extremely low frequency magnetic fields on animal cancer and DNA damage: a systematic review and meta-analysis. Prog Biophys Mol Biol. 2024 Dec 31:S0079-6107(24)00116-0. doi: 10.1016/j.pbiomolbio.2024.12.005.

Abstract

The objective of this systematic review and meta-analysis is to assess the carcinogenic effects of extremely low frequency magnetic fields (ELF-MF) by analyzing animal and comet assay studies. We have performed a global meta-analysis on all the animal studies on the relation between ELF-MF and cancer incidence and separate meta-analyses on the incidence of cancer, leukemia, lymphoma, breast cancer, brain cancer and DNA damage assessed with the comet assay. Of the 5145 references identified, 71 studies have been included in our systematic review and 22 studies in our meta-analyses. Our global meta-analysis indicated that ELF-MF exposure had no significant impact on the incidence of cancers in rodents (19 studies, OR = 1.10; 95% CI 0.91-1.32). However, our separate meta-analyses showed that ELF-MF increased the odds of developing leukemia in mice (4 studies, OR = 4.45; 95% CI 1.90-10.38) but not in rats. Our systematic review also suggests that ELF-MF can damage DNA in certain cell types like brain cells. Nevertheless, a meta-analysis on three comet assay studies indicated that ELF-MF did not increase DNA damage in neuroblastoma cells (SMD = -0.08; 95% CI -0.18-0.01). Overall, our results suggest that exposure to ELF-MF does not represent a major hazard for mammals and the carcinogenic effects of these magnetic fields could be limited to leukemia.

Highlights

ELF-MF do not affect the odds of lymphoma, brain cancer and breast cancer in rodents

ELF-MF could increase the odds of developing leukemia in mice but not in rats

ELF-MF have no influence on survival and body weight in rodents

ELF-MF do not increase DNA damage in neuroblastoma cells

ELF-MF could damage DNA of certain cell types like brain cells in rodents

https://pubmed.ncbi.nlm.nih.gov/39746455/

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Effects of extremely low-frequency (50 Hz) electromagnetic fields on vital organs of adult Wistar rats and viability of mouse fibroblast cells

Tekam CKS, Majumdar S, Kumari P, Prajapati SK, Sahi AK, Singh R, Krishnamurthy S, Mahto SK. Effects of extremely low-frequency (50 Hz) electromagnetic fields on vital organs of adult Wistar rats and viability of mouse fibroblast cells. Radiat Prot Dosimetry. 2024 Dec 4:ncae220. doi: 10.1093/rpd/ncae220.

Abstract

In recent years, scientific communities have been concerned about the potential health effects of periodic electromagnetic field exposure (≤1 h/d). The objective of our study is to determine the impact of extremely low-frequency pulsed electromagnetic fields (ELF-PEMF) (1-3 mT, 50 Hz) on mouse fibroblast (red fluorescent protein (RFP)-L929) cells and adult Wistar rats to gain a comprehensive understanding of biological effects. We observed that RFP-L929 exhibits no significant changes in cell proliferation and morphology but mild elevation in aspartate aminotransferases, alanine aminotransferases, total bilirubin, serum creatinine, and creatine kinase-myocardial band levels in ELF-PEMF exposed groups under in vitro and in vivo conditions. However, the histological examination showed no significant alterations in tissue structure and morphologies. Our result suggests that 50-Hz ELF-PEMF exposure (1-3 mT, 50 Hz) with duration (<1 h/d) can trigger mild changes in biochemical parameters, but it is insufficient to induce any pathological alterations.

Conclusions

The present study demonstrates the effects of 50-Hz ELF-PEMF (1–3 mT) using *in vitro* (RFP-L929 mouse fibroblast cells) and *in vivo* (adult male Wistar rats) models. The results reveal that exposure duration of 20 min (each) with a 4-h gap is non-destructive for RFP-L929 cells and causes mild alterations in biochemical parameters but not in organ coefficient, tissue structure, and morphology of adult Wistar rats. The results demonstrated that 50-Hz ELF-PEMF exposure did not cause significant cellular fragmentation and changes in the morphology of mouse fibroblast cells. We observed mild alterations in the biochemical parameters of rats among MF exposed and control groups. Conversely, histological analysis of the selected liver, kidney, and heart sections following ELF-PEMF exposure revealed no significant changes in tissue structure and morphology. Our efforts provide conceptual and experimental support to establish a link between 50-Hz ELF-PEMF exposure and biological systems/tissues in residential and occupational environments.

https://pubmed.ncbi.nlm.nih.gov/39656829/

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Extremely Low-Frequency Electromagnetic Field (ELF-EMF) Increases Mitochondrial Electron Transport Chain Activities and Ameliorates Depressive Behaviors in Mice

Teranishi M, Ito M, Huang Z, Nishiyama Y, Masuda A, Mino H, Tachibana M, Inada T, Ohno K. Extremely Low-Frequency Electromagnetic Field (ELF-EMF) Increases Mitochondrial Electron Transport Chain Activities and Ameliorates Depressive Behaviors in Mice. *International Journal of Molecular Sciences*. 2024; 25(20):11315. https://doi.org/10.3390/ijms252011315

Abstract

Compromised mitochondrial electron transport chain (ETC) activities are associated with depression in humans and rodents. However, the effects of the enhancement of mitochondrial ETC activities on depression remain elusive. We recently reported that an extremely low-frequency electromagnetic field (ELF-EMF) of as low as 10 μT induced hormetic activation of mitochondrial ETC complexes in human/mouse cultured cells and mouse livers. Chronic social defeat stress (CSDS) for 10 consecutive days caused behavioral defects mimicking depression in mice, and using an ELF-EMF for two to six weeks ameliorated them. CSDS variably decreased the mitochondrial ETC proteins in the prefrontal cortex (PFC) in 10 days, which were increased by an ELF-EMF in six weeks. CSDS had no effect on the mitochondrial oxygen consumption rate in the PFC in 10 days, but using an ELF-EMF for six weeks enhanced it. CSDS inactivated SOD2 by enhancing its acetylation and increased lipid peroxidation in the PFC. In contrast, the ELF-EMF activated the Sirt3-FoxO3a-SOD2 pathway and suppressed lipid peroxidation. Furthermore, CSDS increased markers for mitophagy, which was suppressed by the ELF-EMF in six weeks. The ELF-EMF exerted beneficial hormetic effects on mitochondrial energy production, mitochondrial antioxidation, and mitochondrial dynamics in a mouse model of depression. We envisage that an ELF-EMF is a promising therapeutic option for depression.

Open access paper: https://www.mdpi.com/1422-0067/25/20/11315

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Effects of light, electromagnetic fields and water on biological rhythms

Martel J, Rouleau N, Murugan NJ, Chin WC, Ojcius DM, Young JD. Effects of light, electromagnetic fields and water on biological rhythms. Biomed J. 2024 Dec 11:100824. doi: 10.1016/j.bj.2024.100824.

Abstract

The circadian rhythm controls a wide range of functions in the human body and is required for optimal health. Disruption of the circadian rhythm can produce inflammation and initiate or aggravate chronic diseases. The modern lifestyle involves long indoor hours under artificial lighting conditions as well as eating, working, and sleeping at irregular times, which can disrupt the circadian rhythm and lead to poor health outcomes. Seasonal solar variations, the sunspot cycle and anthropogenic electromagnetic fields can also influence biological rhythms. The possible mechanisms underlying these effects are discussed, which include resonance, radical-pair formation in retina cryptochromes, ion cyclotron resonance, and interference, ultimately leading to variations in melatonin and cortisol. Intracellular water, which represents a coherent, ordered phase that is sensitive to infrared light and electromagnetic fields, may also respond to solar variations and man-made electromagnetic fields. We describe here various factors and underlying mechanisms that affect the regulation of biological rhythms, with the aim of providing practical measures to improve human health.

Open access paper:
https://www.sciencedirect.com/science/article/pii/S2319417024001276?via%3Dihub

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The origins of light-independent magnetoreception in humans

Shibata T, Hattori N, Nishijo H, Kuroda S, Takakusaki K. The origins of light-independent magnetoreception in humans. Front Hum Neurosci. 2024 Nov 29;18:1482872. doi: 10.3389/fnhum.2024.1482872.

Abstract

The Earth's abundance of iron has played a crucial role in both generating its geomagnetic field and contributing to the development of early life. In ancient oceans, iron ions, particularly around deep-sea hydrothermal vents, might have catalyzed the formation of macromolecules, leading to the emergence of life and the Last Universal Common Ancestor. Iron continued to influence catalysis, metabolism, and molecular evolution, resulting in the creation of magnetosome gene clusters in magnetotactic bacteria, which enabled these unicellular organisms to detect geomagnetic field. Although humans lack a clearly identified organ for geomagnetic sensing, many life forms have adapted to geomagnetic field-even in deep-sea environments-through mechanisms beyond the conventional five senses. Research indicates that zebrafish hindbrains are sensitive to magnetic fields, the semicircular canals of pigeons respond to weak potential changes through electromagnetic induction, and human brainwaves respond to magnetic fields in darkness. This suggests that the trigeminal brainstem nucleus and vestibular nuclei, which integrate multimodal magnetic information, might play a role in geomagnetic processing. From iron-based metabolic systems to magnetic sensing in neurons, the evolution of life reflects ongoing adaptation to geomagnetic field. However, since magnetite-activated, torque-based ion channels within cell membranes have not yet been identified, specialized sensory structures like the semicircular canals might still be necessary for detecting geomagnetic orientation. This mini-review explores the evolution of life from Earth's formation to light-independent human magnetoreception, examining both the magnetite hypothesis and the electromagnetic induction hypothesis as potential mechanisms for human geomagnetic detection.

Conclusion

Eukaryotic cells, and vertebrates have developed magnetoreception systems to adapt to the geomagnetic field. Numerous studies on magnetoreception in birds, particularly concerning the upper beak and inner ear, suggest that in humans, the trigeminal nerve, vestibular nerve, and hindbrain might be involved in light-independent magnetoreception pathways. However, the specific sensory organ in humans that detects the geomagnetic field has not yet been identified. Unlike traditional senses, geomagnetic information is transmitted without attenuation through the scalp, bones, and cerebrospinal fluid, similar to gravity. It also generates eddy currents and lorentz forces accompanying the relative movement of the geomagnetic field (Arago and Flourens, 1856). Considering these unique properties, vertebrates might have evolved to detect the geomagnetic field in a light-independent manner, not only through direct detection using torque-based magnetic particles but also through indirect detection of electric potentials using electromagnetic induction. Further research into this evolutionary adaptation could help unravel the mystery of geomagnetic field detection in humans.

Open access paper: https://www.frontiersin.org/journals/human-neuroscience/articles/10.3389/fnhum.2024.1482872/full

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Effects of anthropogenic electromagnetic fields used for subsurface oil and gas exploration (controlled-source electromagnetics, CSEM) on the early development of Atlantic haddock

Guillebon C, Perrichon P, Browman HI, Cresci A, Sivle LD, Skiftesvik AB, Zhang G, Durif CMF. Effects of anthropogenic electromagnetic fields used for subsurface oil and gas exploration (controlled-source electromagnetics, CSEM) on the early development of Atlantic haddock (Melanogrammus aeglefinus). Mar Pollut Bull. 2024 Dec 12;211:117425. doi: 10.1016/j.marpolbul.2024.117425.

Abstract

Controlled source electromagnetics (CSEM) uses electromagnetic fields (EMF) to detect oil reservoirs. Atlantic haddock, Melanogrammus aeglefinus, is a commercially important demersal fish species that can potentially be impacted by such surveys due to potential overlap with egg distribution. In this study, haddock eggs were exposed to EMF, replicating CSEM survey conditions in a laboratory. Three different EMF intensities were used to replicate different distances between the EMF source and the organism. Exposures lasted for 15 min. A worst-case scenario, i.e. 1 h exposure at the highest EMF level was also carried out. None of the treatments caused malformations, mortality or affected hatching of eggs. However, EMF exposure induced tachycardia in newly hatched larvae and reduced the size of their yolk sac reserve. The effect was significant at the lowest EMF intensity (corresponding to 1000 m between the EMF source and the exposed subject) and increased with exposure time and intensity

Open access paper:
https://www.sciencedirect.com/science/article/pii/S0025326X24014024?via%3Dihub

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The effect of mobile phone electromagnetic fields on the human resting state wake EEG and event-related potential: A systematic review and meta-analysis

Prins AC, Baas K, van der Meer JN, Jacobs M, Nederveen AJ. The effect of mobile phone electromagnetic fields on the human resting state wake EEG and event-related potential: A systematic review and meta-analysis. Bioelectromagnetics. 2024 Nov 22. doi: 10.1002/bem.22531.

Abstract

The rapid growth of mobile phone usage and its use of radiofrequency electromagnetic fields (RF-EMF) have raised concerns about potential health risks. Researchers have conducted studies to examine the effects of RF-EMF on the brain using electroencephalography (EEG). We conducted a systematic quality assessment and meta-analysis of published research in this field to establish high-quality studies as references for future protocols. The electronic search yielded 244 records from which a total of 51 studies were included in the review after excluding studies based on study design, and data or report availability. Of these 51 studies, 31 (61%) focused on resting state wake EEG and 20 (39%) on event-related potentials (ERP). None of the 51 studies were free from risk of bias. From the 51 included studies, we were able to use seven studies to create three different groups for meta-analysis for resting

state wake EEG and five studies to create 10 different groups for meta-analysis for ERP. Per group the number of studies varies from 1 to 5. Our procedure is the first systematic quality assessment in this field and revealed three important findings. First, there is evidence of an effect on the EEG of a 2G protocol using an eyes-open condition. Second, we did not find evidence for EEG effects during task performance. This suggests that the impact of EMF during task performance is less pronounced compared to the resting state condition. Third, this meta-analysis shows that the field is unable to create an evidence base for most comparisons due to heterogeneity. We therefore advise that all future studies are double-blind in nature, adhere to the methodological standard of randomized experiments, and publish their protocols first.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/bem.22531

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Electromagnetic fields exposure on fetal and childhood abnormalities: Systematic review and meta-analysis

Kashani ZA, Pakzad R, Fakari FR, Haghparast MS, Abdi F, Kiani Z, Talebi A, Haghgoo SM. Electromagnetic fields exposure on fetal and childhood abnormalities: Systematic review and meta-analysis. Open Med (Wars). 2023 May 12;18(1):20230697. doi: 10.1515/med-2023-0697

Abstract

Today, in the modern world, people are often exposed to electromagnetic waves, which can have undesirable effects on cell components that lead to differentiation and abnormalities in cell proliferation, deoxyribonucleic acid (DNA) damage, chromosomal abnormalities, cancers, and birth defects. This study aimed to investigate the effect of electromagnetic waves on fetal and childhood abnormalities. PubMed, Scopus, Web of Science, ProQuest, Cochrane Library, and Google Scholar were searched on 1 January 2023. The Cochran's *Q*-test and I^2 statistics were applied to assess heterogeneity, a random-effects model was used to estimate the pooled odds ratio (OR), standardized mean difference (SMD), and mean difference for different outcomes, and a meta-regression method was utilized to investigate the factors affecting heterogeneity between studies. A total of 14 studies were included in the analysis, and the outcomes investigated were: change in gene expression, oxidant parameters, antioxidant parameters, and DNA damage parameters in the umbilical cord blood of the fetus and fetal developmental disorders, cancers, and childhood development disorders. Totally, the events of fetal and childhood abnormalities were more common in parents who have been exposed to EMFs compared to those who have not (SMD and 95% confidence interval [CI], 0.25 [0.15-0.35]; I^2, 91%). Moreover, fetal developmental disorders (OR, 1.34; CI, 1.17-1.52; I^2, 0%); cancer (OR, 1.14; CI, 1.05-1.23; I^2, 60.1%); childhood development disorders (OR, 2.10; CI, 1.00-3.21; I^2, 0%); changes in gene expression (mean difference [MD], 1.02; CI, 0.67-1.37; I^2, 93%); oxidant parameters (MD, 0.94; CI, 0.70-1.18; I^2, 61.3%); and DNA damage parameters (MD, 1.01; CI, 0.17-1.86; I^2, 91.6%) in parents who have been exposed to EMFs were more than those in parents who have not. According to meta-regression, publication year has a significant effect on heterogeneity (coefficient: 0.033; 0.009-0.057). Maternal exposure to electromagnetic fields, especially in the first trimester of pregnancy, due to the high level of stem cells and their high sensitivity to this radiation, the biochemical parameters of the umbilical cord blood examined was shown increased oxidative stress reactions, changes in protein gene expression, DNA damage, and increased embryonic abnormalities. In addition, parental exposure to ionizing and non-

ionizing radiation can lead to the enhancement of different cell-based cancers and developmental disorders such as speech problems in childhood.

Conclusions

Studies are associated with mothers' exposure to EMFs during pregnancy and non-ionizing radiation (RF and ELF-EMFs) with fetal complications such as significant enhancement of oxidant factors, decrease of antioxidant factors, and increase in DNA damage parameters, as well as changes in expression proteins in cord blood genes. On the other hand, close maternal exposure in prenatal and postnatal (residence or occupational exposure) with EMFs of high voltages power lines more than 1 mG or 50 Hz with congenital anomalies (CNS defect, spina bifida) and fetal developmental disorders (such as reduced embryonic bud length) and neurodevelopmental disorders in childhood (e.g., speech problems in children) are associated. Moreover, parents' exposure to ionizing and non-ionizing radiation (X-ray, ELF-EMF, and RF examinations) before and after birth is also associated with enhancement of the risk of cancers (such as rhabdomyosarcoma, ALL, brain tumors, and neuroectoderm) in childhood and adolescence. However, due to the limitations of studies, such as inaccurate measurement of exposure to ELF-EMF (e.g., interviews based on participants' reminders) or inaccurate measure of the actual rate of exposure to EMF or case–control model of most studies, the effects of EMF on fetal and childhood abnormalities should be interpreted with caution. Considering the widespread exposure to non-ionizing radiation, a little enhancement of exposure to EMF could lead to unacceptable health consequences for future generations. Although the number of epidemiological studies examining the undesirable effects of EMF exposure in humans is limited, the findings of this study should prompt further research on this significant environmental danger for pregnant women.

Open access paper: https://www.degruyter.com/document/doi/10.1515/med-2023-0697/html?lang=en

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Systematic Review of Exposure Studies to Radiofrequency Electromagnetic Fields: Spot Measurements and Mixed Methodologies

Ramirez-Vazquez R, Escobar I, Arribas E, Vandenbosch GAE. Systematic Review of Exposure Studies to Radiofrequency Electromagnetic Fields: Spot Measurements and Mixed Methodologies. *Applied Sciences*. 2024; 14(23):11161. https://doi.org/10.3390/app142311161

Abstract

This work presents a review and evaluation of studies measuring exposure to Radiofrequency Electromagnetic Fields (RF-EMF). The review meets the basic quality criteria and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines after the eligibility criteria of the PECO (Population, Exposure, Comparator, and Outcome) methodology and the instrument Critical Appraisal Skills Programme Español (CASPe). A total of 86 papers published between 1 January 1998 and 31 December 2023 are included: 61 studies with spot measurements and 25 studies with mixed methodologies (spot measurements, personal measurements with volunteers or with a trained researcher and prediction models) are highlighted. Forty-three percent of the studies use Spectrum Analyzers in the spot measurements, mainly the Narda SRM–3006, followed by the Narda SRM-3000, highlighting the introduction and use of Sensors for this kind of study. The minimum mean value was measured in Palestine at 0.0600 $\mu W/m^2$, and the maximum mean value was measured in Norway at

200,000 μW/m^2. The RF-EMF exposure levels measured in the different microenvironments are minimal and far from the maximum levels established by the ICNIRP guidelines.

Conclusions

This study reviewed 86 scientific works on personal exposure to RF-EMF that conducted measurements through spot measurements and/or using different methods (mixed method) combining spot measurements, personal measurements with volunteers or with trained researchers, spatiotemporal exposure measurements and in some cases using model predictions.

In addition to the exposure measurement studies, we want to refer to a study recently published by McKenzie [143] in which electromagnetic fields produced by "smart" devices used daily in a modern "smart" home are measured. It is interesting to see the activity of these EMFs in different periods of time while they are used. This study has not been included in this review because although specific measures have been taken, exposure to these fields has not been measured.

As far as we know, today, despite the different methodologies used, the results are comparable with international reference levels and comparable between microenvironments and countries; although it is true that some values are higher than others, they are still lower than these reference levels. The minimum average was measured in Palestine at 0.0600 μW/m2 in 2017, and the maximum average was measured in Norway at 200,000 μW/m2 in 2022, equivalent to 0.200 W/m2, far below the permitted international reference levels. During the development of this work, we have seen that the statistical data confirm that the exposure levels to RF-EMF are much lower than the maximum levels allowed in the ICNIRP guidelines, both for the general public scenario (10 W/m2) and for the occupational scenario (50 W/m2). However, these values can change over time, considering the new 5G technologies introduced everywhere right at this moment, so it is recommended to stay vigilant and continue expanding research in this field.

As previously indicated, with this work, we want to help researchers scrutinize this field with a review that classifies, orders, and synthesizes, thus making a reference for future research and comparisons. We believe that in the future, some research areas may be prioritized in the field of radiofrequency electromagnetic exposure fields: exploring new measurement devices, such as the use of sensors that have already begun to be used to monitor RF-EMF [111], as well as carrying out longitudinal studies to evaluate possible long-term effects.

We want to highlight that in this society in which we currently live, in which we are always immersed in a sea of electromagnetic waves, the importance of clear and effective communication of the possible risks associated with RF-EMF exposure, as well as the need to educate the public on how to minimize exposure in everyday environments.

Open access paper: https://www.mdpi.com/2076-3417/14/23/11161

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Causal associations between mobile phone usage and glaucoma risk: A Mendelian randomization study

Song R, Wang Y, Kong Y, Fan X, Yuan C, Zha X. Causal associations between mobile phone usage and glaucoma risk: A Mendelian randomization study. Medicine (Baltimore). 2024 Nov 29;103(48):e40666. doi: 10.1097/MD.0000000000040666.

Abstract

Previous research has indicated a possible link between mobile phone usage and the incidence of glaucoma. This study employs a 2-sample Mendelian randomization (MR) analysis to examine the causal relationship between mobile phone use and glaucoma risk. We used single nucleotide polymorphisms (SNPs) from publicly accessible genome-wide association study (GWAS) datasets as instrumental variables (IVs). The primary analytical method was the inverse variance weighted (IVW) approach, with MR-Egger and weighted median analyses serving as complementary methods. Sensitivity was evaluated using Cochran's Q test and MR-Egger regression. The results demonstrate a causal effect of mobile phone usage on an increased risk of glaucoma (OR IVW = 1.358, 95% CI: 1.052-1.752, P = .019; OR MR-Egger = 1.882, 95% CI: 0.53-6.682, P = .337; OR Weighted median = 1.387, 95% CI: 1.012-1.900, P = .042; OR MR-PRESSO = 1.358, 95% CI: 1.052-1.752, P = .026). Sensitivity analyses confirmed the robustness and reliability of these findings. The study identifies mobile phone usage as a potentially modifiable risk factor for glaucoma, providing new avenues for exploring the specific mechanisms underlying these ocular disorders.

Open access paper: https://journals.lww.com/md-journal/fulltext/2024/11290/causal_associations_between_mobile_phone_usage_and.12.aspx

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Association between mobile phone use and incidence of dementia: A prospective cohort study using the UK Biobank

Zhao H, Wen Q, Zhuo L, Wang S, Zhan S. Association between mobile phone use and incidence of dementia: A prospective cohort study using the UK Biobank. Gerontology. 2023 Jul 26. doi: 10.1159/000531847.

Abstract

Introduction: The rapid growth in mobile phone use has led to public concern about its potential effects on the risk of dementia. This study aimed to investigate the association between mobile phone use in daily life and the risk of dementia incidence in community-dwelling adults based on the data from the UK Biobank.

Methods: Participants in the UK Biobank aged 60 years or older with no diagnosis of dementia at the time of recruitment were included in this prospective cohort study. A Cox regression model adjusted for sociodemographic characteristics, general health factors, mental health, lifestyle factors, comorbidities, and medication use was used to estimate the hazard ratio (HR) and confidence interval (CI) of the association between mobile phone use and dementia risk.

Results: The final analyses included 213,181 participants. During a median follow-up period of 12.4 years, 6,344 cases of incident dementia occurred. Mobile phone use displayed a modest association with lower risk of dementia incidence, with HRs of 0.85 (95% CI: 0.79-0.91), 0.85 (95% CI: 0.80-0.91),

0.78 (95% C: 0.71-0.86), 0.86 (95% CI: 0.77-0.96), and 0.83 (95% CI: 0.70-0.98) for participants who reported phone call usage of fewer than 5 minutes, 5-29 minutes, 30-59 minutes, 1-3 hours, and more than 3 hours per week, respectively, compared with non-users. In addition, the proportions of the association medicated by family/friend visits and other leisure/social activities were 2.62% (95% CI: -0.64-6.51) and 2.22% (95% CI: 1.12-4.12), respectively.

Conclusions: Daily mobile phone use is significantly associated with a reduced risk of incident dementia in community-dwelling adults in the UK Biobank population. This association seems to be mediated by improved social and mental activities.

https://pubmed.ncbi.nlm.nih.gov/37494916/

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Protective Properties of Botanical Extracts against 5G Radiation-induced Damage to Human Skin, as Demonstrated in Preliminary Data from a Keratinocyte Cell Culture Model

Havas F, Cohen M, Krispin S, Attia-Vigneau J. Protective Properties of Botanical Extracts against 5G Radiation-induced Damage to Human Skin, as Demonstrated in Preliminary Data from a Keratinocyte Cell Culture Model. *Front. Biosci. (Landmark Ed)* 2024, 29(1). doi: 10.31083/j.fbl2901031.

Abstract

Background: Next-generation 5G communication technology involves increasing use of 3–100 GHz wireless bands in population centers. Though still non-ionizing, this implies higher radiation energy vs. existing bands. The range is also shorter, needing more numerous emitters, closer to the user—resulting in higher electromagnetic energy exposure. With no universal consensus regarding exposure risks, there is some concern among the public and the scientific community, following indications that 5G radiation can impact immune function, trigger inflammatory responses, and influence expression of genes affecting protein folding, oxidative stress, tissue/extracellular matrix (ECM) matrix turnover, and more. This work aims at identifying botanical extracts for protection of human skin from these impacts, based on a preliminary cell culture-based model.

Methods: We irradiated human epidermal keratinocytes at 6 GHz, evaluating effects on Interleukin1-α (IL1-α), a key inflammatory cytokine; TIMP metallopeptidase inhibitor 1 (TIMP1), shown to inhibit collagenase; Angiopoietin-like protein 4 (ANGPLT4), which plays a role in wound healing and epidermal differentiation; and S100 calcium-binding protein A9 (S100A9), involved in immune recruitment during injury, by enzyme-linked immunosorbent assay (ELISA) and immunostaining. We next used this model to identify substances able to mitigate the effects of 5G irradiation, through the evaluation of the influence of treatment by one of several botanical extracts on the observed effects of 5G irradiation.

Results: After a remarkably short 1-h exposure, clear effects on keratinocyte function were observed: increased inflammatory cytokine IL1-α; reduced collagenase inhibitor TIMP1; increased wound healing/differentiation facilitator ANGPLT4; and increased SA100A9, involved in immune recruitment during injury. On this basis, we then showed the protective effects of selected botanical extracts, capable of reducing the increase in IL1-α induced by 5G exposure, possibly in part due to anti-inflammatory and antioxidant properties of compounds present in these extracts.

Conclusions: Our results show a clear influence of 5G irradiation on the keratinocytes, possibly indicating injury and damage responses. What's more, we showed how these preliminary data can be used to identify botanical extracts capable of offering some protection against these effects for users of 5G technology, e.g., when employed as active ingredients in protective cosmetic applications.

Open access paper: https://doi.org/10.31083/j.fbl2901031

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Preliminary Study on the Impact of 900MHz Radiation on Human Sperm: An In Vitro Molecular Approach

Keskin I, Karabulut S, Kaplan AA, Alagöz M, Akdeniz M, Tüfekci KK, Davis DL, Kaplan S. Preliminary Study on the Impact of 900MHz Radiation on Human Sperm: An In Vitro Molecular Approach. Reprod Toxicol. 2024 Nov 4:108744. doi: 10.1016/j.reprotox.2024.108744.

Abstract

The use of technologies that produce and emit electromagnetic fields (EMF) is growing exponentially worldwide. The biological effects of EMF-emitting equipment, such as mobile phones and other wireless devices, have been studied in the last decade using in vitro and in vivo methods. Infertility is a growing health problem, and nearly half of cases are because of male-factor. This study investigated the direct in vitro effects of 900 MHz radiation exposure on sperm parameters, genetic status, apoptotic markers, and the PI3K/AKT signaling pathway in healthy normozoospermic men. Semen samples were divided into four groups, two control (30 min and 1 h) and two EMF exposure (30 min and 1 h). Sperm parameters (motility, progressive motility, acrosomal index, morphology), genetic status (DNA fragmentation and chromatin integrity), apoptotic markers (cytokine-c and caspase-3 expression) and the PI3K/AKT signaling pathway (phosphoinoitide 3-kinase-PI3K- and phosphorylated AKT- p-AKT-) were analysed. Sperm motility were significantly reduced in 30 min EMF exposure while a significant increase in the expression of p-AKT were observed in 1 h EMF exposure group. An increased vacuolisation, acrosomal defect, extension of subacrosomal space, uncondensed chromatin structure, apoptotic signs and disrupted axoneme were observed in both EMF groups which were not observed in the control group. Other sperm parameters (morphology and acrosomal index), genetic status, apoptotic markers and the PI3K expression rates had no significant change.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0890623824002119

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Sensory Processing Sensitivity, and Not Gender, Drives Electromagnetic Hypersensitivity and Nature Connection

Watten RG, Volden F, Visnes H. Sensory Processing Sensitivity, and Not Gender, Drives Electromagnetic Hypersensitivity and Nature Connection. Ecopsychology. Nov 28, 2024. https://doi.org/10.1089/eco.2024.0027

Abstract

Electromagnetic hypersensitivity (EHS) is a biomedical condition associated with exposure to man-made radio-frequency electromagnetic fields. Common sources are devices like mobile phones, wireless networks, base stations, computers, TVs, and more. Identifying individuals at risk of developing EHS is important. Those with heightened sensory processing sensitivity (SPS; the ability to perceive, process, and react to environmental stimuli, approximately 25% to 30% of the population) are of special interest. SPS could also be associated with connectedness to nature (CNS) and EHS. In the current gender-matched cross-sectional study (*n* = 450; 225 men and 225 women) we assessed gender differences in environmental sensitivity assessed as SPS, EHS, and CNS. Women had higher general EHS prevalence than men (13.3% vs. 5.3%), higher mean values on perceived sensitivity for 5 out of 9 categories of electromagnetic equipment (computers, electrical appliances, fluorescent lighting, mobile phones, and television) and they had higher scores on the three EHS Scales EHS General, EHS Scale, and EHS Index, in addition to higher SPS and CNS scores. The gender differences vanished when adjusting for SPS in the multivariate analyses of variance (MANOVA) analyses, suggesting that the differences in these scales were associated with SPS. The statistical equation modeling (SEM) results showed a significant positive direct effect of SPS on CNS, and a significant indirect effect mediated by EHS. The present study provides the first empirical evidence that highly sensitive individuals are capable of perceiving electromagnetic radiation. The results indicate that perceived EHS and CNS are driven by SPS and not by gender.

https://www.liebertpub.com/doi/10.1089/eco.2024.0027

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Exploring RF-EMF levels in Swiss microenvironments: An evaluation of environmental and auto-induced downlink and uplink exposure in the era of 5G

Veludo AF, Stroobandt B, Van Bladel H, Sandoval-Diez N, Guxens M, Joseph W, Röösli M. Exploring RF-EMF levels in Swiss microenvironments: An evaluation of environmental and auto-induced downlink and uplink exposure in the era of 5G. Environmental Research, 2024, doi: 10.1016/j.envres.2024.120550.

Highlights

A new protocol was created to measure environmental and auto-induced RF-EMF levels.

Environmental RF-EMF was mainly attributed to downlink frequency bands

Inducing downlink and uplink traffic increased RF-EMF exposure levels notably

Auto-induced downlink exposure was mainly attributed to the 5G band at 3.5 GHz

The main contributor to auto-induced uplink exposure was the band at 2.1 GHz

Abstract

The advancement of cellular networks requires updating measurement protocols to better study radiofrequency electromagnetic field (RF-EMF) exposure emitted from devices and base stations. This paper aims to present a novel activity-based microenvironmental survey protocol to measure environmental, auto-induced downlink (DL), and uplink (UL) RF-EMF exposure in the era of 5G. We present results when applying the protocol in Switzerland. Five study areas with different degrees of urbanization were selected, in which microenvironments were defined to assess RF-EMF exposure in the

population. Three scenarios of data transmission were performed using a user equipment in flight mode (non-user), inducing DL traffic (max DL), or UL traffic (max UL). The exposimeter ExpoM-RF 4, continuously measuring 35 frequency bands ranging from broadcasting to Wi-Fi sources, was carried in a backpack and placed 30cm apart from the user equipment. The highest median RF-EMF levels during the non-user scenario were measured in an urban business area (1.02 mW/m2). Here, DL and broadcasting bands contributed the most to total RF-EMF levels. Compared to the non-user scenario, exposure levels increased substantially during max DL due to the 5G band at 3.5 GHz with 50% of the median levels between 3.20-12.13 mW/m2, mostly in urban areas. Note that the time-division nature of this band prevents distinguishing between exposure contribution from DL beamforming or UL signals emitted at this frequency. The highest levels were measured during max UL, especially in rural microenvironments, with 50% of the median levels between 12.08-37.50 mW/m2. Mobile UL 2.1 GHz band was the primary contributor to exposure during this scenario. The protocol was successfully applied in Switzerland and used in nine additional countries. Inducing DL and UL traffic resulted in a substantial increase in exposure, whereas environmental exposure levels remained similar to previous studies. This data is important for epidemiological research and risk communication/management.

Conclusion

A novel activity-based microenvironmental survey protocol was developed and successfully carried out to disentangle environmental from auto-induced downlink and uplink exposure in the era of 5G. The measurements conducted in Switzerland demonstrate that higher RF-EMF exposure levels were measured when inducing maximum downlink and uplink traffic using a user equipment, with the 5G band at 3.5 GHz and the UL band at 2.1 GHz the main contributors to exposure, respectively. This data is important for epidemiological research, risk communication and risk management, but also for future dosimetry and modelling studies. Future research understanding auto-induced DL and UL exposure from more realistic case scenarios remains necessary for a better characterization of the exposure levels. Future research will consist of the application of the proposed protocol in various countries and the comparison of the exposure values.

Open access paper: https://www.sciencedirect.com/science/article/pii/S001393512402454X

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Electromagnetic intensity investigation of emitted non-ionizing radiation from base transcriptive stations in the urban region of southern Iran

Abbasi F, Badeenezhad A, Abouee E, Shademanpour Z, Janghorban F, Janatshoar H, Naserpour M, Mohammadpour A. Electromagnetic intensity investigation of emitted non-ionizing radiation from base transcriptive stations in the urban region of southern Iran. Int J Environ Health Res. 2024 Dec 2:1-12. doi: 10.1080/09603123.2024.2435484. Epub ahead of print. PMID: 39620927.

Abstract

Their monitoring in urban regions is essential for policymakers and the population. In this study, the electromagnetic intensity (EMI) was measured around 30 stations of base transcriptive stations (BTS) at both distances lower than 20m and higher than 200m using real-time equipment SMP2-dual in summer and winter. Results have shown that EMI in summer (range: 2-6500 mW/m2) was more than in winter (1.5-5000), and the intensity of about 93% of samples exceeded WHO standards. EMI has consistently

decreased with the increasing distance from BTS. There was a negative correlation between the temperature and EMI in summer and humidity and EMI for both distances. The mapping of EMI depicted the highest value of EMI across the central region from south to eastern north at a distance lower than 20 m in winter. The clustering of the EMI in this region was influenced by the geographical location of BTS.

https://pubmed.ncbi.nlm.nih.gov/39620927/

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Effect of microwave radiation on adult neurogenesis and behavior of prenatally exposed rats

Popovičová A, Račeková E, Martončíková M, Fabianová K, Raček A, Žideková M. Effect of microwave radiation on adult neurogenesis and behavior of prenatally exposed rats. IBRO Neuroscience Reports, 17:234-244, 2024. doi: 10.1016/j.ibneur.2024.08.007.

Abstract

Postnatal neurogenesis appears to be highly sensitive to environmental factors, including microwave electromagnetic radiation (MWR). Here, we investigated the impact of MWR during intrauterine development on juvenile and adult neurogenesis in the rostral migratory stream (RMS) and the dentate gyrus of the hippocampus in the rat brain, as well as its effect on animal behavior. Female rats were exposed to MWR at a frequency of 2.45 GHz for 2 hours daily throughout pregnancy. The offspring of irradiated mothers survived to either juvenile age or adulthood. The brains of the rats were subjected to morphological analysis, assessing cell proliferation and death in both neurogenic regions. In the RMS, the differentiation of nitrergic neurons was also investigated. The effect of MWR on behavior was evaluated in rats surviving to adulthood. Prenatal MWR exposure caused significant changes in the number of proliferating and dying cells, depending on the age of the animals and the observed neurogenic region. In addition, MWR attenuated the maturation of nitrergic neurons in the RMS in both juvenile and adult rats. Morphological alterations in neurogenesis were accompanied by changes in animals' behavior. Affected neurogenesis and changes in animal behavior suggest a high sensitivity of the developing brain to MWR.

Open access paper: https://www.sciencedirect.com/science/article/pii/S2667242124000782

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The histological investigation of the effects of electromagnetic radiation on rat ovaries

Kartal B, Alimoğulları E, Akkurt G, Alimogulları M, Çaylı S. The histological investigation of the effects of electromagnetic radiation on rat ovaries. J Mol Histol. 2024 Dec 4;56(1):29. doi: 10.1007/s10735-024-10319-w.

Abstract

People are now exposed to higher levels of electromagnetic radiation (EMR) due to the widespread use of mobile phones in recent years. The possible effects of this exposure on human health are related to EMR. It has been suggested that exposure to EMR has serious effects on reproduction. The study aimed

to investigate the impact of exposure to EMR (4.5 GB; 2600 MHz) emitted by mobile phones on rat ovaries. 18 adult female Wistar albino rats were used in the study, and the animals were divided into three groups (n = 6): control, stand-by, and dialing. For 8 weeks, the experimental groups were subjected to 4.5 GB EMR at 2600 MHz while on standby and making 10-min calls every hour. The rats in the control group received no exposure. Hematoxylin-eosin (H&E) staining of ovarian tissues was performed for histomorphological examinations. Additionally, immunoexpression of autophagy-related protein Beclin-1, apoptosis marker Caspase-3, ovarian reserve marker FSH, and oxidative stress marker iNOS were investigated in the rat ovaries. Microscopic examinations showed follicular degeneration in the ovaries of the rats in the stand-by and dialing groups. The immunoexpression of Beclin-1, Caspase-3, FSH, and iNOS was detected in granulosa cells and the corpus luteum in ovarian tissues obtained from the two EMR-exposed groups. There was a significant increase in the immunoexpression of Beclin-1 and Caspase-3 in the dialing group compared to the other two groups. Additionally, the iNOS and FSH expressions were increased in both EMR exposure groups compared to the control. Our results suggest that EMR exposure harms the ovaries, and autophagy and apoptosis are involved in this process.

https://pubmed.ncbi.nlm.nih.gov/39630206/

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Exposure to a 0.9-GHz electromagnetic field on postnatal days 21-45 may trigger the renin-angiotensin system in male rat: a histological and biochemical study

Keleş Aİ, Kaya H, Keleş G, Erol HS, Mercantepe T, Odaci E. Exposure to a 0.9-GHz electromagnetic field on postnatal days 21-45 may trigger the renin-angiotensin system in male rat: a histological and biochemical study. J Mol Histol. 2024 Dec 4;56(1):22. doi: 10.1007/s10735-024-10317-y.

Abstract

The aim of this study was to examine the relationship between the renin-angiotensin system (RAS) and histological and biochemical changes occurring in the kidney tissue of male rats exposed to a 0.9 GHz electromagnetic field (EMF). Twelve male rats aged 21 days were randomly assigned to control (C-Gr) and EMF (EMF-Gr) groups. No procedure was performed on C-Gr, while the EMF-Gr rats were exposed to a 0.9 GHz EMF on postnatal days 21-45 (one hour a day for 25 days). Tissues were removed at the end of the experiment and evaluated using biochemical, and histopathological methods. Increased kidney tissue volume and weight and total body weight were determined in the group exposed to EMF. Lipid peroxidation, glutathione, catalase, and superoxide dismutase also increased in the kidney tissue of the EMF-Gr rats. Histopathological evaluation revealed cortical/medullary bleeding/obstruction and widespread fibrosis, dilatation, vacuolization, and degeneration in distal and proximal tubules, decreased and atypical parietal cells, and degeneration in epithelial cells. Additionally, dilated and degenerated glomeruli in the Malpighian body, Bowman's membrane degeneration and degeneration in the vascular pole, podocyte, pedicel and mesangial cells were also observed. As a result of exposure to EMF, oxidative stress, tissue volume and weight increased, and histopathological changes caused the formation of a pathway that triggers RAS in kidney tissues. In conclusion, long-term exposure to 0.9 GHz EMF can activate the renin-angiotensin system in the rat kidney, and we think that such activation may be associated with structural, histopathological, and biochemical changes occurring in renal tissue.

https://pubmed.ncbi.nlm.nih.gov/39627484/

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Oxidative Stress and Energy Metabolism in Male Reproductive Damage from Single and Combined High-Power Microwave Exposure at 1.5 and 4.3Ghz

Li Y, Yao B, Men J, Pang Y, Gao J, Bai Y, Wang H, Zhang J, Zhao L, Xu X, Dong J, Li C, Peng R. Oxidative Stress and Energy Metabolism in Male Reproductive Damage from Single and Combined High-Power Microwave Exposure at 1.5 and 4.3Ghz. Reprod Toxicol. 2024 Nov 29:108759. doi: 10.1016/j.reprotox.2024.108759.

Abstract

The effect of multi-frequency electromagnetic environments on male reproduction has attracted the medical community's interest. Studies have investigated the effects and mechanisms of single-frequency microwave exposure on male reproduction, but comparative research on high-power microwave (HPM) composite and single exposure remains scarce. This study aimed to examine the effects and mechanisms of combined 1.5GHz and 4.3GHz microwave exposure on male reproduction. Male Wistar rats were exposed to 1.5GHz (L-band) and 4.3GHz (C-band) electromagnetic radiation for 15minutes. The four groups were: sham, 10mW/cm² L-band, 10mW/cm² C-band, and 5mW/cm² L-band and 5mW/cm² C-band compound. Assessments were made on the pathological structures of testes, sperm viability, serum sex hormones, oxidative stress, and energy metabolism levels after radiation. Exposure to 1.5GHz and 4.3GHz microwaves individually resulted in testicular tissue damage and reduced sperm quality. There was little difference between the damage caused by HPM composite and single exposure. The exposed groups showed histological and ultrastructural changes, with reduced spermatozoa viability, motility parameters, and serum testosterone, luteinizing hormone, follicle-stimulating hormone, and serum inhibin-B on days 1 and 7 after exposure. These tended to recover partially by day 14. Adenosine triphosphate content and lactate dehydrogenase and succinate dehydrogenase activities in the exposed testicular tissue decreased, corresponding to decreased superoxide dismutase activity and increased malondialdehyde content. Both single and combined exposure to L- and C-band HPM affect the male reproductive system. Exposure to single and compound HPM shows no significant difference in risks, with oxidative stress and energy metabolism disturbances playing key roles.

Open access paper:
https://www.sciencedirect.com/science/article/pii/S0890623824002260?via%3Dihub

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Impact of exposure to extremely low-frequency magnetic fields on blood pressure, heart rate variation and disturbance to quality of sleep on industrial workers in Korea

Amila Madhushanka Weerasinghe SDNAM, Liyanage S, Rajitha Kawshalya MAD, Hong SC. Impact of exposure to extremely low-frequency magnetic fields on blood pressure, heart rate variation and disturbance to quality of sleep on industrial workers in Korea. Int J Occup Saf Ergon. 2024 Nov 23:1-8. doi: 10.1080/10803548.2024.2413816.

Abstract

Objectives: This study investigates the potential health risks associated with exposure to extremely low-frequency magnetic fields (ELF-MFs), focusing on the impact on sleep quality. The hypothesis is that

increasing ELF-MF exposure will correlate with elevated blood pressure (BP), altered heart rate (HR) dynamics and poorer sleep quality among occupational workers in Korea.

Methods: The study involved 85 participants. Assessment of ELF-MF exposure was carried out continuously for 24 h in the two groups. Measurements of BP parameters, HR and sleep quality were conducted accordingly.

Results: The study found significant ELF-MF exposure levels in both working and sleeping times for industrial factory workers (0.19 ± 0.38 and 0.17 ± 0.23 μT, $p < 0.05$). Long-term exposure among industrial workers may contribute to a significant difference in systolic blood pressure (SBP) (125.61 ± 9.60 mm Hg, $p < 0.05$). Additionally, a significant difference in deep sleep analysis was observed between the high-exposure and low-exposure groups (67.13 ± 31.15 min, $p < 0.05$).

Conclusion: The hypothesis was confirmed, indicating possible effects of high ELF-MF exposure on SBP and deep sleep. However, further research on long-term exposure and its association with sleep quality disturbances is needed for validation

Open access paper: https://www.tandfonline.com/doi/full/10.1080/10803548.2024.2413816

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Biological issue of electromagnetic fields and waves

Koyama S. Biological issue of electromagnetic fields and waves. Chapter 12 in Shinohara N. Wireless Power Transfer Technologies: Theory and Technologies (2nd edition). Aug 6, 2024.

Abstract

In the past few decades, the use of electromagnetic fields (EMF) has become prevalent throughout the world, and we no longer intend to stop using this technology. The widespread use of electromagnetic sources in daily life has induced an inevitable exposure to EMF. Recently, the rapid introduction of EMF has witnessed an upsurge in the use of EMF for telecommunication. Mobile phone use has become ubiquitous. Wireless communication devices emit nonionizing electromagnetic radiofrequency (RF) fields in the range of 300 MHz to 300 GHz, raising public concern regarding the increasing use of mobile phones and their potential health-related risks. The intermediate frequency (IF) EMF (300 Hz to 10 MHz) is also now widely used for wireless power transmission (WPT) or domestic kitchen appliances such as induction heating (IH) cooking. Unfortunately, although plenty of research has been conducted on RF, little information exists on the potential health effects associated with the exposure to IF magnetic fields. With growing concerns regarding the potential health hazards, it has become necessary to investigate the risks of IF magnetic fields in more detail.

12.5 Conclusions on IF and RF studies

A handful of cellular studies exist on IF exposure. The usage of IF is now spreading all over the world, and more devices are using this frequency. Although the research on IF is urgent, so far it seems that the low-power intensity of IF might not induce any adverse effects on the cellular response. However, no general conclusions can be drawn on this frequency range.

There are still contradictory results about the effects of exposure to RF on the cellular response. However, RF energy does not directly cleave intercellular DNA since most genotoxicity studies have indicated negative results. Some positive data at high SARs seem to relate mainly thermal effect by exposure to RF. Several interesting results of HSP and apoptosis should be validated shortly. Further studies on RF effects using improved biotechnological methods are warranted for precise conclusions.

https://doi.org/10.1049/PBPO256E_ch12

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Fifty-hertz magnetic fields induce DNA damage through activating mPTP associated mitochondrial permeability transition in senescent human fetal lung fibroblasts

Sun C, Wang S, Zhang J, Zhou X, Zhu T, Mao G. Fifty-hertz magnetic fields induce DNA damage through activating mPTP associated mitochondrial permeability transition in senescent human fetal lung fibroblasts. Biophysical Chemistry. Volume 318, 2025, doi: 10.1016/j.bpc.2024.107367.

Abstract

With the rapid development and using of electromagnetic technology, artificial electromagnetic fields (EMFs) have become an emerging environmental factor in our daily life. Extremely-low-frequency (ELF) magnetic fields (MFs), generally generated by power lines and various electric equipment, is one of the most common EMFs in the environment which were concerned for the potential impact on human health. Base on limited evidence, ELF-MFs have been classified as possible carcinogen to human by International Agency for Research on Cancer (IARC), but the mechanisms have not been fully elucidated. Senescent cells are a group of special cells, characterized by cell cycle arrest, senescence-associated secretory phenotype (SASP), accumulation of macromolecular damage, and metabolic disturbance, play important role in fetal development, tissue aging, and even carcinogenesis. Thus, EMFs may promote carcinogenesis by affecting senescent cells, however, there are few studies. In this study, we found that exposure to 50 Hz MFs at 1.0 mT for 24 h could induce significant DNA damage in senescent but not non-senescent human fetal lung fibroblast suggested that senescent cells are more sensitive to 50 Hz MFs on DNA damage, and further results revealed that reactive oxygen species (ROS) generation mediated by mitochondrial permeability transition pore (mPTP) activation play critical role in this process. Our results indicated that cellular senescence can lead to cell sensitivity to the DNA damage effect of 50 Hz MFs, however, whether this play important role in mediating the carcinogenesis of EMFs await further study.

https://www.sciencedirect.com/science/article/pii/S0301462224001960

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Effects of electric fields on the release and content of extracellular vesicles

Wang Y, Worrell GA, Wang HL. Effects of electric fields on the release and content of extracellular vesicles. J Extracell Biol. 2024 Nov 29;3(11):e70018. doi: 10.1002/jex2.70018.

Abstract

Extracellular vesicles (EVs) are small membrane-bound structures that originate from various cell types and carry molecular cargos to influence the behaviour of recipient cells. The use of EVs as biomarkers for diagnosis and as delivery vehicles for treatment in a wide range of human disease is a rapidly growing field in research and clinical practice. We hypothesized that electric fields (EFs) could influence the release and content of EVs. To examine this hypothesis, we developed a specialized bioreactor enabling cells to thrive in a three-dimensional setting, replicating in-vivo conditions amidst programmable EF environments. We established a three-step EV purification protocol to achieve high-density production of EVs. We also performed mass spectrometry-based proteomics analysis on EV-carrying proteins and used high-resolution nanoparticle flowcytometry for single-vesicle analysis. Findings from this report suggest that electrical stimulation, employing physiologically relevant amplitudes typical in therapeutic deep brain stimulation, influences the release of EVs and their cargo content in a frequency-dependent fashion. This conclusion could carry significant implications for both fundamental biological understanding and medical advancements. First, it raises an intriguing question about how the endogenous electrical activity of neuronal and other cellular assemblies influence the production and composition of EVs. Second, it reveals a novel underlying mechanism of how therapeutic electrical stimulations can modulate EVs and treat human brain disorders. Third, it provides a novel approach to utilize electrical stimulation for generating desired EV cargos in a programmable setting.

Open access paper: https://pmc.ncbi.nlm.nih.gov/articles/PMC11605478/

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Extremely low frequency magnetic fields (ELF-MF) in Switzerland: From exposure monitoring to daily exposure scenarios

Loizeau N, Haas D, Zahner M, Stephan C, Schindler J, Gugler M, Fröhlich J, Ziegler T, Röösli M. Extremely low frequency magnetic fields (ELF-MF) in Switzerland: From exposure monitoring to daily exposure scenarios. Environment International. 2024. doi: 10.1016/j.envint.2024.109181.

Abstract

Exposure to extremely low frequency magnetic fields (ELF-MF) is ubiquitous in our daily environment. This study aims to provide a comprehensive overview of the ambient ELF-MF exposure in Switzerland and presents a novel environmental exposure matrix for exposure assessment and risk communication. Magnetic flux density levels (μT) were measured using a portable exposimeter carried in a backpack for the main ELF sources: railway power (16.7 Hz), domestic power (50 Hz), and tram ripple current (300 Hz). We collected ELF-MF levels between 2022 and 2024 in various environments representative of the Swiss population: 300 outdoor areas (e.g. city centres, residential areas), 245 public spaces (e.g. train stations, schools), 348 transport journeys (e.g. train, cars), and in 59 homes (e.g. bedrooms, living rooms). Over all environments, the highest ELF-MF exposure levels were measured in train stations (median: 0.48 μT), trains (median: 0.40 μT), and in living rooms near (<200 m) highest voltage lines of 220 kV and 380 kV (median: 0.37 μT). ELF-MF median levels measured two years apart showed high Pearson correlation coefficients in the same 150 outdoor areas (r = 0.88) and 86 public spaces (r = 0.87), without any significant changes. All measurements are well below the Swiss ambient regulatory limit based on the ICNIRP 1998 guidelines (median: 0.2 %). Finally, we derived an environmental exposure matrix and modelled 27 daily time-weighted average ELF-MF exposure scenarios by combining typical time spent at home, work and transport environments. People who do not live near highest voltage

lines or work in highly exposed environments are typically exposed to less than 0.3 μT on average, while those who do are likely to exceed this level. This novel environmental exposure matrix is a useful tool for public communication and agent-based exposure modelling for future epidemiological research.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024007670

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Biophysical mechanism of animal magnetoreception, orientation and navigation

Panagopoulos DJ, Karabarbounis A, Chrousos GP. Biophysical mechanism of animal magnetoreception, orientation and navigation. Sci Rep. 2024 Dec 3;14(1):30053. doi: 10.1038/s41598-024-77883-9.

Abstract

We describe a biophysical mechanism for animal magnetoreception, orientation and navigation in the geomagnetic field (GMF), based on the ion forced oscillation (IFO) mechanism in animal cell membrane voltage-gated ion channels (VGICs) (IFO-VGIC mechanism). We review previously suggested hypotheses. We describe the structure and function of VGICs and argue that they are the most sensitive electromagnetic sensors in all animals. We consider the magnetic force exerted by the GMF on a mobile ion within a VGIC of an animal with periodic velocity variation. We apply this force in the IFO equation resulting in solution connecting the GMF intensity with the velocity variation rate. We show that animals with periodic velocity variations, receive oscillating forces on their mobile ions within VGICs, which are forced to oscillate exerting forces on the voltage sensors of the channels, similar or greater to the forces from membrane voltage changes that normally induce gating. Thus, the GMF in combination with the varying animal velocity can gate VGICs and alter cell homeostasis in a degree depending, for a given velocity and velocity variation rate, on GMF intensity (unique in each latitude) and the angle between velocity and GMF axis, which determine animal position and orientation.

Open access paper: https://www.nature.com/articles/s41598-024-77883-9

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Relationship between radiofrequency-electromagnetic radiation from cellular phones and brain tumor: meta-analyses using various proxies for RF-EMR exposure-outcome assessment

My Note: The journal *Environmental Health* published a systematic review and meta-analytic study on cell phone use and brain tumor risk by Moon et al. (2024). The study found significantly elevated risks for three types of brain tumors when examining tumors on the side of the head where cell phones were held and for heavy, long-term cell phone use.

Six other systematic reviews and meta-analyses of case-control studies published in peer-reviewed journals since 2016 have also found significant associations between heavy, long-term cellphone use and brain tumor risk (Wang & Guo, 2016; Bortkiewicz et al., 2017; Carlberg & Hardell, 2017; Prasad et al., 2017, Yang et al., 2017; Choi et al., 2020).

These seven peer-reviewed meta-analytic studies contradict the conclusion of the recent WHO systematic review conducted by Karipidis et al. (2024) that there is no evidence cell phone use causes

brain cancer. To learn about serious problems with the WHO systematic reviews on the health effects of radiofrequency radiation see:

Biased WHO-commissioned review claims no cancer link to cellphone use

WHO Radiofrequency EMF Health Risk Assessment Monograph (EHC series)

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Wang & Guo (2016). Meta-analysis of association between mobile phone use and glioma risk. *J Cancer Research Therapy* http://bit.ly/2o1dVcn

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Carlberg & Hardell (2017). 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*. http://bit.ly/2WwBX1K

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Yang et al (2017). Mobile phone use and glioma risk: A systematic review and meta-analysis. *PLOS One*. https://bit.ly/3U0kafd

Choi, Moskowitz, et al (2020). Cellular phone use and risk of tumors: Systematic review and meta-analysis. *Int J Envir Res Public Health*. https://doi.org/10.3390/ijerph17218079.

Karipidis et al. (2020). The effect of exposure to radiofrequency fields on cancer risk in the general and working population: A systematic review of human observational studies - Part I: Most researched outcomes. *Environ Int.* https://doi.org/10.1016/j.envint.2024.108983

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Moon J, Kwon J, Mun Y. Relationship between radiofrequency-electromagnetic radiation from cellular phones and brain tumor: meta-analyses using various proxies for RF-EMR exposure-outcome assessment. *Environ Health* **23**, 82 (2024). https://doi.org/10.1186/s12940-024-01117-8.

Abstract

Introduction

The authors conducted meta-analyses regarding the association between cellular and mobile phone use and brain tumor development by applying various radiofrequency-electromagnetic radiation (RF-EMR) exposure subcategories. With changing patterns of mobile phone use and rapidly developing Wireless Personal Area Network (WPAN) technology (such as Bluetooth), this study will provide insight into the importance of more precise exposure subcategories for RF-EMR.

Methods

The medical librarian searched MEDLINE (PubMed), EMBASE, and the Cochrane Library until 16 December 2020.

Results

In these meta-analyses, 19 case-control studies and five cohort studies were included. Ipsilateral users reported a pooled odds ratio (OR) of 1.40 (95% CI 1.21–1.62) compared to non-regular users. Users with years of use over 10 years reported a pooled OR of 1.27 (95% CI 1.08–1.48). When stratified by each type of brain tumor, only meningioma (OR 1.20 (95% CI 1.04–1.39)), glioma (OR 1.45 (95% CI 1.16–1.82)), and malignant brain tumors (OR 1.93 (95% CI 1.55–2.39)) showed an increased OR with statistical significance for ipsilateral users. For users with years of use over 10 years, only glioma (OR 1.32 (95% CI 1.01–1.71)) showed an increased OR with statistical significance. When 11 studies with an OR with cumulative hours of use over 896 h were synthesized, the pooled OR was 1.59 (95% CI 1.25–2.02). When stratified by each type of brain tumor, glioma, meningioma, and acoustic neuroma reported the pooled OR of 1.66 (95% CI 1.13–2.44), 1.29 (95% CI 1.08–1.54), and 1.84 (95% CI 0.78–4.37), respectively. For each individual study that considered cumulative hours of use, the highest OR for glioma, meningioma, and acoustic neuroma was 2.89 (1.41–5.93) (both side use, > 896 h), 2.57 (1.02–6.44) (both side use, > 896 h), and 3.53 (1.59–7.82) (ipsilateral use, > 1640 h), respectively. For five cohort studies, the pooled risk ratios (RRs) for all CNS tumors, glioma, meningioma, and acoustic neuroma, were statistically equivocal, respectively. However, the point estimates for acoustic neuroma showed a rather increased pooled RR for ever-use (1.26) and over 10 years of use (1.61) compared to never-use, respectively.

Excerpts

“In consideration of these rapidly changing mobile phone technologies, the currently used proxies for RF-EMR exposure assessment are crude and insufficient to clarify the relationship between RF-EMR exposure from cell phones and brain tumor incidence.... The usual exposure measures, such as the years of mobile phone use, the cumulative duration of calls, and the number of calls per week, are rough indicators of mobile phone use.... the authors conducted a series of meta-analyses and subgroup analyses using various exposure measuring categories, from crude to more precise ones. In consideration of crude exposure classifications used in previous meta-analyses, this study will give insight into the importance of more precise exposure subcategories in investigating this topic."

"... the authors analyzed the risk of bias regarding selection and recall bias for the amount of cell phone use and misclassification and recall bias for ipsilateral/contralateral use. A major reason was that typical risk of bias rating tools such as the National Toxicology Program Office of Health Assessment and Translation Risk of Bias rating tool (NTP OHAT RoB rating tool, Supplementary material B) were not appropriate for assessing individual studies regarding this topic." [Note: The WHO systematic reviews relied on this rating tool.]

"With the conversion from 2G cellular phones through 3G and 4G mobile phones to current 5G mobile phones, transmission of large data became possible. With the introduction of 3G technology, all aspects of our society and daily lives have changed drastically. Currently, we are using mobile phones nearly continuously and putting mobile phones near our bodies even when we are not using them. For example, if people use their mobile phone for morning-alarming purposes, they might put their mobile phone near the bed, sometimes even beside their head, all night. These changed patterns of mobile phone use could increase exposure to RF-EMR from cellular and mobile phones. Therefore, precise exposure assessment for RF-EMR from mobile phones would become more complex in future studies."

"The results of cumulative meta-analyses according to precision indicated that the pooled OR was biased downwards with the addition of studies with lower precision. This indicates that the results of studies with a lower precision should be interpreted cautiously."

"Because brain tumors require a latency period to develop [29], an accurate assessment of brain tumor risk associated with RF-EMR exposure requires a long observation span. However, each included study did not consider a sufficient latency period in their study design. This could have led to a possible underestimation of brain tumor risk. Future studies with long observation spans might resolve this problem."

"In this meta-analysis, as the applied exposure subcategories became more concrete, the pooled ORs showed more increased values with statistical significance. Even though the meta-analysis of cohort studies showed statistically equivocal pooled effect estimates, (i) as the number of included studies increases and (ii) as the applied exposure subcategory becomes more concrete, the pooled RRs could show a different aspect in future studies. Furthermore, changing patterns of mobile phone use and increasing use of earphones or headphones with WPAN technology should be sufficiently considered in future studies. Relatively short observation spans for brain tumor incidence and age of starting exposure and brain tumor diagnosis should also be considered in future studies. Previous studies that adjusted for selection and recall bias for the amount of cellphone use and misclassification and recall bias for ipsilateral/contralateral use showed possible underestimations of previous risk estimates. Future studies should try to adjust for these biases in their study design."

Open access paper: https://ehjournal.biomedcentral.com/articles/10.1186/s12940-024-01117-8

Supplementary material: https://static-content.springer.com/esm/art%3A10.1186%2Fs12940-024-01117-8/MediaObjects/12940_2024_1117_MOESM1_ESM.docx

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Electromagnetic fields of cellular communication as risk factors able to produce negative effects on the central nervous system of children and adolescents (review)

Khorseva NI, Grigoriev PE. Electromagnetic fields of cellular communication as risk factors able to produce negative effects on the central nervous system of children and adolescents (review). Part 1. Modeling. Parameters of electroencephalography and sensorimotor reactions. Health Risk Analysis, 2024, no. 2, pp. 162–169. doi: 10.21668/health.risk/2024.2.15.eng.

Abstract

It is quite relevant to investigate possible outcomes of exposure to radio frequency electromagnetic fields (RF EMF) since contemporary children and adolescents have become active users of the most advanced technologies. They are especially susceptible to electromagnetic factors; therefore, it is necessary to have a proper insight into outcomes of such exposures for the body.

The central nervous system (CNS) is one of the main targets under exposure to RF EMF. In most cases, users hold mobile phones close to their heads thereby directly exposing their brains to RF EMF.

As the analysis of literature data has shown, there are few studies in this area; however, proposed options for assessing the impact of RF EMF on children and adolescents are very diverse.

This part of the review focuses on various types of modeling. These are not only phantom, voxel models or the finite difference method but also new approaches such as distribution matrices, Monte Carlo

simulations and an integrated radio frequency model based on the results of magnetic resonance imaging of the brain and other methods.

The review provides the results obtained by investigating encephalography under exposure to RF EMF created by mobile communication devices. They are rather contradictory; however, changes in the bioelectrical activity of the brain are detected in most cases, in particular, a decrease in the alpha rhyme.

Since the characteristics of sensorimotor reactions quite clearly reflect the power relations in the cerebral cortex, we analyzed changes in the parameters of simple auditory-motor and visual-motor reactions in children and adolescents who were mobile communication users. In addition, the review covers the results of changes in working capacity, fatigue, the duration of an individual minute and the reproduction of a given rhythm.

Open access paper: health-risk-analysis-2024-2-15.pdf

Assessing the risk of negative effects produced by electromagnetic fields of cellular communication on the central nervous system of children and adolescents (review). Part 2. Indicators of cognitive processes

Khorseva NI, Grigoriev PE. Assessing the risk of negative effects produced by electromagnetic fields of cellular communication on the central nervous system of children and adolescents (review). Part 2. Indicators of cognitive processes. Health Risk Analysis, 2024, no. 3, pp. 146–154. doi: 10.21668/health.risk/2024.3.15.eng

Abstract

This paper continues the authors' review that dwells on modeling radiofrequency electromagnetic fields (RF EMF) and results obtained by measuring electroencephalography indicators, sensorimotor reactions, fatigue, work capacity, duration of an individual minute and the reproduction of a given rhythm in children and adolescents.

Health risk assessment is always based on data obtained by either laboratory tests or epidemiological studies. This paper analyses publications that describe effects of RF EMF exposure, including Wi-Fi, on cognitive processes in children and adolescents as well as methodical approaches to investigating this exposure. However, there are few such studies; in particular, effects produced by Wi-Fi exposure on cognitive indicators of adolescents aged 14–17 years, were found only in two publications.

Literature analysis has established that research findings do not always give an unambiguous estimation of RF EMF effects. The review covers the reasons for ambiguous interpretation of research results: a variable range of test-systems used for investigating indicators of cognitive processes; simultaneous analysis of single exposures including descriptions of 'effect of improvement' in indicators; changes in cognitive indicators registered for a group of children and adolescents in a wide age range.

Nevertheless, most results give evidence of negative changes in attention and memory of children and adolescents. Given that, longitudinal studies are becoming especially relevant since they estimate changes in various indicators in dynamics, including those induced by changes in mobile phone use. The review highlights the relevance of comprehensive investigations with their focus on health outcomes of RF EMF exposure intrinsic to 5G technologies considering their global implementation.

Open access paper: https://journal.fcrisk.ru/eng/2024/3/15

Russian version: https://journal.fcrisk.ru/sites/journal.fcrisk.ru/files/upload/article/787/health-risk-analysis-2024-3-15.pdf

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Autonomous nervous system responses to environmental-level exposure to 5G's first deployed band (3.5 GHz) in healthy human volunteers

Jamal L, Michelant L, Delanaud S, Hugueville L, Mazet P, Lévêque P, Baz T, Bach V, Selmaoui B. Autonomous nervous system responses to environmental-level exposure to 5G's first deployed band (3.5 GHz) in healthy human volunteers. Exp Physiol. 2024 Oct 15. doi: 10.1113/EP092083.

Abstract

Following the global progressive deployment of 5G networks, considerable attention has focused on assessing their potential impact on human health. This study aims to investigate autonomous nervous system changes by exploring skin temperature and electrodermal activity (EDA) among 44 healthy young individuals of both sexes during and after exposure to 3.5 GHz antenna-emitted signals, with an electrical field intensity ranging from 1 to 2 V/m. The study employed a randomized, cross-over design with triple-blinding, encompassing both 'real' and 'sham' exposure sessions, separated by a maximum interval of 1 week. Each session comprised baseline, exposure and postexposure phases, resulting in the acquisition of seven runs. Each run initiated with a 150 s segment of EDA recordings stimulated by 10 repeated beeps. Subsequently, the collected data underwent continuous decomposition analysis, generating specific indicators assessed alongside standard metrics such as trough-to-peak measurements, global skin conductance and maximum positive peak deflection. Additionally, non-invasive, real-time skin temperature measurements were conducted to evaluate specific anatomical points (hand, head and neck). The study suggests that exposure to 3.5 GHz signals may potentially affect head and neck temperature, indicating a slight increase in this parameter. Furthermore, there was a minimal modulation of certain electrodermal metrics after the exposure, suggesting a potentially faster physiological response to auditory stimulation. However, while the results are significant, they remain within the normal physiological range and could be a consequence of an uncontrolled variable. Given the preliminary nature of this pilot study, further research is needed to confirm the effects of 5G exposure.

Open access paper: https://physoc.onlinelibrary.wiley.com/doi/10.1113/EP092083

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Does radiofrequency radiation impact sleep? A double-blind, randomised, placebo-controlled, crossover pilot study

Bijlsma N, Conduit R, Kennedy G, Cohen M. Does radiofrequency radiation impact sleep? A double-blind, randomised, placebo-controlled, crossover pilot study. Front Public Health. 2024 Oct 29;12:1481537. doi: 10.3389/fpubh.2024.1481537.

Abstract

The most common source of Radiofrequency Electromagnetic Field (RF-EMF) exposures during sleep includes digital devices, yet there are no studies investigating the impact of multi-night exposure to electromagnetic fields emitted from a baby monitor on sleep under real-world conditions in healthy adults. Given the rise in the number of people reporting to be sensitive to man-made electromagnetic fields, the ubiquitous use of Wi-Fi enabled digital devices and the lack of real-world data, we investigated the effect of 2.45 GHz radiofrequency exposure during sleep on subjective sleep quality, and objective sleep measures, heart rate variability and actigraphy in healthy adults. This pilot study was a 4-week randomised, double-blind, crossover trial of 12 healthy adults. After a one-week run-in period, participants were randomised to exposure from either an active or inactive (sham) baby monitor for 7 nights and then crossed over to the alternate intervention after a one-week washout period. Subjective and objective assessments of sleep included the Pittsburgh Insomnia Rating Scale (PIRS-20), electroencephalography (EEG), actigraphy and heart rate variability (HRV) derived from electrocardiogram. Sleep quality was reduced significantly ($p < 0.05$) and clinically meaningful during RF-EMF exposure compared to sham-exposure as indicated by the PIRS-20 scores. Furthermore, at higher frequencies (gamma, beta and theta bands), EEG power density significantly increased during the Non-Rapid Eye Movement sleep ($p < 0.05$). No statistically significant differences in HRV or actigraphy were detected. Our findings suggest that exposure to a 2.45 GHz radiofrequency device (baby monitor) may impact sleep in some people under real-world conditions; however, further large-scale real-world investigations with specified dosimetry are required to confirm these findings.

Open access paper:

https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2024.1481537/full

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A review on the consequences of molecular & genomic alterations following exposure to EMF: Remodeling of neuronal network & cognitive changes

Abtin S, Seyedaghamiri F, Aalidaeijavadi Z, Farrokhi AM, Moshrefi F, Ziveh T, Zibaii MI, Aliakbarian H, Rezaei-Tavirani M, Haghparast A. A review on the consequences of molecular and genomic alterations following exposure to electromagnetic fields: Remodeling of neuronal network and cognitive changes. Brain Research Bulletin, Volume 217, 2024. doi: 10.1016/j.brainresbull.2024.111090.

Abstract

The use of electromagnetic fields (EMFs) is essential in daily life. Since 1970, concerns have grown about potential health hazards from EMF. Exposure to EMF can stimulate nerves and affect the central nervous system, leading to neurological and cognitive changes. However, current research results are often vague and contradictory. These effects include changes in memory and learning through changes in neuronal plasticity in the hippocampus, synapses and hippocampal neuritis, and changes in metabolism and neurotransmitter levels. Prenatal exposure to EMFs has negative effects on memory and learning, as well as changes in hippocampal neuron density and histomorphology of hippocampus. EMF exposure also affects the structure and function of glial cells, affecting gate dynamics, ion conduction, membrane concentration, and protein expression. EMF exposure affects gene expression and may change epigenetic regulation through effects on DNA methylation, histone modification, and microRNA

biogenesis, and potentially leading to biological changes. Therefore, exposure to EMFs possibly leads to changes in cellular and molecular mechanisms in central nervous system and alter cognitive function.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0361923024002247

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Impact of non-ionising radiation of male fertility: a systematic review

Motchidlover L, Sari-Minodier I, Sunyach C, Metzler-Guillemain C, Perrin J. Impact of non-ionising radiation of male fertility: a systematic review. French Journal of Urology. 35(1), 2025, doi: 10.1016/j.fjurol.2024.102800.

Abstract

Exposure to non-ionizing radiation has become inevitable because people cannot escape sources of electromagnetic fields, such as Wi-Fi or cell phones. Among the mechanisms mentioned, the energy emitted by this non-ionizing radiation could cause heating which would have harmful effects on semen quality. The objective of our study was to carry out a systematic review of the literature concerning the impact of exposure to non-ionizing radiation from mobile phones (or other sources) on sperm parameters. We selected 12 studies: the majority of in vivo studies in humans and in vitro studies in animals report a significant impact on sperm count, mobility and vitality. Mobility and vitality seem to be the parameters most regularly impacted by exposure to non-ionizing radiation. Additional studies are necessary to complete this study in order to deepen knowledge with new generations of mobile phones which can raise health concerns.

https://www.sciencedirect.com/science/article/pii/S2950393024002675

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Exposure to Radiofrequency Electromagnetic Fields Enhances Melanin Synthesis by Activating the P53 Signaling Pathway in Mel-Ab Melanocytes

Kim JH, Kang D-J, Seok JY, Kim M-H, Kim D-S, Jeon S-B, Choi H-D, Moon JI, Kim N, Kim HR. Exposure to Radiofrequency Electromagnetic Fields Enhances Melanin Synthesis by Activating the P53 Signaling Pathway in Mel-Ab Melanocytes. *International Journal of Molecular Sciences*. 2024; 25(22):12457. https://doi.org/10.3390/ijms252212457

Abstract

The skin is the largest body organ that can be physiologically affected by exposure to radiofrequency electromagnetic fields (RF-EMFs). We investigated the effect of RF-EMFs on melanogenesis; Mel-Ab melanocytes were exposed to 1760 MHz radiation with a specific absorption rate of 4.0 W/kg for 4 h/day over 4 days. Exposure to the RF-EMF led to skin pigmentation, with a significant increase in melanin production in Mel-Ab melanocytes. The phosphorylation level of cAMP response element binding protein (CREB) and the expression of microphthalmia-associated transcription factor (MITF), which regulate the expression of tyrosinase, were significantly increased in Mel-Ab after RF-EMF

exposure. Interestingly, the expression of tyrosinase was significantly increased, but tyrosinase activity was unchanged in the RF-EMF-exposed Mel-Ab cells. Additionally, the expression of p53 and melanocortin 1 receptor (MC1R), which regulate MITF expression, was significantly increased. These results suggest that the RF-EMF induces melanogenesis by increasing phospho-CREB and MITF activity. Importantly, when Mel-Ab cells were incubated at 38 °C, the melanin production and the levels of tyrosinase significantly decreased, indicating that the increase in melanin synthesis by RF-EMF exposure is not due to a thermal effect. In conclusion, RF-EMF exposure induces melanogenesis in Mel-Ab cells through the increased expression of tyrosinase via the activation of MITF or the phosphorylation of CREB, which are initiated by the activation of p53 and MC1R.

Conclusion: In summary, we have shown that 1760 MHz RF-EMF exposure (SAR of 4.0 W/kg for 4 h/d over 4 d) could induce hyperpigmentation by activating the melanin synthesis pathway in Mel-Ab melanocytes, suggesting that skin pigmentation could be affected by RF-EMF exposure in a way that is distinct from simple thermal effects.

Open access paper: https://www.mdpi.com/1422-0067/25/22/12457

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Genotoxicity of radiofrequency electromagnetic fields on mammalian cells in vitro: A systematic review with narrative synthesis

My note: This is not one the ten systematic reviews commissioned by the WHO. Nonetheless, this review of *in vitro* studies dismisses most evidence of adverse effects from RF-EMF.

"Genotoxicity, a key characteristic of human carcinogens (Smith et al. 2016), is one of the most investigated outcomes in experimental studies on the effects of RF-EMF (SCHEER 2023). However, none of the ten systematic reviews commissioned by the World Health Organization (WHO) in the framework of an updated RF-EMF hazard and risk assessment, deals with this topic (Verbeek et al. 2021)."

Romeo S, Sannino A, Scarfì MR, Lagorio S, Zeni O. Genotoxicity of radiofrequency electromagnetic fields on mammalian cells in vitro: A systematic review with narrative synthesis. Environment International, 2024, doi: 10.1016/j.envint.2024.109104.

Abstract

Background: Over the last decades, great concern has been raised about possible adverse effects to human health due to exposures to radiofrequency electromagnetic fields (RF-EMF, 100 kHz – 300 GHz) emitted by wireless communication technologies. In 2011 the International Agency for Research on Cancer classified RF-EMF as possibly carcinogenic to humans, highlighting that the evidence was weak and far from conclusive. Updated systematic reviews of the scientific literature on this topic are lacking, especially for mechanistic studies.

Objectives: To perform a systematic review of the scientific literature on genotoxic effects induced by RF-EMF in in vitro experimental models. The overall aim is to assess the confidence and level of evidence of the induced effects in mammalian cell cultures.

Methods: Full details regarding the eligibility criteria, information sources, and methods developed to assess risk of bias in the included study, are reported in our published protocol (Romeo et al. 2021). The

databases NCBI PubMed, Web of Science, and EMF-Portal were used as information sources (last searched on 31st December 2022). In developing the systematic review, we followed the guidelines provided by the National Toxicology Program-Office of Health Assessment and Translation (NTP-OHAT), adapted to the evaluation of in vitro studies. A narrative synthesis of the body of evidence was performed by tabulating data classified according to meaningful groups (endpoints) and sub-groups (exposure parameters). This report, abstract included, conforms to the PRISMA 2020 (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines.

Results: Out of 7750 unique records identified, 159 articles were eligible for inclusion. From the extracted data, we identified 1111 experiments (defined as independent specific combinations of diverse biological and electromagnetic parameters). The large majority (80%) of experiments reviewed did not show statistically significant genotoxic effects of RF-EMF exposures, and most "positive" studies were rated as of moderate to low quality, with negative ratings in the key bias domains. A qualitative evidence appraisal was conducted at the endpoint level, and then integrated across endpoints.

Discussion: To the best of our knowledge, this is the first systematic review of the scientific literature on genotoxic effects in mammalian cell cultures in relation to RF-EMF exposure, which confirms and strengthens conclusions from previous syntheses of this specific topic thanks to the use of transparently reported methods, pre-defined inclusion criteria, and formal assessment of susceptibility to bias. Limitations of the evidence included were the frequent reporting of findings in graphical display only, and the large heterogeneity of experimental data, which precluded a meta-analysis.

Conclusions: In the assessment restricted to studies reporting a significant effect of the exposure on the outcome, we reached an overall assessment of "low" confidence in the level of evidence that RF-EMF induce genotoxic effects in mammalian cells However, 80% of experiments reviewed showed no effect of RF exposure on the large majority of endpoints, especially the irreversible ones, independently of the exposure features, level, and duration (moderate evidence of no effect). Therefore, we conclude that the analysis of the papers included in this review, although only qualitative, suggests that RF exposure does not increase the occurrence of genotoxic effects in vitro.

Framework and funding: This systematic review addresses one of the evidence streams considered in a larger systematic review of the scientific literature on the potential carcinogenicity of RF-EMF, performed by scientists from several Italian public research agencies. The project is supported by the Italian Workers' Compensation Authority (INAIL) in the framework of the CRA with the Istituto Superiore di Sanità "BRiC 2018/06 – Scientific evidence on the carcinogenicity of electromagnetic fields".

Excerpt

Conclusions

The main conclusion of our systematic analysis is that the certainty of evidence for genotoxic effects of RF-EMF in mammalian cell cultures is weak. No genotoxic effects of RF exposure were observed in most experiments, especially those concerning irreversible endpoints, independently of the exposure features, level, and duration (moderate evidence of no effect). In the whole, we conclude that the analysis of the papers included in this review, although only qualitative, suggests that RF exposure does not increase the occurrence of genotoxic effects *in vitro*, also considering that the absence of significant

effects prevails among the studies classified in tier-1 and tier-2 categories, whereas for the tier-3 studies the trend is reversed, highlighting how methodological quality affects the studies outcome (Simko et al. 2016).

This systematic review may provide support to panels of experts involved in policy making regarding safety of exposure to RF-EMF.

Furthermore, it is possible to state that, although the number of publications on this topic has considerably increased in recent years, this has not translated into an improvement of the experimental quality. Only a small number of the reviewed studies qualified for inclusion in the tier 1 category, while most of them, including those of moderate quality, still present considerable criticalities in key experimental features (use of sham samples, adequate dosimetry, exposure to a uniformly distributed electromagnetic field, appropriateness of biological methods, presence of positive control and outcome analysis blind to the exposure). It is evident that methodological quality is demanded for future research into this field, which will aim at producing sufficiently similar and unbiased data to be aggregated in meaningful categories.

Open access paper:
https://www.sciencedirect.com/science/article/pii/S0160412024006901?via%3Dihub

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The role of digital device use on the risk of migraine: a univariable and multivariable Mendelian randomization study

He Z, Qiu F, Yang J, Zhao M. The role of digital device use on the risk of migraine: a univariable and multivariable Mendelian randomization study. Front Neurol. 2024 Oct 30;15:1462414. doi: 10.3389/fneur.2024.1462414.

Abstract

Background: The pervasive integration of digital devices into daily life has raised concerns about their potential health impacts. This study aimed to explore the causal relationships between digital device use and the risk of migraine using Mendelian randomization (MR).

Methods: Genetic data on digital device use and migraines were sourced from large-scale genome-wide association studies conducted by the UK Biobank, the FinnGen study, and the International Headache Genetics Consortium. Univariable MR (UVMR), meta-analysis, and multivariable MR (MVMR) approaches were conducted to explore and verify the causal effects of digital device use (including mobile phone use, computer use, playing computer games, and watching television) on migraine risk. Sensitivity analyses were conducted using Cochran's Q, MR-Egger intercept test, MR pleiotropy residual sum and outlier, MR Radial, MR Steiger, and leave-one-out methods.

Results: UVMR analyses revealed that genetically predicted mobile phone use was significantly associated with an increased risk of overall migraine (odds ratio [OR] = 2.39, p = 9.78e-5) and migraine without aura (MO) (OR = 2.25, p = 0.024). Additionally, there were significant positive associations between genetically predicted television watching and the risk of overall migraine (OR = 1.63, p = 2.12e-5) and MO (OR = 2.10, p = 4.98e-5). These results were further supported by the meta-analysis and MVMR analysis. Sensitivity analysis indicated no heterogeneity or pleiotropy.

Conclusion: This comprehensive MR study provides preliminary evidence for the causal impact of mobile phone use and television watching on the risk of migraines. Further studies are needed to explore these associations across different populations.

Open access paper:
https://www.frontiersin.org/journals/neurology/articles/10.3389/fneur.2024.1462414/full

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The Effect of Exposure to Mobile Phones on Electrical Cardiac Measurements: A Multivariate Analysis and a Variable Selection Algorithm to Detect the Relationship With Mean Changes

Alharbi N, Alassiri M. The Effect of Exposure to Mobile Phones on Electrical Cardiac Measurements: A Multivariate Analysis and a Variable Selection Algorithm to Detect the Relationship With Mean Changes. Int J Cell Biol. 2024 Oct 3;2024:7093771. doi: 10.1155/2024/7093771.

Background: The exponential growth in mobile phone usage has raised concerns about electromagnetic field (EMF) exposure and its health risks. Blood pressure and BMI, which impair heart function due to decreased adrenoreceptor responsiveness, parasympathetic tone withdrawal, and increased sympathetic activity, may further exacerbate these risks. However, the effects of radiofrequency electromagnetic (RF-EM) exposure from mobile phones on electrocardiograms (ECGs) and heart rate variability (HRV) in individuals remain unclear.

Purpose: Building upon our previous findings on HRV changes due to mobile phone proximity, this study is aimed at significantly enhancing the analytical approach used to assess the effects of mobile phones on cardiac parameters. This study exploits data from a previous study but with a different purpose. The aim of this study is twofold: (a) to examine whether exposure to mobile phones changes the five variables (P-R, QRS, QT, ST, and HR) in a multivariate manner and (b) to examine whether the blood pressure and/or the body mass index (BMI), which acts as a proxy for obesity, have an effect on the change of these five variables. For both aspects of the study, four cycles are performed.

Method: We conducted multivariate analysis on previously collected electrical cardiac measurement data from 20 healthy male subjects exposed to mobile phone EMF, with the mobile phones placed at four different body locations. The one-sample Hotelling T 2 test on the mean vector of differences was utilised instead of multiple paired t-tests. This multivariate method comprehensively analyzes data features and accounts for variable correlations, unlike multiple univariate analyses. Given our small sample size, we employed the MMPC variable selection algorithm to identify predictor variables significantly related to mean changes.

Results: Significant alterations in ECG intervals and heart rate were noted in the subjects before and after the first EMF exposure cycle, independent of their BMI. Notably, heart rate, P-R, and QRS intervals fell postexposure while QT and ST intervals increased. These changes were influenced by variations in systolic blood pressure, with BMI showing no significant effect.

Conclusion: The observed modifications in cardiac electrical measurements due to mobile phone EMF

exposure are attributed to the effects of EMF itself, with no impact from BMI on the extent of these changes.

https://regulatoryinfo.apple.com/rfexposure/iphone5,1/en

Open access paper: https://onlinelibrary.wiley.com/doi/10.1155/2024/7093771

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Use of Mobile Phones and Radiofrequency-Emitting Devices in the COSMOS-France Cohort

Deltour I, Guida F, Ribet C, Zins M, Goldberg M, Schüz J. Use of Mobile Phones and Radiofrequency-Emitting Devices in the COSMOS-France Cohort. *International Journal of Environmental Research and Public Health*. 2024; 21(11):1514. doi: 10.3390/ijerph21111514.

Abstract

COSMOS-France is the French part of the COSMOS project, an international prospective cohort study that investigates whether the use of mobile phones and other wireless technologies is associated with health effects and symptoms (cancers, cardiovascular diseases, neurologic pathologies, tinnitus, headaches, or sleep and mood disturbances). Here, we provide the first descriptive results of COSMOS-France, a cohort nested in the general population-based cohort of adults named Constances.

Methods: A total of 39,284 Constances volunteers were invited to participate in the COSMOS-France study during the pilot (2017) and main recruitment phase (2019). Participants were asked to complete detailed questionnaires on their mobile phone use, health conditions, and personal characteristics. We examined the association between mobile phone use, including usage for calls and Voice over Internet Protocol (VoIP), cordless phone use, and Wi-Fi usage with age, sex, education, smoking status, body mass index (BMI), and handedness.

Results: The participation rate was 48.4%, resulting in 18,502 questionnaires in the analyzed dataset. Mobile phone use was reported by 96.1% (N = 17,782). Users reported typically calling 5–29 min per week (37.1%, N = 6600), making one to four calls per day (52.9%, N = 9408), using one phone (83.9%, N = 14,921) and not sharing it (80.4% N = 14,295), mostly using the phone on the side of the head of their dominant hand (59.1%, N = 10,300), not using loudspeakers or hands-free kits, and not using VoIP (84.9% N = 15,088). Individuals' age and sex modified this picture, sometimes markedly. Education and smoking status were associated with ever use and call duration, but neither BMI nor handedness was. Cordless phone use was reported by 66.0% of the population, and Wi-Fi use was reported by 88.4%.

Conclusion: In this cross-sectional presentation of contemporary mobile phone usage in France, age and sex were important determinants of use patterns.

Open access paper: https://www.mdpi.com/1660-4601/21/11/1514

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Effects of 1800 MHz and 2100 MHz mobile phone radiation on the blood-brain barrier of New Zealand rabbits

Kizilçay AO, Tütüncü B, Koçarslan M, Gözel MA. Effects of 1800 MHz and 2100 MHz mobile phone radiation on the blood-brain barrier of New Zealand rabbits. Med Biol Eng Comput. 2024 Nov 16. doi: 10.1007/s11517-024-03238-1.

Abstract

In this study, the impact of mobile phone radiation on blood-brain barrier (BBB) permeability was investigated. A total of 21 New Zealand rabbits were used for the experiments, divided into three groups, each consisting of 7 rabbits. One group served as the control, while the other two were exposed to electromagnetic radiation at frequencies of 1800 MHz with a distance of 14.5 cm and 2100 MHz with a distance of 17 cm, maintaining a constant power intensity of 15 dBm, for a duration equivalent to the current average daily conversation time of 38 min. The exposure was conducted under non-thermal conditions, with RF radiation levels approximately ten times lower than normal values. Evans blue (EB) dye was used as a marker to assess BBB permeability. EB binds to plasma proteins, and its presence in brain tissue indicates a disruption in BBB integrity, allowing for a quantitative evaluation of radiation-induced permeability changes. Left and right brain tissue samples were analyzed using trichloroacetic acid (TCA) and phosphate-buffered solution (PBS) solutions to measure EB amounts at 620 nm via spectrophotometry. After the experiments, BBB tissue samples were collected from the right and left brains of all rabbits in the three groups and subjected to a series of medical procedures. Samples from Group 1 were compared with those from Group 2 and Group 3 using statistical methods to determine if there were any significant differences. As a result, it was found that there was no statistically significant difference in the BBB of rabbits exposed to 1800 MHz radiation, whereas there was a statistically significant difference at a 95% confidence level in the BBB of rabbits exposed to 2100 MHz radiation. A decrease in EB values was observed upon the arithmetic examination of the BBB.

https://pubmed.ncbi.nlm.nih.gov/39548043/

Excerpts

When compromised, the BBB is linked to neurological disorders such as Alzheimer's disease, stroke, and multiple sclerosis, leading researchers to develop models for in vitro studies of its mechanisms [9, 10]. However, BBB permeability can be influenced by various factors, including pathological conditions, multiple sclerosis, stroke, and diabetes, as well as exposure to ionizing and non-ionizing radiation [11]. For instance, radiofrequency (RF) radiation has been shown to increase BBB permeability, allowing normally excluded substances to penetrate the brain, potentially impacting neurological health [5]. Furthermore, ultra-wideband electromagnetic pulses have demonstrated the ability to disrupt BBB integrity in animal models [8]....

The two primary frequencies utilized in contemporary mobile telecommunications, 1800 MHz and 2100 MHz, have garnered substantial attention due to their widespread application in cellular networks worldwide [13, 14]. For example, in ref. [15], it has been demonstrated that radiation from mobile phones at 900, 1800, and 2100 MHz frequencies can increase oxidative damage in the frontal lobes of rat brain tissues, an increase in lipid peroxidation, and oxidative DNA damage. Additionally, exposure to 2100 MHz radiofrequency radiation has been shown to induce single-strand breaks in DNA. In ref. [16], it was observed and presented that exposure to 900–1800 MHz radiation caused oxidative stress in the tissues of pregnant mothers and their offspring. In ref. [17], it has been observed that radiofrequency

radiation at 2100 MHz can damage the nasal septal mucosa and disrupt mucociliary clearance in rats. While numerous studies have explored the biological effects of radiofrequency radiation, the specific impact of these frequencies on BBB permeability remains an area of ongoing investigation [18,19,20]....

Our research was conducted with three distinct groups, each consisting of seven female rabbits with an average weight ranging from 2 to 5 kg. These groups were categorized as follows: with “N” signifying the number of subjects in each group: Group I, control female group (N = 7); Group II, 1800 MHz GSM group (N = 7); and Group III, 2100 MHz GSM group (N = 7)....

The exposure duration of rabbits to RF radiation was determined to be 38 min, taking into account the current average daily talk time of 19 min for mobile phone users [29]....

It is evident that various studies have investigated the impact of electromagnetic radiation at different frequencies on brain tissue. The analysis of these studies indicates that while lower frequencies may affect brain structure over a longer time frame, higher frequencies like 2.1 GHz have more immediate, statistically significant impacts, suchas compromising BBB integrity. This comparison underscores the importance of further investigating the threshold effects of different frequencies, especially those commonly used in mobile telecommunications.

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Effects of 4G Long-Term Evolution Electromagnetic Fields on Thyroid Hormone Dysfunction and Behavioral Changes in Adolescent Male Mice

Kim HY, Son Y, Jeong YJ, Lee SH, Kim N, Ahn YH, Jeon SB, Choi HD, Lee HJ. Effects of 4G Long-Term Evolution Electromagnetic Fields on Thyroid Hormone Dysfunction and Behavioral Changes in Adolescent Male Mice. Int J Mol Sci. 2024 Oct 10;25(20):10875. doi: 10.3390/ijms252010875.

Abstract

Radiofrequency electromagnetic fields (RF-EMFs) can penetrate tissues and potentially influence endocrine and brain development. Despite increased mobile phone use among children and adolescents, the long-term effects of RF-EMF exposure on brain and endocrine development remain unclear. This study investigated the effects of long-term evolution band (LTE) EMF exposure on thyroid hormone levels, crucial for metabolism, growth, and development. Four-week-old male mice (C57BL/6) were exposed to LTE EMF (whole-body average specific absorption rate [SAR] 4 W/kg) or a positive control (lead; Pb, 300 ppm in drinking water) for 4 weeks. Subsequently, the mice underwent behavioral tests including open field, marble burying, and nest building. Blood pituitary and thyroid hormone levels, and thyroid hormone-regulating genes within the hypothalamus-pituitary-thyroid (HPT) axis were analyzed. LTE exposure increased T3 levels, while Pb exposure elevated T3 and T4 and decreased ACTH levels. The LTE EMF group showed no gene expression alterations in the thyroid and pituitary glands, but hypothalamic *Dio2* and *Dio3* expressions were significantly reduced compared to that in the sham-exposed group. Pb exposure altered the hypothalamic mRNA levels of *Oatp1c1* and *Trh*, pituitary mRNA of *Trhr*, and *Tpo* and *Tg* expression in the thyroid. In conclusion, LTE EMF exposure altered hypothalamic *Dio2* and *Dio3* expression, potentially impacting the HPT axis function. Further research is needed to explore RF-EMF's impacts on the endocrine system.

Open access paper: https://www.mdpi.com/1422-0067/25/20/10875

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Characterising core body temperature response of free-moving C57BL/6 mice to 1.95 GHz whole-body radiofrequency-electromagnetic fields

Sylvester E, Deng C, McIntosh R, Iskra S, Frankland J, McKenzie R, Croft RJ. Characterising core body temperature response of free-moving C57BL/6 mice to 1.95 GHz whole-body radiofrequency-electromagnetic fields. Bioelectromagnetics. 2024 Oct 14. doi: 10.1002/bem.22527.

Highlights

- Exposure of 1.95 GHz electromagnetic fields at 5 W/kg whole-body average specific absorption rate increases core body temperature by 0.4°C.
- The increased thermal energy at 3.75 W/kg is effectively managed by thermoregulation (max increase = 0.24°C).
- An extended habituation period prior to RF-EMF exposure is necessary to account for the large effect of handling on mice core body temperature.

Abstract

The present study investigated the core body temperature (CBT) response of free-moving adult male and female C57BL/6 mice, during and following a 2-h exposure to 1.95 GHz RF-EMF within custom-built reverberation chambers, using temperature capsules implanted within the intraperitoneal cavity and data continuously logged and transmitted via radiotelemetry postexposure. Comparing RF-EMF exposures (WBA-SAR of 1.25, 2.5, 3.75, and 5 W/kg) to the sham-exposed condition, we identified a peak in CBT within the first 16 min of RF-EMF exposure (+0.15, +0.31, +0.24, +0.37°C at 1.25, 2.5, 3.75, and 5 W/kg respectively; statistically significant at WBA-SAR ≥ 2.5 W/kg only), which largely dissipated for the remainder of the exposure period. Immediately before the end of exposure, only the CBT of the 5 W/kg condition was statistically differentiable from sham. Based on our findings, it is apparent that mice are able to effectively compensate for the increased thermal load at RF-EMF strengths up to 5 W/kg. In addition, the elevated CBT at the end of the exposure period in the 5 W/kg condition was statistically significantly reduced compared to the sham condition immediately after RF-EMF exposure ceased. This would indicate that measures of CBT following the end of an RF-EMF exposure period may not reflect the actual change in the CBT of mice caused by RF-EMF exposure in mice.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/bem.22527

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Effects of radiofrequency electromagnetic radiation emitted by mobile phones on rat parotid gland histology - an experimental study

Matei LI, Neag MA, Mocan LP, Sufleţel RT, Cuţaş A, Onofrei MM, Gherman LM, Armencea G, Mihu C, Ilea A, Mihu CM, Bordea IR, Inchingolo F, Dipalma G, Melincovici CS. The effects of radiofrequency electromagnetic radiation emitted by mobile phones on rat parotid gland histology - an experimental study. Eur Rev Med Pharmacol Sci. 2024 Oct;28(20):4405-4419. doi: 10.26355/eurrev_202410_36864.

Abstract

Objective: The advancement of telecommunication technology and devices promptly transformed mobile phones into indispensable objects in our day-to-day lives, but their biological effects remain unclear. Therefore, this study aimed to investigate the potential histopathological changes induced by mobile phone radiation in the parotid gland and the nearby tissues.

Materials and methods: Thirty female Rattus Norvegicus rats were divided into three groups: group 1 (exposed for 30 days), group 2 (exposed for 60 days), and control group (non-exposed). Each subject was exposed to mobile phone radiation in the form of a phone call for two hours every day for their subsequent exposure time. The exposure was always directed towards the same side of the face throughout the whole exposure period. At the end of the exposure period, a comprehensive examination was conducted, including inspection of the orofacial structures, tissue sections of the parotid glands, overlying skin, oral mucosa, and cervical lymph nodes, as well as obtaining smears from the oral cavity. To highlight the presence of micronuclei within the exfoliated squamous cells of the oral epithelium, Feulgen stain was performed.

Results: The results showed a significant activation of the fibroblasts in the parotid gland septa, in both exposed experimental groups, compared to the control group. We also detected significant cervical lymph node reactive changes, hyperkeratosis of the oral epithelium, and activated fibroblasts in the dermis and oral mucosa lamina propria in both experimental groups. Dermal fibrosis and lamina propria fibrosis were significantly increased in the second experimental group, compared to the control group. Moreover, vascular congestion in the parotid gland, dermal, and lamina propria fibrosis were significantly increased in the second study group compared to the first one.

Conclusions: These findings suggest that exposure to mobile phone radiation may lead to pathological changes in the parotid gland and nearby tissues of experimental rats.

Open access paper: https://www.europeanreview.org/article/36864

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Frequency-Dependent Antioxidant Responses in HT-1080 Human Fibrosarcoma Cells Exposed to Weak Radio Frequency Fields

Gurhan H, Barnes F. Frequency-Dependent Antioxidant Responses in HT-1080 Human Fibrosarcoma Cells Exposed to Weak Radio Frequency Fields. *Antioxidants*. 2024; 13(10):1237. doi: 10.3390/antiox13101237.

Abstract

This study explores the complex relationship between radio frequency (RF) exposure and cancer cells, focusing on the HT-1080 human fibrosarcoma cell line. We investigated the modulation of reactive oxygen species (ROS) and key antioxidant enzymes, including superoxide dismutase (SOD), peroxidase, and glutathione (GSH), as well as mitochondrial superoxide levels and cell viability. Exposure to RF fields in the 2–5 MHz range at very weak intensities (20 nT) over 4 days resulted in distinct, frequency-specific

cellular effects. Significant increases in SOD and GSH levels were observed at 4 and 4.5 MHz, accompanied by reduced mitochondrial superoxide levels and enhanced cell viability, suggesting improved mitochondrial function. In contrast, lower frequencies like 2.5 MHz induced oxidative stress, evidenced by GSH depletion and increased mitochondrial superoxide levels. The findings demonstrate that cancer cells exhibit frequency-specific sensitivity to RF fields even at intensities significantly below current safety standards, highlighting the need to reassess exposure limits. Additionally, our analysis of the radical pair mechanism (RPM) offers deeper insight into RF-induced cellular responses. The modulation of ROS and antioxidant enzyme activities is significant for cancer treatment and has broader implications for age-related diseases, where oxidative stress is a central factor in cellular degeneration. The findings propose that RF fields may serve as a therapeutic tool to selectively modulate oxidative stress and mitochondrial function in cancer cells, with antioxidants playing a key role in mitigating potential adverse effects.

Open access paper: https://www.mdpi.com/2076-3921/13/10/1237

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The influence of eyelashes on electric field distribution and absorbed power density in the cornea under millimeter-wave exposure

Foroughimehr N, Vilagosh Z, Yavari A, Wood A. The influence of eyelashes on electric field distribution and absorbed power density in the cornea under millimeter-wave exposure. Bioelectromagnetics. 2024 Oct 14. doi: 10.1002/bem.22526.

Abstract

As millimeter wave (MMW) technology, particularly in fifth-generation (5G) devices, gains prominence, there is a crucial need for comprehensive electromagnetic (EM) models of ocular tissues to understand and characterize EM exposure conditions accurately. This study employs numerical modeling to investigate the interaction between MMW and the cornea, aiming to characterize EM field distributions and absorption within an anatomically accurate eye model while considering the influence of eyelashes. Using the finite-difference time-domain (FDTD) method, we conduct simulations of EM radiation interactions from 20.0 to 100.0 GHz with a human eye model. Moreover, we analyze the temperature distribution increase within the eye model using a thermal sensor in XFdtd, employing a scheme based on the finite difference (FD) method. Our findings reveal a nonuniform distribution of the EM field, particularly intensified in corneal regions adjacent to eyelashes and eyelids. Despite similar EM field patterns, the presence or absence of eyelashes has minimal impact on temperature differences. However, the study highlights increased radiation absorption by the eyelid's epidermis at 100.0 GHz, reducing the rise in the cornea's temperature.

https://pubmed.ncbi.nlm.nih.gov/39402869/

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Exploring the potential link between prostate cancer and magnetic fields

Dart DA, Koushyar S, Uysal-Onganer P. Exploring the potential link between prostate cancer and magnetic fields. Medical Hypotheses. Volume 189, 2024. doi: 10.1016/j.mehy.2024.111384.

Abstract

Prostate cancer is the most common solid cancer in men worldwide. Various lifestyle factors have been established as contributors to cancer risk, and prostate cancer is no exception. Elements such as advanced age, diet, obesity, smoking, alcohol consumption, circadian rhythm disruptions, Afro-Caribbean ethnicity, and sexual activity have all been linked to an increased risk of prostate cancer. Notably, famous male guitarists from bands spanning the last few decades are now entering the age demographic most closely associated with prostate cancer. It is not surprising that they may fall into the 'at-risk' category. Media speculation has hinted at a potentially higher incidence of prostate cancer among guitarists compared to their bandmates, although no tangible correlation has been established. This speculation piqued our curiosity and prompted an exploration into potential reasons why musicians, particularly guitarists, might be at an elevated risk of developing prostate cancer. We hypothesise the electromagnetic fields generated by the electric guitar may in part explain the possible increase in prostate cancer risk among electric guitarists. This study delves into these intriguing possibilities, shedding light on an area of research that remains speculative but warrants further investigation.

Highlights

Prostate cancer is the most common solid cancer in men globally.
Age, diet, ethnicity, sexual activity and circadian rhythm disruptions, are identified as contributors to prostate cancer risk.
Magnetic fields (MF) and electromagnetic fields (EMF) may amplify prostate cancer risks.
Magnetic fields may potentially affect the behaviour of quantum systems within biological molecules.

https://www.sciencedirect.com/science/article/pii/S0306987724001270

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Electromagnetic Field Exposure in the Public Space of the Slovakian City

Trnka M, Gálik P, Kráľová E, Važan R. Electromagnetic Field Exposure in the Public Space of the Slovakian City. Scientific Letters of the University of Zilina 2023, 25(1):G1-G6. doi: 10.26552/com.C.2023.014

The main objective of our research was to map the exposure to electromagnetic smog in the frequented space of shopping centres in the city of Bratislava and to compare our results to the actual hygienic limits. The measurements of the low- and high-frequency electromagnetic fields were performed at different places in shopping centres. Our results did not exceed the Slovak current limits in any of the measurements. However, almost all of them markedly exceed new permitted limits according to EUROPAEM. Based on our results, stricter limits in many European countries and increasing evidence on possible harmfulness of long-term exposures to artificial electromagnetic fields, preventive carefulness can be recommended - to support the research in this field, to prepare professional public education and possibly to prepare the stricter Slovak exposure limits.

Open access paper: https://komunikacie.uniza.sk/pdfs/csl/2023/01/08.pdf

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Development of electromagnetic pollution maps utilizing Gaussian process spatial models

Kiouvrekis Y, Zikas S, Katis I, Tsilikas I, Filippopoulos I. Development of electromagnetic pollution maps utilizing Gaussian process spatial models. Sci Total Environ. 2024 Oct 21;955:176907. doi: 10.1016/j.scitotenv.2024.176907.

Abstract

The rapid proliferation of wireless technologies in everyday environments demands the quick and precise estimation of electromagnetic field distribution. This distribution is commonly depicted through the electric field strength across various geographical areas. The objective of this research is to determine the most effective geospatial model for generating a national-level electric field strength map within the 30 MHz-6 GHz frequency range. To achieve this, we employed five different methodologies for constructing the electric field strength map. Four of these methodologies are based on Gaussian process regression, while the fifth utilizes the classical weighted-average method of the nearest neighbor. Our study focused on a country with a total area of 9251 km^2, using a dataset comprising 3621 measurements. The findings reveal that Gaussian process spatial models, also known as Kriging models, generally outperform other methods when applied to spatial data. However, it was observed that, after excluding some outlier data points, the performance of the classical nearest neighbor models becomes comparable to that of the Gaussian process models. This indicates the potential for both approaches to be effective, depending on the data quality and the presence of outliers.

Excerpts

For the Total (Fig. 4 and Table 2), the mean stands at 4.78 V/m, with a maximum value of 37.99 V/m, a minimum of 0.28 V/m, and a median of 3.42 V/m....

The present research constitutes the first step of many that can be implemented in the future regarding the construction of systems for mapping EMR exposure. Initially, future research should be conducted in cities, exploring characteristics related to urban infrastructure, such as building materials, density, and height. This novel approach regards not only improving the model's performance but also developing models that consider these characteristics between measurement points to better capture the spatial distribution of EMR within urban and semi-urban areas. Additionally, it would be interesting to incorporate temporal patterns to account for the various varieties of EMR over time, considering factors such as daily, seasonal, and yearly variations. In a subsequent stage, the inclusion of data from environmental sources, such as weather conditions, levels of atmospheric pollution, and population density, could be beneficial to enhance the predictive capability of the models. Furthermore, research into improving the interpretability of the models should be conducted to provide meaningful insights into the factors influencing EMR levels in different environments (urban, semi-urban, and rural). All of the above should be combined with conducting validation studies in collaboration with stakeholders for the effectiveness of the developed models in real-world scenarios.

https://pubmed.ncbi.nlm.nih.gov/39442732/

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An Analysis of Radio Frequency Radiation Emitted by Smartphones

Manoharan S, Mahalakshmi B, Ananthi K, Sindhu MP. An Analysis of Radio Frequency Radiation Emitted by Smartphones. 2024 8th International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC), Kirtipur, Nepal, 2024, pp. 301-307, doi: 10.1109/I-SMAC61858.2024.10714888.

Abstract

The introduction of smartphones has transformed how we interact, access information, and entertains ourselves. Nevertheless, as the usage of smartphones continues to rise, there has been greater concern over the possible health implications of Radio Frequency radiation released by these devices. RF radiation, also known as radiofrequency radiation, is a kind of electromagnetic radiation utilized for wireless communication in devices like smartphones. This study seeks to offer a thorough analysis of RF radiation and its emissions from smartphones, as well as the potential health implications associated with their use and strategies to minimize exposure. This research study also explores the importance of Specific Absorption Rate (SAR) testing in the context of 5G technologies, including testing methodologies, regulatory frameworks, and the implications of 5G frequency bands on SAR measurements.

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=10714888&isnumber=10714582

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The 5G-FR1 Signals: Beams of the Phased Antennas Array and Time-Recurrence of Emissions with Consequences on Human Exposure

Deaconescu DB, Miclaus S. The 5G-FR1 Signals: Beams of the Phased Antennas Array and Time-Recurrence of Emissions with Consequences on Human Exposure. *Electronics*. 2023; 12(2):297. doi: 10.3390/electronics12020297.

Abstract

The fifth generation (5G) of mobile communication technology poses lots of questions while introducing significant improvements compared with previous generations. The most sensitive question is related to the safety of human exposure. The aim of present work was to analyze, with a few chosen examples, two of the most significant features of 5G emissions: the extreme spatial variability of the exposure and the nonlinear dynamics characteristics of the temporal variability of the exposure. Two models of patch antenna arrays operating at 3.7 GHz with varying beam forming and beam steering capabilities were considered for an analysis of the specific absorption rate of electromagnetic energy deposition in tissues of a head model. This allowed clear emphasis on the influence of the antenna geometry and feeding peculiarities on the spatial variability of exposure. The second approach implemented the original idea of following the nonlinear recurrence behavior of exposure in time, and underlined the time variability characteristics of emissions with a real-life mobile phone running different 5G applications. Time series of the emitted electric-field strengths were recorded by means a real-time spectrum analyzer and two

near-field probes differently positioned in the beam. The presence of laminar emissions, chaotic emissions, determinism and recurrence in the exposures prove the potential for recurrence quantification in predicting time variability features of 5G exposure. Overall, the impact of 5G signals on living bodies, with the highest possible man-made spatial and temporal variability, may have very unpredictable bio-medical consequences.

Open access paper: https://www.mdpi.com/2079-9292/12/2/297

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Preliminary Study on the Impact of 900MHz Radiation on Human Sperm: An In Vitro Molecular Approach

Keskin I, Karabulut S, Kaplan AA, Alagöz M, Akdeniz M, Tüfekci KK, Davis DL, Kaplan S. Preliminary Study on the Impact of 900MHz Radiation on Human Sperm: An In Vitro Molecular Approach. Reprod Toxicol. 2024 Nov 4:108744. doi: 10.1016/j.reprotox.2024.108744.

Abstract

The use of technologies that produce and emit electromagnetic fields (EMF) is growing exponentially worldwide. The biological effects of EMF-emitting equipment, such as mobile phones and other wireless devices, have been studied in the last decade using in vitro and in vivo methods. Infertility is a growing health problem, and nearly half of cases are because of male-factor. This study investigated the direct in vitro effects of 900MHz radiation exposure on sperm parameters, genetic status, apoptotic markers, and the PI3K/AKT signaling pathway in healthy normozoospermic men. Semen samples were divided into four groups, two control (30min and 1h) and two EMF exposure (30min and 1h). Sperm parameters (motility, progressive motility, acrosomal index, morphology), genetic status (DNA fragmentation and chromatin integrity), apoptotic markers (cytokine-c and caspase-3 expression) and the PI3K/AKT signaling pathway (phosphoinoitide 3-kinase-PI3K- and phosphorylated AKT- p-AKT-) were analysed. Sperm motility were significantly reduced in 30min EMF exposure while a significant increase in the expression of p-AKT were observed in 1h EMF exposure group. An increased vacuolisation, acrosomal defect, extension of subacrosomal space, uncondensed chromatin structure, apoptotic signs and disrupted axoneme were observed in both EMF groups which were not observed in the control group. Other sperm parameters (morphology and acrosomal index), genetic status, apoptotic markers and the PI3K expression rates had no significant change.

https://pubmed.ncbi.nlm.nih.gov/39505052/

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Quantitative Assessment of Thermal Effects on the Auricle Region Caused by Mobile Phones Operating in Different Modes

Rok T, Kacprzyk A, Rokita E, Kantor D, and Taton G. Quantitative Assessment of Thermal Effects on the Auricle Region Caused by Mobile Phones Operating in Different Modes. *AIMS Biophys* 11, no. 4 (2024): 427–44. https://doi.org/10.3934/biophy.2024023.

Abstract

To analyze thermal effects caused by mobile phones on the human auricle region, we performed an experiment with controlled exposure to mobile phones operating in different modes for a group of 40 men. Temperature changes were measured with the use of infrared thermography. Thermograms were taken before and after a standardized 15-minute phone call when the mobile phone was placed lightly against the skin surface in the auricle region. The measurements were performed in three modes: OFF, ON, and FLIGHT. Statistically significant differences ($p = 0.03$) were observed between the experimental temperature increase of the auricle region in OFF mode (average temperature rise = 1.1 °C ± 0.2 °C) and in ON mode (average temperature rise = 1.9 °C ± 0.3 °C), while between FLIGHT (average temperature rise = 1.4 °C ± 0.2 °C) and ON modes, no statistical differences were observed ($p = 0.20$). Based on thermographic measurements and the model of heat transfer between the ear and the phone, it was shown that the human ear is the largest heat source in the system and that the increase in skin temperature is mainly caused by the handheld mobile phone restricting heat dissipation from the skin surface.

Excerpt for the assessment of near-field exposure, Received Signal Strength Indicator (RSSI) and Specific Absorption Rate (SAR) were used. During exposure sessions RSSI values were continuously measured and retrospectively controlled. All the participants received exposure at an arbitrary mean value of RSSI between −90 and −80 dBm. The SAR quantifies the absorption of RF-EMF in tissues, and for the human body, it depends on the dielectric properties of tissues due to the complexity of the human head anatomy its estimation is a subject of great challenge [21],[22] and for the phone used (Huawei P20 Lite), it was reported as 0.75 W/kg in the manual.

For the far-field exposure a personal exposure meter (ExpoM-RF, Zurich, Switzerland) performing a spectral analysis of RF-EMF within 16 different frequency bands from 87.5 MHz up to 5.875 GHz was used. Based on electric field strength, the power density was calculated as 45 µW. The uplink and downlink radiation remained on a comparable level throughout a simulated phone call.

In OFF mode, the smartphone was switched off, while in FLIGHT mode, there was no connection with the GSM network, so music was constantly playing. In ON mode, the mobile phone was fully connected to the GSM network and the smartphone was operating at a frequency of 1800 MHz.

Open access paper: http://www.aimspress.com/article/doi/10.3934/biophy.2024023

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Rat brain and testicular tissue effects of radiofrequency radiation exposure: Histopathological, DNA damage of brain and qRT-PCR analysis

Yavas MC, Kilitci A, Çelik E, Yegin K, Sirav B, Varol S. Rat brain and testicular tissue effects of radiofrequency radiation exposure: Histopathological, DNA damage of brain and qRT-PCR analysis. INTERNATIONAL JOURNAL OF RADIATION RESEARCH. JUL 2024. 22(3):529-536. doi: 10.61186/ijrr.22.3.529

Abstract

We evaluate the effects of radiofrequency electromagnetic field (RF-EMF) on rat brain and testicular tissue using histopathology, comet assay, and real-time quantitative PCR techniques.

Materials and Methods: Two equal groups of fourteen rats one for sham-control and the other for exposure (n = seven) were created. For a duration of 14 days, the exposure group (2100 MHz, testicular tissue SAR values of 163 mW/kg for 10 g, brain tissue SAR values of 292 mW/ kg on average) was subjected to five hours of exposure per day. Evaluations were conducted on tissue gene expression levels, histopathology, and DNA damage to brain tissue.

Results: The histological examination of brain tissue from the exposed group revealed vascular alterations and significant edema ($p < 0.05$). It was determined that RF radiation-induced much more cellular damage in the exposed group (18.26% tail DNA) than in the control group (4.06% tail DNA). Signs of deterioration in spermatogenic cells in the testicular tissue of the exposed group also changed significantly ($p < 0.05$). The Bax and bcl-2 genes showed a significant difference ($p < 0.05$) in the mRNA level data, whereas the p53 genes showed no significant change ($p > 0.05$).

Conclusion: These findings suggest that it may cause some histopathological and cellular damage in brain and testis tissue.

Open access paper: https://ijrr.com/article-1-5507-en.html

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Does Radiofrequency Radiation From Mobile Phones Affect the Formation of Parotid Gland Malignancy? An Experimental Study

Ozergin Coskun Z, Tumkaya L, Yilmaz A, Dursun E, Mercantepe T, Kalkan Y, Ersoz S. Does Radiofrequency Radiation From Mobile Phones Affect the Formation of Parotid Gland Malignancy? An Experimental Study. Ear Nose Throat J. 2024 Sep 27:1455613241287295. doi: 10.1177/01455613241287295.

Abstract

Objectives: The use of mobile phone is increasing around the world. Although it is beneficial in terms of communication, the electromagnetic radiations emitted by mobile phones may cause undesirable biological effects on the human body. In practical use, the tissue with which mobile phones come into most and are closest is the parotid gland. This study investigated the effects of the 1800 MHz electromagnetic field created by a generator on the parotid gland in rats.

Methods: A total of 21 Sprague-Dawley Albino rats were included in the study. The rats were randomly divided into three equal groups. To simulate a mobile phone in conversation mode, the first study group was exposed to an 1800-MHz electromagnetic field for 6 hours a day for 30 days, and the second study group was exposed to an 1800-MHz electromagnetic field for 12 hours a day for 30 days. After 30 days, rats were sacrificed, and histopathological and immunohistochemical methods were used to evaluate the effects on the parotid gland. The total antioxidant level and the total oxidant level were measured biochemically in homogenized parotid tissue.

Results: Histopathological results showed an increase in degeneration in rats exposed to electromagnetic fields for 6 and 12 hours a day, and immunohistochemical analysis showed an increase in the apoptotic index in both study groups ($P = .001$, $P < .001$). Intranuclear inclusions was observed during histopathological examination performed by electron microscopy.

Conclusions: This study observed that the 1800 MHz electromagnetic field caused undesirable adverse histopathological and biochemical effects on the parotid gland of rats. Histopathological and biochemical findings were detected with increasing contact and exposure time. This study will lead to other studies on this topic and contribute to the literature by completing other studies.

Excerpts

This study used a generator (Anritsu MG3670 B type, Japan) that produces microwave radiation at 1800 MHz radiofrequency to create exposure in mobile communion. The generator peak power was fixed at 2 W during exposure. In the digital signal generator used in this study, the carrier frequency was 1800 MHz, the modulation frequency was 217 Hz, there was a pulse of 577 µseconds, and the maximum peak power was 2 W. The average specific absorption rate (SAR) of the whole body was 0.117 W/kg. The study was carried out on a total of 21 rats divided in 3 groups (n = 7).

Groups 1, 2, and 3 were exposed to microwave radiation for 0 (control group), 6, and 12 hours, respectively. A generator with an external antenna was placed in the lower middle part of the cages.[5] The rats in the study group were exposed to microwave radiation for the specified hours in the mobile phone conversation mode....

The parotid tissue has been reported to absorb 40% of the electromagnetic energy emitted by mobile phones on phones held in place. This absorbed energy can cause thermal and nonthermal effects in the parotid tissue.[14] ....

Conclusion

In light of our knowledge of the literature, this is the first study to investigate the effects of an 1800-MHz electromagnetic field on the parotid gland of rats with biochemical tests, immunohistochemically in light microscopy and histopathologically in electron microscopy. This study observed that an 1800-MHz electromagnetic field causes undesirable adverse histopathological and biochemical effects on the parotid gland of rats. Histopathological and biochemical findings were detected with increasing contact and exposure time. This study will lead other studies on this topic and contribute to the literature in this area.

Open access paper: https://journals.sagepub.com/doi/10.1177/01455613241287295

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Blueberry anthocyanins regulate SIRT1/FoxO1 pathway to inhibit oxidative stress and reduce testicular tissue damage induced by microwave radiation in rats

Pang Y, Men J, Li Y, Zhang J, Zhao L, et al. Blueberry anthocyanins regulate SIRT1/FoxO1 pathway to inhibit oxidative stress and reduce testicular tissue damage induced by microwave radiation in rats. Journal of Functional Foods. Vol. 122, 2024. doi: 10.1016/j.jff.2024.106523.

Abstract

Researches have shown that microwave radiation could cause oxidative stress injury in male reproductive system, and blueberry anthocyanins had excellent oxidation resistance. Our study aimed to investigate the protective effect of blueberry anthocyanins (100, 200 and 400 mg/kg/d) on testicular tissue damage in Wistar rats exposed to 2.856 GHz microwave and the optimal dose. We found that blueberry anthocyanins could ameliorate the decrease of sperm motility and sex hormone levels and testicular tissue structure damage caused by microwave radiation, increase SIRT1 expression and decrease FoxO1 expression, increase GSH/GSSG, SOD and inhibit MDA. The LDH, SDH and ATP synthase were increased, and Caspase-3 expression was decreased, and the high-dose of blueberry anthocyanins (400 mg/kg/d) had the best protective effect. These results suggested that blueberry anthocyanins could inhibit oxidative stress injury induced by 2.856 GHz microwave radiation in rat testicular tissue by regulating SIRT1/FoxO1 pathway, enhance energy metabolism and reduce cell apoptosis.

Open access paper: https://www.sciencedirect.com/science/article/pii/S1756464624005255

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Effects of 4.9 GHz Radiofrequency Field Exposure on Brain Metabolomic and Proteomic Characterization in Mice

Wang X, Zhou G, Lin J, Zhang Z, Qin T, Guo L, Wang H, Huang Z, Ding G. Effects of 4.9 GHz Radiofrequency Field Exposure on Brain Metabolomic and Proteomic Characterization in Mice. Biology (Basel). 2024 Oct 10;13(10):806. doi: 10.3390/biology13100806.

Abstract

Electromagnetic exposure has become increasingly widespread, and its biological effects have received extensive attention. The purpose of this study was to explore changes in the metabolism profile of the brain and serum and to identify differentially expressed proteins in the brain after exposure to the 4.9 GHz radiofrequency (RF) field. C57BL/6 mice were randomly divided into a Sham group and an RF group, which were sham-exposed and continuously exposed to a 4.9 RF field for 35 d, 1 h/d, at an **average power density (PD) of 50 W/m^2**. After exposure, untargeted metabolomics and Tandem Mass Tags (TMT) quantitative proteomics were performed. We found 104 and 153 up- and down-regulated differentially expressed metabolites (DEMs) in the RF_Brain group and RF_Serum group, and the DEMs were significantly enriched in glycerophospholipid metabolism. Moreover, 10 up-regulated and 51 down-regulated differentially expressed proteins (DEPs) were discovered in the RF group. Functional correlation analysis showed that most DEMs and DEPs showed a significant correlation. These results suggested that 4.9 GHz exposure induced disturbance of metabolism in the brain and serum, and caused deregulation of proteins in the brain.

Simple Summary

The brain, as the central nervous system that controls the body's sensory, behavior, and mental symptoms, is sensitive to RF exposure, and lots of studies have explored the potential health hazards of RF-EMR with different frequencies to the brain. Our previous study found that 4.9 GHz radiofrequency radiation induced depression-like behavior in mice, but the mechanism of the behavioral changes was unclear. Studies have shown that changes in peripheral energy metabolism might affect brain lipid levels, and thereby cortical excitability, and a deregulated hippocampus proteome might influence the

healthy functioning of the brain. Here, we provide evidence that 4.9 GHz RF exposure altered metabolite expression patterns in brain tissue and serum, especially glycerophospholipid metabolism. In addition, 4.9 GHz RF exposure induced an imbalance in the protein profile of brain tissue and may alter gap junction communication. Our results initially revealed the biological effects of 5G communication frequency exposure and provided a possible mechanism for electromagnetic radiation-induced behavioral changes from the perspective of metabolome and proteome.

Open access paper: https://www.mdpi.com/2079-7737/13/10/806

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Cellular signaling pathways in the nervous system activated by various mechanical and electromagnetic stimuli

Kazuhito M, Ferguson AR, Aboubacar W, Youngjae R. Cellular signaling pathways in the nervous system activated by various mechanical and electromagnetic stimuli. Frontiers in Molecular Neuroscience. Vol. 17. 2024. doi: 10.3389/fnmol.2024.1427070.

Abstract

Mechanical stimuli, such as stretch, shear stress, or compression, activate a range of biomolecular responses through cellular mechanotransduction. In the nervous system, studies on mechanical stress have highlighted key pathophysiological mechanisms underlying traumatic injury and neurodegenerative diseases. However, the biomolecular pathways triggered by mechanical stimuli in the nervous system has not been fully explored, especially compared to other body systems. This gap in knowledge may be due to the wide variety of methods and definitions used in research. Additionally, as mechanical stimulation techniques such as ultrasound and electromagnetic stimulation are increasingly utilized in psychological and neurorehabilitation treatments, it is vital to understand the underlying biological mechanisms in order to develop accurate pathophysiological models and enhance therapeutic interventions. This review aims to summarize the cellular signaling pathways activated by various mechanical and electromagnetic stimuli with a particular focus on the mammalian nervous system. Furthermore, we briefly discuss potential cellular mechanosensors involved in these processes

Open access paper: https://www.frontiersin.org/journals/molecular-neuroscience/articles/10.3389/fnmol.2024.1427070

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Neurobiological effects and mechanisms of magnetic fields: a review from 2000 to 2023

Wang X, Ye Y, Zuo H, Li Y. Neurobiological effects and mechanisms of magnetic fields: a review from 2000 to 2023. BMC Public Health. 2024 Nov 8;24(1):3094. doi: 10.1186/s12889-024-18987-9.

Abstract

Magnetic fields are widely used in medical diagnostics because of their superior non-invasive properties. In addition, with the widespread use of magnetic fields in transportation and other areas, their potential hazards to human health and the assessment of their safety have attracted considerable attention. The effects of magnetic fields on living organisms have a long history. The biological effects of magnetic field exposure in mice and rats depend on the magnetic field strength, exposure time, and direction; depending on these and potentially other factors, magnetic fields can cause a series of neurobiological effects. We reviewed global research on the neurobiological effects of magnetic fields from recent years to provide an overview and insights into the underlying mechanisms. This review focuses on the biological effects of static and dynamic magnetic fields of different frequencies and intensities on animals and nerve cells and their mechanisms of action.

Conclusion

In summary, this article reviews the progress in research on the neural effects of SMF and DMF at the level of animal models and nerve cells in recent years. The number of studies on the effects of MFs on learning memory, emotional behavior, nerve cells, and neurotransmitters is gradually increasing, but owing to the diversity of MF parameters, experimental subjects, and conditions, the conclusions are inconsistent. Certain conditions of MF exposure can lead to changes in emotional behavior and learning memory and cause or relieve anxiety-like and depressive behaviors, with or without significant effects. The biological effects of MFs on neurons and glial cells include alterations in cell proliferation, cell cycle distribution, and apoptosis. However, some problems remain unclear. Due to the unspecific nature of MFs, their neurobiological effects are difficult to target experimentally. Urgent problems to be solved by future research include how to establish proper experimental animal and neural cell models, and how to select the appropriate MF exposure intensity and time.

Open access paper: https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-024-18987-9

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Cellular and Molecular Effects of Magnetic Fields

Tota M, Jonderko L, Witek J, Novickij V, Kulbacka J. Cellular and Molecular Effects of Magnetic Fields. Int J Mol Sci. 2024 Aug 17;25(16):8973. doi: 10.3390/ijms25168973.

Abstract

Recently, magnetic fields (MFs) have received major attention due to their potential therapeutic applications and biological effects. This review provides a comprehensive analysis of the cellular and molecular impacts of MFs, with a focus on both in vitro and in vivo studies. We investigate the mechanisms by which MFs influence cell behavior, including modifications in gene expression, protein synthesis, and cellular signaling pathways. The interaction of MFs with cellular components such as ion channels, membranes, and the cytoskeleton is analyzed, along with their effects on cellular processes like proliferation, differentiation, and apoptosis. Molecular insights are offered into how MFs modulate oxidative stress and inflammatory responses, which are pivotal in various pathological conditions. Furthermore, we explore the therapeutic potential of MFs in regenerative medicine, cancer treatment, and neurodegenerative diseases. By synthesizing current findings, this article aims to elucidate the complex bioeffects of MFs, thereby facilitating their optimized application in medical and biotechnological fields.

Open access paper: https://www.mdpi.com/1422-0067/25/16/8973

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Morphological, biochemical and genotoxic effects of non-ionizing radiation at 1800 MHz and 2400 MHz frequencies in Allium cepa L

Sharma A, Bahel S, Katnoria JK. Morphological, biochemical and genotoxic effects of non-ionizing radiation at 1800 MHz and 2400 MHz frequencies in Allium cepa L. Environ Sci Pollut Res Int. 2024 Oct 30. doi: 10.1007/s11356-024-35414-z.

Abstract

The frequent use of electronic devices in daily lives, predominantly reliant on non-ionizing radiation, has increased the prevalence of electromagnetic radiation (EMR) in natural environment. In light of this, effects of EMR at frequencies of 1800 MHz and 2400 MHz characterized by a power of 10.0 dBm (0.01 W), across varying exposure durations of 1 h/day, 2 h/day, 4 h/day, 6 h/day, and 8 h/day for 7 days, in Allium cepa L. were studied. The effects of the treatment on the morphological features (root length, fresh weight, and dry weight of roots) and biochemical characteristics (protein content and antioxidative enzymes, namely, ascorbate peroxidase (APX), glutathione reductase (GR), superoxide dismutase (SOD), glutathione-S-transferase (GST), guaiacol peroxidase (POD), catalase (CAT), and dehydroascorbate (DHAR)) were studied in roots and bulbs of Allium cepa L. Further genotoxicity for different exposure periods at both frequencies was also conducted. Prolonged exposure to electromagnetic radiation (EMR) at both frequencies was found to reduce root length, fresh weight, and dry weight of plant. Furthermore, significant effects were observed on protein content, indicating a reduction with prolonged exposure duration. Investigation into the activities of antioxidative enzymes such as APX, GR, GST, DHAR, CAT, SOD, and POD at a frequency of 1800 MHz and 2400 MHz in roots and bulbs demonstrated a significant enhancement in enzyme activity during 6 h/day and 8 h/day exposure periods. Additional investigation during genotoxicity studies demonstrated the induction of chromosomal aberrations in the root tip cells of the Allium cepa L. plant test system. The current study revealed the initiation of oxidative stress and genotoxicity resulting from long-term exposure to electromagnetic radiation in the studied plant test systems.

https://pubmed.ncbi.nlm.nih.gov/39472374/

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Representations of 5G in the Chinese and British press: a corpus-assisted critical discourse analysis

Pei, J., Cheng, L. Representations of 5G in the Chinese and British press: a corpus-assisted critical discourse analysis. *Humanit Soc Sci Commun* **11**, 400 (2024). https://doi.org/10.1057/s41599-024-02896-8

Abstract

This study employs a corpus-assisted critical discourse analysis to demystify the dominant patterns of representations around 5G in the Chinese and British press. Keyword analyses identify four thematic categories around the representation of 5G: the nature of 5G, social actors in 5G discourse, actions around 5G and timing in 5G discourse. Findings suggest that the Chinese press tends to use positive

evaluative expressions to depict 5G as a trustworthy and beneficial issue and stress China's strong support for 5G development. In contrast, the British press prefers to frame 5G as a product of geopolitical rivalry and an issue with scientific uncertainties and controversies by repeatedly employing negative language patterns related to 5G risks and conspiracy theories. Besides, a subtle but varying "self versus other" schema is constructed by the two presses. The Chinese press is inclined to use positive predication strategies to construct a positive self-representation, whereas the British press tends to adopt negative predication strategies to portray China as an outgroup and meanwhile use scapegoating strategies to profile Britain as a positive self by using recurrent patterns denoting the pressure exerted on Britain by the United States. Such differences could result from their journalistic ideologies and values and the contrasting socio-political contexts where the two presses are situated.

Open access paper: https://www.nature.com/articles/s41599-024-02896-8

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Magnetic fields from indoor transformer stations and risk of cancer in adults: a cohort study

Juutilainen J, Khan MW, Naarala J, Roivainen P. Magnetic fields from indoor transformer stations and risk of cancer in adults: a cohort study. Occup Environ Med. 2024 Nov 18:oemed-2024-109466. doi: 10.1136/oemed-2024-109466.

Abstract

Objectives: Studies assessing the association of adult cancers with extremely low frequency (ELF) magnetic fields (MF) have provided inconclusive results, probably affected by limitations such as low exposure levels, confounding and various forms of bias. This study investigated the association between residential ELF MF exposure and adult cancer using a design that avoids the main limitations of previous studies.

Methods: Persons who have lived in buildings with indoor transformer stations during the period 1971-2016 formed the study cohort. Their MF exposure was assessed based on the location of their apartment in relation to the transformer room. Information on their cancer diagnoses was obtained from the Finnish Cancer Registry. SIR with 95% CI was calculated to investigate the association of MF exposure with overall cancer and specific cancers.

Results: The SIR for all primary sites was 1.01 (95% CI 0.93 to 1.09). An increased risk of digestive organ cancers was observed among the exposed persons, with a SIR of 1.23 (95% CI 1.03 to 1.46). The highest SIR was observed for gallbladder cancer (3.92, 95% CI 1.44 to 8.69). Increased risk of testicular cancer was observed among men exposed to MF during childhood, but this is likely to be due to confounding associated with living on the lowest floors. No other significant associations were observed for other primary cancer sites studied.

Conclusions: Overall cancer risk was not affected by residential MF exposure. The increased risk of digestive organ cancers among MF-exposed persons is a novel finding requiring confirmation in further studies.

WHAT IS ALREADY KNOWN ON THIS TOPIC

- Extremely low frequency magnetic fields (ELF MFs) have been classified as possibly carcinogenic. The evidence is strongest for increased risk of childhood leukaemia and more inconsistent for risks of adult cancers.

WHAT THIS STUDY ADDS

- This study was carried out using a unique database of residential buildings with indoor transformer stations. Many limitations of previous studies could be avoided. The study suggested an association between residential MF exposure and digestive organ cancers. The overall cancer risk was not affected by MF exposure.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- As there is little previous evidence of an association between digestive organ cancers and MF exposure, further research on this topic is required. Compared with previous studies, this study included higher exposure levels and thus provides a useful addition to the data available for health risk assessment and risk communication.

https://pubmed.ncbi.nlm.nih.gov/39557565/

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Exploring Non-Thermal Mechanisms of Biological Reactions to Extremely Low-Frequency Magnetic Field Exposure

Radil R, Carnecka L, Judakova Z, Pobocikova I, Bajtos M, Janousek L. Exploring Non-Thermal Mechanisms of Biological Reactions to Extremely Low-Frequency Magnetic Field Exposure. *Applied Sciences*. 2024; 14(20):9409. https://doi.org/10.3390/app14209409

Abstract

The increasing evidence regarding biological effects of exposure to an extremely low frequency magnetic field is of utmost interest not only to the scientific community, but also to legislative bodies and the public. However, the research in this field is full of controversial and inconsistent results, originated from a lack of widely acceptable physical mechanisms that could sufficiently describe the principle of such a field's action. This experimental study addresses and points to possible sources of ambiguities via investigation of the ion parametric resonance mechanism at 50 Hz frequency. The chosen methodology incorporates exposure of the Saccharomyces cerevisiae yeast strain based on an established exposure protocol with special attention to the measurement of an applied time-varying magnetic field corresponding to the ion parametric resonance requirements. Subsequently, the differences in cell growth as a reaction to changes in magnetic flux density are evaluated and statistically analyzed. It is found that fluctuations in the magnetic field within the exposure setup need to be addressed properly, since this could have an impact on replication of the experiments and reliability of the results. Furthermore, comparison of two independently performed sets of 10 experiments showed statistically significant effects even in conditions that did not fulfill the requirements of the resonance

theory, putting the validity and practical application of the ion parametric resonance model into question.

Open access paper: https://www.mdpi.com/2076-3417/14/20/9409

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Migratory birds can extract positional information from magnetic inclination and magnetic declination alone

Packmor F, Kishkinev D, Zechmeister T, Mouritsen H, Holland RA. Migratory birds can extract positional information from magnetic inclination and magnetic declination alone. Proc Biol Sci. 2024 Nov;291(2034):rspb20241363. doi: 10.1098/rspb.2024.1363.

Abstract

Migratory birds are able to navigate over great distances with remarkable accuracy. The mechanism they use to achieve this feat is thought to involve two distinct steps: locating their position (the 'map') and heading towards the direction determined (the 'compass'). For decades, this map-and-compass concept has shaped our perception of navigation in animals, although the nature of the map remains debated. However, some recent studies suggest the involvement of the Earth's magnetic field in the map step. Here, we tested whether migratory songbirds, Eurasian reed warblers (*Acrocephalus scirpaceus*), can determine their position based on two magnetic field components that are also associated with direction finding, i.e. magnetic inclination and magnetic declination. During a virtual magnetic displacement experiment, the birds were exposed to altered magnetic inclination and magnetic declination values that would indicate a displacement from their natural migratory corridor, but the total intensity of the field remained unchanged, creating a spatial mismatch between these components. The response was a change in the birds' migratory direction consistent with a compensatory re-orientation. This suggests that birds can extract positional as well as directional information from these cues, even when they are in conflict with another component of the magnetic field. It remains to be seen whether birds use the total intensity of Earth's magnetic field for navigation.

Open access paper: https://royalsocietypublishing.org/doi/10.1098/rspb.2024.1363

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Indoor & outdoor artificial light-at-night (ALAN) & cancer risk: A systematic review & meta-analysis of multiple cancer sites with a critical appraisal of exposure assessment

Palomar-Cros A, Deprato A, Papantoniou K, Straif K, Lacy P, Maidstone R, Adan A, Haldar P, Moitra S, Navarro JF, Durrington H, Moitra S, Kogevinas M, Harding BN. Indoor and outdoor artificial light-at-night (ALAN) and cancer risk: A systematic review and meta-analysis of multiple cancer sites and with a critical appraisal of exposure assessment. Science of The Total Environment, Vol 955, 2024. doi: 10.1016/j.scitotenv.2024.177059.

Abstract

Exposure to artificial light-at-night (ALAN) has been linked to cancer risk. Few meta-analyses on this topic have reviewed only breast cancer. This study aimed to systematically review and meta-analyze

existing studies on ALAN exposure and cancer incidence, thoroughly evaluating exposure assessment quality. We considered observational studies (cohort, case-control, cross-sectional) on ALAN exposure (indoor and outdoor) and cancer incidence, measured by relative risk, hazard ratio, and odds ratio. We searched six databases, two registries, and Google Scholar from inception until April 17, 2024. Quality of studies was assessed using the Joanna Briggs Institute (JBI) critical appraisal tools. Random-effects meta-analysis was used to estimate relative risks (RR) and 95 % confidence intervals (CI) for ALAN exposures. We identified 9835 studies and included 28 for qualitative synthesis with 2,508,807 individuals (15 cohort, 13 case-control). Out of the included studies, 20 studies on breast cancer (731,493 individuals) and 2 studies on prostate cancer (53,254 individuals) were used for quantitative synthesis. Higher levels of outdoor ALAN were associated with breast cancer risk (meta-estimate = 1.12, 95 % CI 1.03–1.23 (I2 = 69 %)). We observed a non-significant positive association between indoor ALAN levels and breast cancer risk (meta-estimate = 1.07, 0.95–1.21, I2 = 60 %), and no differences by menopausal status. The meta-analysis for prostate cancer suggested a non-statistically significant increased risk for higher levels of outdoor ALAN (meta-estimate = 1.43, 0.75–2.72, I2 = 90 %). In the qualitative synthesis, we observed positive associations with non-Hodgkin lymphoma and colorectal, pancreatic and thyroid cancer. We found an association between outdoor ALAN and breast cancer risk. However, most studies relied on satellite-images with a very low resolution (1 to 5 km, from the Defense Meteorological Program [DMSP]) and without information on color of light. Future studies with better exposure assessment should focus on investigating other cancer sites.

https://www.sciencedirect.com/science/article/pii/S0048969724072164

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Effect of exposure to RF on cancer risk: A systematic review of human observational studies – Part I: Most researched outcomes (WHO SR 1A)

My note: See Biased WHO-commissioned review claims no cancer link

Karipidis K, Baaken D, Loney T, Blettner M, Brzozek C, Elwood M, Narh C, Orsini N, Röösli M, Paulo MS, Lagorio S. The effect of exposure to radiofrequency fields on cancer risk in the general and working population: A systematic review of human observational studies – Part I: Most researched outcomes. Environment International (2024), doi: 10.1016/j.envint.2024.108983. Open access paper: https://doi.org/10.1016/j.envint.2024.108983

Abstract

Background The objective of this review was to assess the quality and strength of the evidence provided by human observational studies for a causal association between exposure to radiofrequency electromagnetic fields (RF-EMF) and risk of the most investigated neoplastic diseases.

Methods Eligibility criteria: We included cohort and case-control studies of neoplasia risks in relation to three types of exposure to RF-EMF: near-field, head-localized, exposure from wireless phone use (SR-A); far-field, whole body, environmental exposure from fixed-site transmitters (SR-B); near/far-field occupational exposures from use of hand-held transceivers or RF-emitting equipment in the workplace (SR-C). While no restrictions on tumour type were applied, in the current paper we focus on incidence-based studies of selected “critical” neoplasms of the central nervous system (brain, meninges, pituitary

gland, acoustic nerve) and salivary gland tumours (SR-A); brain tumours and leukaemias (SR-B, SR-C). We focussed on investigations of specific neoplasms in relation to specific exposure sources (i.e. E-O pairs), noting that a single article may address multiple E-O pairs.

Information sources: Eligible studies were identified by literature searches through Medline, Embase, and EMF-Portal.

Risk-of-bias (RoB) assessment: We used a tailored version of the Office of Health Assessment and Translation (OHAT) RoB tool to evaluate each study's internal validity. At the summary RoB step, studies were classified into three tiers according to their overall potential for bias (low, moderate and high).

Data synthesis: We synthesized the study results using random effects restricted maximum likelihood (REML) models (overall and subgroup meta-analyses of dichotomous and categorical exposure variables), and weighted mixed effects models (dose–response meta-analyses of lifetime exposure intensity).

Evidence assessment: Confidence in evidence was assessed using the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) approach.

Results We included 63 aetiological articles, published between 1994 and 2022, with participants from 22 countries, reporting on 119 different E-O pairs. RF-EMF exposure from mobile phones (ever or regular use vs no or non-regular use) was not associated with an increased risk of glioma [meta-estimate of the relative risk (mRR) = 1.01, 95 % CI = 0.89–1.13), meningioma (mRR = 0.92, 95 % CI = 0.82–1.02), acoustic neuroma (mRR = 1.03, 95 % CI = 0.85–1.24), pituitary tumours (mRR = 0.81, 95 % CI = 0.61–1.06), salivary gland tumours (mRR = 0.91, 95 % CI = 0.78–1.06), or paediatric (children, adolescents and young adults) brain tumours (mRR = 1.06, 95 % CI = 0.74–1.51), with variable degree of across-study heterogeneity (I2 = 0 %-62 %). There was no observable increase in mRRs for the most investigated neoplasms (glioma, meningioma, and acoustic neuroma) with increasing time since start (TSS) use of mobile phones, cumulative call time (CCT), or cumulative number of calls (CNC). Cordless phone use was not significantly associated with risks of glioma [mRR = 1.04, 95 % CI = 0.74–1.46; I2 = 74 %) meningioma, (mRR = 0.91, 95 % CI = 0.70–1.18; I2 = 59 %), or acoustic neuroma (mRR = 1.16; 95 % CI = 0.83–1.61; I2 = 63 %). Exposure from fixed-site transmitters (broadcasting antennas or base stations) was not associated with childhood leukaemia or paediatric brain tumour risks, independently of the level of the modelled RF exposure. Glioma risk was not significantly increased following occupational RF exposure (ever vs never), and no differences were detected between increasing categories of modelled cumulative exposure levels.

Discussion In the sensitivity analyses of glioma, meningioma, and acoustic neuroma risks in relation to mobile phone use (ever use, TSS, CCT, and CNC) the presented results were robust and not affected by changes in study aggregation.

In a leave-one-out meta-analyses of glioma risk in relation to mobile phone use we identified one influential study. In subsequent meta-analyses performed after excluding this study, we observed a substantial reduction in the mRR and the heterogeneity between studies, for both the contrast Ever vs

Never (regular) use (mRR = 0.96, 95 % CI = 0.87–1.07, I2 = 47 %), and in the analysis by increasing categories of TSS ("<5 years": mRR = 0.97, 95 % CI = 0.83–1.14, I2 = 41 %; "5-9 years ": mRR = 0.96, 95 % CI = 0.83–1.11, I2 = 34 %; "10+ years": mRR = 0.97, 95 % CI = 0.87–1.08, I2 = 10 %).

There was limited variation across studies in RoB for the priority domains (selection/attrition, exposure and outcome information), with the number of studies evenly classified as at low and moderate risk of bias (49 % tier-1 and 51 % tier-2), and no studies classified as at high risk of bias (tier-3). The impact of the biases on the study results (amount and direction) proved difficult to predict, and the RoB tool was inherently unable to account for the effect of competing biases. However, the sensitivity meta-analyses stratified on bias-tier, showed that the heterogeneity observed in our main meta-analyses across studies of glioma and acoustic neuroma in the upper TSS stratum (I2 = 77 % and 76 %), was explained by the summary RoB-tier. In the tier-1 study subgroup, the mRRs (95 % CI; I2) in long-term (10+ years) users were 0.95 (0.85–1.05; 5.5 %) for glioma, and 1.00 (0.78–1.29; 35 %) for acoustic neuroma.

The time-trend simulation studies, evaluated as complementary evidence in line with a triangulation approach for external validity, were consistent in showing that the increased risks observed in some case-control studies were incompatible with the actual incidence rates of glioma/brain cancer observed in several countries and over long periods. Three of these simulation studies consistently reported that RR estimates > 1.5 with a 10+ years induction period were definitely implausible, and could be used to set a "credibility benchmark". In the sensitivity meta-analyses of glioma risk in the upper category of TSS excluding five studies reporting implausible effect sizes, we observed strong reductions in both the mRR [mRR of 0.95 (95 % CI = 0.86–1.05)], and the degree of heterogeneity across studies (I2 = 3.6 %).

Conclusions Consistently with the published protocol, our final conclusions were formulated separately for each exposure-outcome combination, and primarily based on the line of evidence with the highest confidence, taking into account the ranking of RF sources by exposure level as inferred from dosimetric studies, and the external coherence with findings from time-trend simulation studies (limited to glioma in relation to mobile phone use).

For near field RF-EMF exposure to the head from mobile phone use, there was moderate certainty evidence that it likely does not increase the risk of glioma, meningioma, acoustic neuroma, pituitary tumours, and salivary gland tumours in adults, or of paediatric brain tumours.

For near field RF-EMF exposure to the head from cordless phone use, there was low certainty evidence that it may not increase the risk of glioma, meningioma or acoustic neuroma.

For whole-body far-field RF-EMF exposure from fixed-site transmitters (broadcasting antennas or base stations), there was moderate certainty evidence that it likely does not increase childhood leukaemia risk and low certainty evidence that it may not increase the risk of paediatric brain tumours. There were no studies eligible for inclusion investigating RF-EMF exposure from fixed-site transmitters and critical tumours in adults.

For occupational RF-EMF exposure, there was low certainty evidence that it may not increase the risk of brain cancer/glioma, but there were no included studies of leukemias (the second critical outcome in SR-

C).

The evidence rating regarding paediatric brain tumours in relation to environmental RF exposure from fixed-site transmitters should be interpreted with caution, due to the small number of studies. Similar interpretative cautions apply to the evidence rating of the relation between glioma/brain cancer and occupational RF exposure, due to differences in exposure sources and metrics across the few included studies.

Other This project was commissioned and partially funded by the World Health Organization (WHO). Co-financing was provided by the New Zealand Ministry of Health; the Istituto Superiore di Sanità in its capacity as a WHO Collaborating Centre for Radiation and Health; and ARPANSA as a WHO Collaborating Centre for Radiation Protection. Registration: PROSPERO CRD42021236798. Published protocol: [(Lagorio et al., 2021) DOI https://doi.org/10.1016/j.envint.2021.106828].

Open access paper:
https://www.sciencedirect.com/science/article/pii/S0160412024005695?via%3Dihub

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The effects of radiofrequency exposure on adverse female reproductive outcomes: A systematic review of human observational studies with dose–response meta-analysis (WHO SR 3 female)

My note: See WHO Radiofrequency EMF Health Risk Assessment Monograph (EHC series)

Johnson EE, Kenny RPW, Adesanya AM, Richmond C, Beyer F, Calderon C, Rankin J, Pearce MS, Toledano M, Craig D, Pearson F. The effects of radiofrequency exposure on adverse female reproductive outcomes: A systematic review of human observational studies with dose-response meta-analysis. Environ Int. 2024 Jun 12;190:108816. doi: 10.1016/j.envint.2024.108816.

Abstract

Background To inform radiofrequency electromagnetic field (RF-EMF) exposure guidelines the World Health Organization (WHO) is bringing together evidence on RF-EMF in relation to health outcomes prioritised for evaluation by experts in this field. Given this, a network of topic experts and methodologists have conducted a series of systematic reviews collecting, assessing, and synthesising data of relevance to these guidelines. Here we present a systematic review of the effect of RF-EMF exposure on adverse pregnancy outcomes in human observational studies which follows the WHO handbook for guideline development and the COSTER conduct guidelines.

Methods We conducted a broad, sensitive search for potentially relevant records within the following bibliographic databases: MEDLINE; Embase; and the EMF Portal. Grey literature searches were also conducted through relevant databases (including OpenGrey), organisational websites and via consultation of RF-EMF experts. We included quantitative human observational studies on the effect of RF-EMF exposure in adults' preconception or pregnant women on pre-term birth, small for gestational age (SGA; associated with intrauterine growth restriction), miscarriage, stillbirth, low birth weight (LBW) and congenital anomalies. In blinded duplicate, titles and abstracts then full texts were screened against eligibility criteria. A third reviewer gave input when consensus was not reached. Citation chaining of

included studies was completed. Two reviewers' data extracted and assessed included studies for risk of bias using the Office of Health Assessment and Translation (OHAT) tool. Random effects meta-analyses of the highest versus the lowest exposures and dose–response meta-analysis were conducted as appropriate and plausible. Two reviewers assessed the certainty in each body of evidence using the OHAT GRADE tool.

Results We identified 18 studies in this review; eight were general public studies (with the general public as the population of interest) and 10 were occupational studies (with the population of interest specific workers/workforces). General public studies. From pairwise meta-analyses of general public studies, the evidence is very uncertain about the effects of RF-EMF from mobile phone exposure on preterm birth risk (relative risk (RR) 1.14, 95% confidence interval (CI): 0.97–1.34, 95% prediction interval (PI): 0.83–1.57; 4 studies), LBW (RR 1.14, 95% CI: 0.96–1.36, 95% PI: 0.84–1.57; 4 studies) or SGA (RR 1.13, 95% CI: 1.02–1.24, 95% PI: 0.99–1.28; 2 studies) due to very low-certainty evidence. It was not feasible to meta-analyse studies reporting on the effect of RF-EMF from mobile phone exposure on congenital anomalies or miscarriage risk. The reported effects from the studies assessing these outcomes varied and the studies were at some risk of bias. No studies of the general public assessed the impact of RF-EMF exposure on stillbirth. Occupational studies. In occupational studies, based on dose–response meta-analyses, the evidence is very uncertain about the effects of RF-EMF amongst female physiotherapists using shortwave diathermy on miscarriage due to very low-certainty evidence (OR 1.02 95% CI 0.94–1.1; 2 studies). Amongst offspring of female physiotherapists using shortwave diathermy, the evidence is very uncertain about the effects of RF-EMF on the risk of congenital malformations due to very low-certainty evidence (OR 1.4, 95% CI 0.85 to 2.32; 2 studies). From pairwise meta-analyses, the evidence is very uncertain about the effects of RF-EMF on the risk of miscarriage (RR 1.06, 95% CI 0.96 to 1.18; very low-certainty evidence), pre-term births (RR 1.19, 95% CI 0.32 to 4.37; 3 studies; very low-certainty evidence), and low birth weight (RR 2.90, 95% CI: 0.69 to 12.23; 3 studies; very low-certainty evidence). Results for stillbirth and SGA could not be pooled in meta-analyses. The results from the studies reporting these outcomes were inconsistent and the studies were at some risk of bias.

Discussion Most of the evidence identified in this review was from general public studies assessing localised RF-EMF exposure from mobile phone use on female reproductive outcomes. In occupational settings, each study was of heterogenous whole-body RF-EMF exposure from radar, short or microwave diathermy, surveillance and welding equipment and its effect on female reproductive outcomes. Overall, the body of evidence is very uncertain about the effect of RF-EMF exposure on female reproductive outcomes. Further prospective studies conducted with greater rigour (particularly improved accuracy of exposure measurement and using appropriate statistical methods) are required to identify any potential effects of RF-EMF exposure on female reproductive outcomes of interest.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024004021

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The effects of radiofrequency exposure on male fertility: A systematic review of human observational studies with dose-response meta-analysis (SR 3 male)

My note: See WHO Radiofrequency EMF Health Risk Assessment Monograph (EHC series)

Kenny RPW, Evelynne Johnson E, Adesanya AM, Richmond C, Beyer F, Calderon C, Rankin J, Pearce MS, Toledano M, Craig D, Pearson F. The effects of radiofrequency exposure on male fertility: A systematic review of human observational studies with dose-response meta-analysis. Environ Int. 2024 Jun 11;190:108817. doi: 10.1016/j.envint.2024.108817.

Abstract

Background: The World Health Organization (WHO) is bringing together evidence on radiofrequency electromagnetic field (RF-EMF) exposure in relation to health outcomes, previously identified as priorities for research and evaluation by experts in the field, to inform exposure guidelines. A suite of systematic reviews have been undertaken by a network of topic experts and methodologists to collect, assess and synthesise data relevant to these guidelines. Following the WHO handbook for guideline development and the COSTER conduct guidelines, we systematically reviewed the evidence on the potential effects of RF-EMF exposure on male fertility in human observational studies.

Methods: We conducted a broad and sensitive search for potentially relevant records within the following bibliographic databases: MEDLINE; Embase; Web of Science and EMF Portal. We also conducted searches of grey literature through relevant databases including OpenGrey, and organisational websites and consulted RF-EMF experts. We hand searched reference lists of included study records and for citations of these studies. We included quantitative human observational studies on the effect of RF-EMF exposure in adult male participants on infertility: sperm concentration; sperm morphology; sperm total motility; sperm progressive motility; total sperm count; and time to pregnancy. Titles and abstracts followed by full texts were screened in blinded duplicate against pre-set eligibility criteria with consensus input from a third reviewer as required. Data extraction from included studies was completed by two reviewers, as was risk of bias assessment using the Office of Health Assessment and Translation (OHAT) tool. We conducted a dose-response meta-analysis as possible and appropriate. Certainty of the evidence was assessed by two reviewers using the OHAT GRADE tool with input from a third reviewer as required.

Results: We identified nine studies in this review; seven were general public studies (with the general public as the population of interest) and two were occupational studies (with specific workers/workforces as the population of interest). General public studies. Duration of phone use: The evidence is very uncertain surrounding the effects of RF-EMF on sperm concentration (10/6 mL) (MD (mean difference) per hour of daily phone use 1.6 10^6/mL, 95 % CI -1.7 to 4.9; 3 studies), sperm morphology (MD 0.15 percentage points of deviation of normal forms per hour, 95 % CI -0.21 to 0.51; 3 studies), sperm progressive motility (MD -0.46 percentage points per hour, 95 % CI -1.04 to 0.13; 2 studies) and total sperm count (MD per hour -0.44 10^6/ejaculate, 95 % CI -2.59 to 1.7; 2 studies) due to very low-certainty evidence. Four additional studies reported on the effect of mobile phone use on sperm motility but were unsuitable for pooling; only one of these studies identified a statistically significant effect. All four studies were at risk of exposure characterisation and selection bias; two of confounding, selective reporting and attrition bias; three of outcome assessment bias and one used an inappropriate statistical method. Position of phone: There may be no or little effect of carrying a mobile phone in the front pocket on sperm concentration, total count, morphology, progressive motility or on time to pregnancy. Of three studies reporting on the effect of mobile phone location on sperm total motility and, or, total motile count, one showed a statistically significant effect. All three studies were at risk of exposure characterisation and selection bias; two of confounding, selective reporting and attrition bias; three of outcome assessment bias and one used inappropriate statistical method. RF-EMF Source: One study indicates there may be little or no effect of computer or other electric device use on

sperm concentration, total motility or total count. This study is at probably high risk of exposure characterisation bias and outcome assessment bias. Occupational studies. With only two studies of occupational exposure to RF-EMF and heterogeneity in the population and exposure source (technicians exposed to microwaves or seamen exposed to radar equipment), it was not plausible to statistically pool findings. One study was at probably or definitely high risk of bias across all domains, the other across domains for exposure characterisation bias, outcome assessment bias and confounding.

Discussion: The majority of evidence identified was assessing localised RF-EMF exposure from mobile phone use on male fertility with few studies assessing the impact of phone position. Overall, the evidence identified is very uncertain about the effect of RF-EMF exposure from mobile phones on sperm outcomes. One study assessed the impact of other RF-EMF sources on male fertility amongst the general public and two studies assessed the impact of RF-EMF exposure in occupational cohorts from different sources (radar or microwave) on male fertility. Further prospective studies conducted with greater rigour (in particular, improved accuracy of exposure measurement and appropriate statistical method use) would build the existing evidence base and are required to have greater certainty in any potential effects of RF-EMF on male reproductive outcomes. Prospero Registration: CRD42021265401 (SR3A).

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Response to letter from Bevington M., Electrosensitivity UK (WHO SR 8)

Bosch-Capblanch X, Esu E, Oringanje CM, Dongus S, Jalilian H, Eyers J, Auer C, Meremikwu M, Röösli M. Response to letter from Bevington M., Electrosensitivity UK. Environment International. 191, 2024. doi: 10.1016/j.envint.2024.108982.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024005683

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Bevington Letter to Editor re: WHO systematic review of RF-EMF effects in human experimental studies of self-reported symptoms (WHO SR 8)

Bevington M. Letter to the Editor, Environment International 'Available evidence shows adverse symptoms from acute non-thermal RF-EMF exposure'. Comment on: Bosch-Capblanch X et al., The effects of radiofrequency electromagnetic fields exposure on human self-reported symptoms: A systematic review of human experimental studies, Envir Int. vol. 187, May 2024, 108612, Environment International, 2024, 108888, doi: 10.1016/j.envint.2024.108888.

No abstract

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024004744

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The effects of radiofrequency electromagnetic field exposure on biomarkers of oxidative stress in vivo and in vitro: A systematic review of experimental studies (WHO SR 9)

My note: SR 9 is the eighth of the WHO SRs (systematic reviews) on RF-EMF effects to be published in *Environment International*.

Like its predecessors, the authors of this SR systematically excluded most of the relevant research. Most of the meta-analyses in this paper suffered from high levels of heterogeneity with little effort to understand the source of the varied results. Some meta-analyses were unreliable as they violated a key assumption of the random effects model, namely, independence of observations. I think a critique of this SR could build a strong case for retraction of this paper.

Meyer F, Bitsch A, Forman HJ, Fragoulis A, Ghezzi P, Henschenmacher B, Kellner R, Kuhne J, Ludwig T, Sachno D, Schmid G, Tsaioun K, Verbeek J, Wright R. The effects of radiofrequency electromagnetic field exposure on biomarkers of oxidative stress in vivo and in vitro: A systematic review of experimental studies. Environment International, 2024. doi: 10.1016/j.envint.2024.108940.

Highlights

The evidence for or against a relation between RF-EMF and biomarkers of oxidative stress is overall of very low certainty.

Inconsistent overall study results.

Need for drastic improvements of studies on RF-EMF and biomarkers of oxidative stress.

Abstract

Background

Oxidative stress is thought to be related to many diseases. Furthermore, it is hypothesized that radiofrequency electromagnetic fields (RF-EMF) may induce excessive oxidative stress in various cell types and thereby have the potential to compromise human and animal health. The objective of this systematic review (SR) is to summarize and evaluate the literature on the relation between the exposure to RF-EMF in the frequency range from 100 kHz to 300 GHz and biomarkers of oxidative stress.

Methods

The SR framework was developed following the guidelines established in the WHO Handbook for Guideline Development and NTP/OHAT's Handbook for Conducting a Literature-Based Health Assessment. We used the latter handbook's methodology for implementing the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach for environmental health assessments. We searched the following databases up until June 30, 2023: PubMed, Embase, Web of Science Core Collection, Scopus, and the EMF-Portal. The reference lists of included studies and retrieved review articles were also manually searched. We rated Risk of Bias (RoB) using the OHAT RoB Rating Tool and assessed publication bias using funnel plots of included studies. We assessed the certainty of the evidence (high, moderate, low, or inadequate) for an association between RF-EMF and oxidative stress using an adapted version of the GRADE framework. Data were extracted according to a predefined set of forms developed in DistillerSR. Data were analysed after grouping them first as in vitro or in vivo and then according to outcome category, species category, and exposed tissue. We synthesized study results using a random effects meta-analysis when study characteristics were judged

sufficiently similar to be combined and heterogeneity (I2) was lower than 75 %, otherwise we describe the findings narratively.

Results

Fifty-six (56) studies, 45 in vivo and 11 in vitro, exposed to frequencies in the range 800–2450 MHz, were included in the SR after eliminating 11,543 publications because they did not meet the criteria defined in the published protocol (Henschenmacher et al., 2022). Of 56 studies 51 studies with 168 individual results were included in the meta-analysis. Together, these studies examined six human in vitro samples and fifty animal samples, including rodents (mice, rats, hamsters, and guinea pigs, [n = 46]) and rabbits [n = 4]. RF-EMF were predominantly applied as continuous wave exposures in these studies. The outcome biomarkers for modified proteins and amino acids were measured in 30 studies, for oxidized DNA bases in 26 studies, for oxidized lipids in 2 studies and hydrogen peroxide production in 2 studies. Outcomes were mostly measured in the brain (n = 22), liver (n = 9), cells (n = 9), blood (n = 6), and testis (n = 2). RoB in studies was high, mainly due to biases in exposure and outcome assessment.

In vivo studies

Brain: The effect on biomarkers for oxidized DNA bases in the rodent brain (five studies, n = 98) had an inconsistent effect, varying from a large decrease with a standardized mean difference (SMD) of −3.40 (95 % CI [−5.15, −1.64]) to a large increase with an SMD of 2.2 (95 % CI [0.78, 3.62]). In the brain of rabbits (two studies, n = 44), the effect sizes also varied, from an SMD of −1.06 (95 % CI [−2.13, 0.00]) to an SMD of 5.94 (95 % CI [3.14, 8.73]). The effect on biomarkers for modified proteins and amino acids in the rodent brain (15 studies, n = 328) also varied from a large decrease with an SMD of −6.11 (95 % CI [−8.16, −4.06]) to a large increase with an SMD of 5.33 (95 % CI [2.49, 8.17]).

The effect on biomarkers for oxidized lipids in the brain of rodents (one study, n = 56) also varied from a large decrease with SMD = −4.10 (95 % CI [−5.48, −2.73]) to SMD = 1.27 (95 % CI [0.45, 2.10]).

Liver: The effect on biomarkers for oxidized DNA bases in the rodent liver (two studies, n = 26) was inconsistent with effect sizes in both directions: SMD = −0.71 (95 % CI [−1.80, 0.38]) and SMD = 1.56 (95 % CI [0.19, 2.92]). The effect on biomarkers for oxidized DNA bases in the rabbits' liver (two studies, n = 60) was medium with a pooled SMD of 0.39 (95 % CI [−0.79, 1.56]).

Biomarkers for modified proteins and amino acids in the liver of rodents (six studies, n = 159) increased with a pooled SMD of 0.55 (95 % CI [0.06, 1.05]).

Blood: The effect of RF-EMF on biomarkers for oxidized DNA bases in rodent blood (four studies, n = 104) was inconsistent, with SMDs ranging from −1.14 (95 % CI [−2.23, −0.06]) to 1.71 (95 % CI [−0.10, 3.53]).

RF-EMF had no effect on biomarkers for modified proteins and amino acids in rodent blood (three studies, n = 40), with a pooled SMD of −0.08 (95 % CI [−1.32, 1.16]).

There was a large increase in biomarkers for oxidized DNA bases in rodent plasma (two studies, n = 38) with a pooled SMD of 2.25 (95 % CI [1.27, 3.24]).

Gonads: There was an increase in biomarkers for oxidized DNA bases in the rodent testis (two studies, n = 24) with a pooled SMD of 1.60 (95 % CI [0.62, 2.59]).

The effect of RF-EMF on biomarkers for modified proteins and amino acids in the ovary of rodents (two studies, n = 52) was inconsistent with a small effect, SMD = 0.24 (95 % CI [−0.74, 1.23])) and a large effect (SMD = 2.08 (95 % CI [1.22, 2.94])).

Thymus: RF-EMF increased biomarkers for modified proteins and amino acids in the thymus of rodents (one study, n = 42) considerably with a pooled SMD of 6.16 (95 % CI [3.55, 8.76]).

Cells: RF-EMF increased oxidized DNA bases in rodent cells with SMD of 2.49 (95 % CI [1.30, 3.67]) (one study, n = 27). There was a small effect in oxidized lipids (one study, n = 18) but not statistically significant with an SMD of 0.34 (95 % CI [−0.62, 1.29]).

In vitro studies

In in vitro studies in human cells (three studies, n = 112), there were inconsistent increases in biomarkers for oxidized DNA bases, where the SMDs varied between 0.01 (95 % CI [−0.59, 0.62]) and 7.74 (95 % CI [2.24, 13.24]) in 4 results (2 of them statistically significant). In rodent cells (three studies, n = 24), there was a not statistically significant large effect in biomarkers for oxidized DNA bases with SMD = 2.07 (95 % CI [−1.38, 5.52]).

The RF-EMF biomarkers for modified proteins and amino acids in human cells (one study, n = 18) showed a large effect with SMD = 1.07 (95 % CI [−0.05, 2.19]). In rodent cells (two studies, n = 24) a medium effect of SMD = 0.56 (95 % CI [−0.29, 1.41]) was observed.

Discussion

The evidence on the relation between the exposure to RF-EMF and biomarkers of oxidative stress was of very low certainty, because a majority of the included studies were rated with a high RoB level and provided high heterogeneity. This is due to inaccurate measurements of exposure and/or of measurement of oxidative stress biomarkers and missing information on the blinding of the research personnel. There may be no or an inconsistent effect of RF-EMF on biomarkers of oxidative stress in the brain, liver, blood, plasma and serum, and in the female reproductive system in animal experiments but the evidence is of very low certainty. There may be an increase in biomarkers of oxidative stress in testes, serum and thymus of rodents but the evidence is of very low certainty. Future studies should improve experimental designs and characterization of exposure systems as well as the use of validated biomarker measurements with positive controls.

Other: This review was partially funded by the World Health Organization. The protocol for this review is registered in PROSPERO (https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42021235573) and published in Environment International (https://doi.org/10.1016/j.envint.2021.106932) (Henschenmacher et al., 2022).

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024005269

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Occupational exposure to radiofrequency electromagnetic fields and brain tumor risk: application of the INTEROCC job-exposure matrix

Maxime Turuban, Hans Kromhout, Javier Vila, Miquel Vallbona-Vistos, Frank de Vocht , Baldi, L Richardson, G Benke, D Krewski, E Parent, S Sadetzki, B Schlehofer, J Schuz, J Siemiatycki, M van Tongeren, A Woodward, E Cardis, M Turner. Occupational exposure to radiofrequency electromagnetic fields and brain tumor risk: application of the INTEROCC job-exposure matrix. International J Cancer. First published: 20 September 2024. doi: 10.1002/ijc.35182.

Abstract

Radiofrequency electromagnetic fields (RF-EMF, 100 kHz to 300 GHz) are classified by IARC as possibly carcinogenic to humans (Group 2B). This study evaluates the potential association between occupational RF-EMF exposure and brain tumor risk, utilizing for the first time, a RF-EMF job-exposure matrix (RF-JEM) developed in the multi-country INTEROCC case-control study. Cumulative and time-weighted average occupational RF-EMF exposures were estimated for study participants based on lifetime job histories linked to the RF-JEM using three different methods: 1) by considering RF-EMF intensity among all exposed jobs, 2) by considering RF-EMF intensity among jobs with an exposure prevalence ≥ the median exposure prevalence of all exposed jobs, and 3) by considering RF-EMF intensity of jobs of participants who reported RF-EMF source use. Stratified conditional logistic regression models were used, considering various lag periods and exposure time windows defined a priori. Generally, no clear associations were found for glioma or meningioma risk. However, some statistically significant positive associations were observed including in the highest exposure categories for glioma for cumulative and time-weighted average exposure in the 1-4 year time window for electric fields (E) in the first JEM application method (ORs = 1.36, 95% CI 1.08, 1.72 64 and 1.27, 95% CI 1.01, 1.59 respectively), as well as for meningioma for cumulative exposure in the 5-9 year time window for electric fields (E) in the third JEM application method (OR = 2.30, 95% CI 1.11, 4.78). We did not identify convincing associations between occupational RF-EMF exposure and risk of glioma or meningioma.

What's New?

Radiofrequency electromagnetic fields have been classified as possibly carcinogenic to humans. Here, the authors applied a novel job-exposure matrix to investigate the link between occupational radiofrequency electromagnetic field exposure and brain tumors within the multi-country INTEROCC case–control study. The findings revealed no clear associations, despite some positive findings for gliomas and meningiomas in the 1- to 4- and 5- to 9-year exposure windows. The study underlines the applicability of the job-exposure matrix in occupational research and the need to further investigate the association between brain tumors and occupational radiofrequency electromagnetic field exposure

Conclusions

The previous SEM-based and the current JEM-based analyses (with three ways of linking the JEM to participant job histories) produced similar results that fail to show clear trends of associations between various RF-EMF exposure measures and either glioma or meningioma risk. Nevertheless, interpretation

of current findings remains challenging. The method of linking JEM estimates to a job only when RF source use was self-reported led to significantly lower exposure prevalences and similarly did not suggest clear evidence of increased risk from occupational IF-RF/RF-EMF exposures. Findings suggest that the RF-JEM could potentially be used in studies without self-reported information available on working with or near RF sources.

While we generally found no associations or inverse associations overall, a few positive associations between exposure to IF-RF/RF in cumulative and TWA exposure analyses were found with glioma in Method 1 in the highest exposure category in the 1- to 4-year time window of exposure, and with meningioma in Method 3 in the 5- to 9-year window prior to diagnosis/reference date. However, these statistically significant results, not consistent across analysis methods, could be due to chance, and will require verification in other independent studies. Integrating additional criteria when using JEM, such as exposure prevalence similar to Method 2 in this paper, when attributing exposure levels could be considered in further work. Future improvements of the RF-JEM, including by collecting and integrating personally measured exposure data could be considered.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/ijc.35182

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Link between Wi-Fi, cordless devices, mobile phone usage patterns, and behavioral problems among Japanese children: A prospective cohort study

Ajmal A, Yamazaki K, Tamura N, Ait Bamai Y, Yoshikawa T, Hikage T, Ikeda A, Kishi R. Link between Wi-Fi, cordless devices, mobile phone usage patterns, and behavioral problems among Japanese children: A prospective cohort study. Environ Res. 2024 Aug 1:119715. doi: 10.1016/j.envres.2024.119715.

Highlights

- Persistence and change in behavioral problem over one year were assessed and grouped into normal, persistent, improved, and concurrent groups.
- Above 75th percentile mobile phone calls duration via Internet was associated with concurrent total difficulties.
- Cordless phone use at home was associated with improved total difficulties.
- Longer cordless phone call durations were less likely to lead to persistent problematic prosocial behavior.
- The observed findings may not be related to RF-EMF and could be affected by residual confounding and chance findings.

Abstract

Background: With the recent advent of technology, it is important to confirm the health and safety of the youth. This study aimed to prospectively evaluate the relationship between Wi-Fi, cordless phones, and mobile phone usage patterns and behavioral problems.

Methods: This study involved 2,465 children aged 8-17 years from the Hokkaido Study on Environment and Children's Health from October 2020 to January 2021, with a follow-up from September 2021 to

March 2022. The mother-child dyad provided information on the presence of residential Wi-Fi and cordless phones, cordless phone call duration, and mobile phone usage pattern (duration of calls using mobile network and internet, online audio streaming, online video streaming, and playing online games) via a baseline questionnaire. Based on the scores on Strength and Difficulties Questionnaire at baseline and follow-up,the children were categorized into four groups: normal, persistent, improved, and concurrent.

Results: No significant association was found between Wi-Fi, mobile phone calls via mobile networks, and behavioral problems. Cordless phone at home had higher odds for improvement in total difficulty scores, and cordless phone for calling more than 4 minutes per week had lower odds of persistent problematic prosocial behavior. Longer duration of mobile phone calling via the internet (>40 min/week) had higher odds of concurrent total difficulties. Mobile phone calling via mobile network for <5 minutes per week had higher odds for improved total difficulty scores. Audio streaming via mobile phones for 60-120 minutes had lower odds of persistent total difficulties.

Conclusion: Our results showed sporadic findings between residential RF-EMF indoor sources and mobile phone usage pattern. These observed findings could be affected by residual confounding and chance findings. Ongoing follow-up studies are necessary to further explore this association through detailed exposure assessment and addressing the potential limitations of our study.

https://pubmed.ncbi.nlm.nih.gov/39096992/

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Evaluating the Effect on Heart Rate Variability of Adults Exposed to Radio-Frequency Electromagnetic Fields in Modern Office Environment

Dale S, Reiz R, Popa S, Ardelean-Dale A, Keller J, Geier JU. Evaluating the Effect on Heart Rate Variability of Adults Exposed to Radio-Frequency Electromagnetic Fields in Modern Office Environment. International Journal of Advanced Computer Science and Applications (IJACSA), 15(6), 2024. doi: 10.14569/IJACSA.2024.0150609.

Abstract

The objective of the study was to investigate whether heart rate variability (HRV) is an appropriate method to describe potential effects of RF-EMF on humans considering a modern office environment radiation level with the frequencies 1.8 GHz (DECT) and 2.45 GHz (Wi-Fi) and an exposure time of 10 min. The emitters were 1 m distant from the test subjects. The HRV parameters SDNN, RMSSD, LF and HF were recorded from 60 adults in three runs, totaling up to 154 recordings. Effects were evident for the parameter SDNN. In two runs, HRV changed from control to exposure phase, in one run from exposure phase to control. The cofactors smoking, coffee consumption, and the use of strong medications did not modulate EMF effects. HRV seems to be suitable to detect effects of radio-frequency electromagnetic fields on humans under certain conditions. In the future, prolonged exposure and new frequencies (5G) should be included in order to provide a better description of RF-EMF effects in modern office environments.

http://dx.doi.org/10.14569/IJACSA.2024.0150609.

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Hypersensitivity to man-made electromagnetic fields (EHS) correlates with immune responsivity to oxidative stress: a case report

Thoradit T, Chabi M, Aguida B, Baouz S, Stierle V, Pooam M, Tousaints S, Akpovi CD, Ahmad M. Hypersensitivity to man-made electromagnetic fields (EHS) correlates with immune responsivity to oxidative stress: a case report. Commun Integr Biol. 2024 Aug 4;17(1):2384874. doi: 10.1080/19420889.2024.2384874.

Abstract

There is increasing evidence that exposure to weak electromagnetic fields (EMFs) generated by modern telecommunications or household appliances has physiological consequences, including reports of electromagnetic field hypersensitivity (EHS) leading to adverse health effects. Although symptoms can be serious, no underlying mechanism for EHS is known and there is no general cure or effective therapy. Here, we present the case study of a self-reported EHS patient whose symptoms include severe headaches, generalized fatigue, cardiac arrhythmia, attention and memory deficit, and generalized systemic pain within minutes of exposure to telecommunications (Wifi, cellular phones), high tension lines and electronic devices. Tests for cerebral, cardiovascular, and other physiological anomalies proved negative, as did serological tests for inflammation, allergies, infections, auto-immune conditions, and hormonal imbalance. However, further investigation revealed deficits in cellular anti-oxidants and increased radical scavenging enzymes, indicative of systemic oxidative stress. Significantly, there was a large increase in circulating antibodies for oxidized Low-Density Lipoprotein (LDLox), byproducts of oxidative stress accumulating in membranes of vascular cells. Because a known primary effect of EMF exposure is to increase the concentration of cellular oxidants, we propose that pathology in this patient may be causally related to a resulting increase in LDLox synthesis. This in turn could trigger an exaggerated auto-immune response consistent with EHS symptoms. This case report thereby provides a testable mechanistic framework for EHS pathology with therapeutic implications for this debilitating and poorly understood condition.

Open access paper: https://www.tandfonline.com/doi/full/10.1080/19420889.2024.2384874

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Effects of 5G radiofrequency electromagnetic radiation on indicators of vitality and DNA integrity of in vitro exposed boar semen

Butković I, Vince S, Lojkić M, Folnožić I, Tur SM, Vilić M, Malarić K, Berta V, Samardžija M, Kreszinger M, Žaja IŽ. Effects of 5G radiofrequency electromagnetic radiation on indicators of vitality and DNA integrity of in vitro exposed boar semen. Theriogenology. 2024 Sep 25;230:243-249. doi: 10.1016/j.theriogenology.2024.09.025.

Abstract

The effects of radiofrequency electromagnetic radiation (RF-EMR) on semen quality have been in the spotlight in recent years, though research results to date have been contradictory. The effects of RF-EMR amongst others depend upon frequency, and there is currently no literature concerning the influence of 5G frequencies on both DNA integrity and spermatozoa vitality in males. The aim of this

study was to investigate the effect of 5G RF-EMR on sperm membrane integrity, mitochondrial potential, and DNA integrity of in vitro exposed semen of breeding boars. The study included semen samples of eight breeding boars of the Pietren breed and four breeding boars of the German Landrace breed, from 1.5 to 3.5 years in age. Freshly diluted semen of each boar was divided into a control (n = 12) and experimental group (n = 12). The samples of the experimental group were exposed for 2 hours to continuous RF-EMR at a single frequency (700 MHz, 2500 MHz and 3500 MHz) and an electromagnetic field strength of 10 V/m using a transverse gigahertz electromagnetic cell. Sperm DNA fragmentation was assessed using a Halomax® kit and sperm membrane integrity and mitochondrial potential was assessed using a PI⁄SYBR-14 LIVE⁄DEAD viability kit with JC-1. A significantly higher proportion of spermatozoa with DNA fragmentation was found in exposed semen samples for all frequencies compared to the control group. The highest DNA damage was recorded in semen samples exposed to 5G RF-EMR at 2500 MHz ($p < 0.01$) and 3500 MHz ($p < 0.05$) vs. control semen samples. A significantly higher proportion of spermatozoa with damaged cell membrane and good mitochondrial potential was recorded in semen samples exposed with 3500 MHz. In vitro exposure of breading boar semen to 5G RF-EMR significantly increases the proportion of DNA fragmentation. The harmful effect of 5G RF-EMR on the proportion of spermatozoa with damaged DNA was frequency dependent. The 3500 MHz frequency displayed the most harmful effects due to significant impacts on DNA integrity and spermatozoa vitality indicators.

https://pubmed.ncbi.nlm.nih.gov/39342826/

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Study of genotoxic and cytotoxic effects induced in human fibroblasts by exposure to pulsed and continuous 1.6 GHz radiofrequency

Massaro L, De Sanctis S , Franchini V, Regalbuto E, Alfano G, Focaccetti C, Benvenuto M, Cifaldi L, Sgura A, Berardinelli F, Marinaccio J, Barbato F, Rossi E, Nardozi D, Masuelli L, Bei R, Lista F. Study of genotoxic and cytotoxic effects induced in human fibroblasts by exposure to pulsed and continuous 1.6 GHz radiofrequency. Frontiers in Public Health, Vol 12. 2024. doi: 10.3389/fpubh.2024.1419525.

Abstract

Background The widespread use of radiofrequency (RF) sources, ranging from household appliances to telecommunications devices and military equipment, raises concerns among people and regulatory agencies about the potential health risks of RF exposure. Consequently, several *in vitro* and *in vivo* studies have been done to investigate the biological effects, in particular non-thermal, of this non-ionizing radiation. To date, this issue is still being debated due to the controversial results that have been reported. Furthermore, the impact of different RF signal modulations on biological systems remains poorly investigated. The present *in vitro* study aims to evaluate the cytotoxicity and genotoxicity of continuous or pulsed 1.6 GHz RF in human dermal fibroblasts (HDF).

Methods HDF cultures were exposed to continuous and pulsed 1.6 GHz RF, for 2 h, with Specific Absorption Rate (SAR) of 0.4 W/kg. The potential biological effects of 1.6 GHz RF on HDF were assessed with a multi-methodological approach, analyzing the effects on cell cycle, ultrastructure, protein expression, mitotic spindle, CREST stained micronuclei, chromosome segregation and γ-H2AX/53BP1 foci.

Results 1.6 GHz RF exposure modified proteins expression and morphology of HDF. Specifically, the expression of different heat-shock proteins (HSP) (i.e., HSP-90, HSP-60, and HSP-25) and phospho-AKT were affected. In addition, both continuous and pulsed RF modified the cytoskeletal organization in HDF and increased the number of lysosomes, while the formation of autophagosomes was observed only after pulsed RF exposure. Mitotic spindle anomalies were also found after exposure. However, no significant effect was observed on cell cycle, chromosome segregation, CREST-stained micronuclei and γ-H2AX/53BP1 foci.

Conclusion The results of the present study show the absence of genotoxic damage in 1.6 GHz RF exposed HDF and, although mitotic spindle alterations were observed, they did not have an aneugenic effect. On the other hand, changes in some proteins expression and cell ultrastructure in exposed HDF suggest that RF can potentially induce cell alterations at the morphological and molecular levels.

Excerpt

In this controversial scientific scenario, our results are in agreement with most *in vitro* findings on different cell models about the lack of genotoxic damage induced by RF, either clastogenic or aneugenic. Despite this, we find alterations of the mitotic spindle, with a significant increase in multipolar spindles following PW exposure and we also observed a tendency of RF to induce non-disjunction events with both signals. However, our study reveals an increase in these spindle abnormalities without a concomitant increase in MN-positive CREST, suggesting no aneuploidy effect probably due to spindle abnormalities reversion, as proposed by other authors (78). Nonetheless, this apparent discordant result requires further investigations.

The reported observations indeed highlight the complexity of cellular response to RF and emphasize the need for further investigations to clarify the overall biological effects of 1.6 GHz PW and CW RF, given the widespread and constant public RF-EMF exposure, mostly due to mobile communication devices.

Open access paper: https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2024.1419525

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Pulsed High-Power Radio Frequency Energy Can Cause Non-Thermal Harmful Effects on the BRAIN

Yaghmazadeh O. Pulsed High-Power Radio Frequency Energy Can Cause Non-Thermal Harmful Effects on the BRAIN. IEEE Open Journal of Engineering in Medicine and Biology, 5:50-53, 2024. doi: 10.1109/OJEMB.2024.3355301.

Abstract

High-power microwave applications are growing for both military and civil purposes, yet they can induce brain-related risks and raise important public health concerns. High-power sub-millisecond radio frequency energy pulses have been demonstrated to be able to induce neurological and neuropathological changes in the brain while being compliant with current regulatory guidelines' limits, highlighting the necessity of revising them.

Impact Statement

This commentary piece looks into the different mechanisms of interaction of pulsed versus continuous-wave RF energy radiation and the brain. It also highlights potential harmful effects of pulsed high-power RF energy on the brain.

Open access paper: https://ieeexplore.ieee.org/document/10402080

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External RF-EMF alters cell number and ROS balance possibly via the regulation of NADPH metabolism and apoptosis

Chow S-C, Zhang Y, Ng RWM , Hui S-YR , Solov'yov IA , Lui W-Y. External RF-EMF alters cell number and ROS balance possibly via the regulation of NADPH metabolism and apoptosis. Frontiers in Public Health. 12 (2024). doi: 10.3389/fpubh.2024.1425023.

Abstract

The influence of weak radio-frequency electromagnetic field (RF-EMF) on living organisms raises new concern because of the Industrial, Scientific, and Medical (ISM) frequency band at 6.78 MHz being promoted by the AirFuel Alliance for mid-range wireless power transfer (WPT) applications and product development. Human exposure to the RF-EMF radiation is unavoidable. In this study, we employed *in vitro* cell culture and molecular biology approach coupled with integrated transcriptomic and proteomic analyses to uncover the effects of RF-EMF on cells at molecular and cellular levels. Our study has demonstrated that weak RF-EMF is sufficient to exert non-thermal effects on human umbilical vein endothelial cells (HUVEC). Exposure of weak RF-EMF promotes cell proliferation, inhibits apoptosis and deregulates ROS balance. Alteration of several signaling pathways and key enzymes involved in NADPH metabolism, cell proliferation and ferroptosis were identified. Our current study provide solid evidence for the first time that the present safety standards that solely considered the thermal effect of RF-EMF on cell tissue are inadequate, prompt response and modification of existing Guidelines, Standards and Regulation are warranted.

Open access paper: https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2024.1425023/full

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No observable non-thermal effect of microwave radiation on the growth of microtubules

Hammarin G, Norder P, Harimoorthy R, Chen G, Berntsen P, Widlund PO, Stoij C, Rodilla H, Swenson J, Brändén G, Neutze R. No observable non-thermal effect of microwave radiation on the growth of microtubules. Sci Rep. 2024 Aug 7;14(1):18286. doi: 10.1038/s41598-024-68852-3.

Abstract

Despite widespread public interest in the health impact of exposure to microwave radiation, studies of the influence of microwave radiation on biological samples are often inconclusive or contradictory. Here we examine the influence of microwave radiation of frequencies 3.5 GHz, 20 GHz and 29 GHz on the growth of microtubules, which are biological nanotubes that perform diverse functions in eukaryotic

cells. Since microtubules are highly polar and can extend several micrometres in length, they are predicted to be sensitive to non-ionizing radiation. Moreover, it has been speculated that tubulin dimers within microtubules might rapidly toggle between different conformations, potentially participating in computational or other cooperative processes. Our data show that exposure to microwave radiation yields a microtubule growth curve that is distorted relative to control studies utilizing a homogeneous temperature jump. However, this apparent effect of non-ionizing radiation is reproduced by control experiments using an infrared laser or hot air to heat the sample and thereby mimic the thermal history of samples exposed to microwaves. As such, no non-thermal effects of microwave radiation on microtubule growth can be assigned. Our results highlight the need for appropriate control experiments in biophysical studies that may impact on the sphere of public interest.

Open access paper: https://www.nature.com/articles/s41598-024-68852-3

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Exploring edible bird nest's potential in mitigating Wi-Fi's impact on male reproductive health

Maluin SM, Jaffar FHF, Osman K, Zulkefli AF, Mat Ros MF, Ibrahim SF. Exploring edible bird nest's potential in mitigating Wi-Fi's impact on male reproductive health. Reprod Med Biol. 2024 Sep 11;23(1):e12606. doi: 10.1002/rmb2.12606.

Abstract

Purpose: This study aimed to evaluate the protective effects of edible bird nest (EBN) against the detrimental impact of Wi-Fi on male reproductive health. Specifically, it examines whether EBN can mitigate Wi-Fi-induced changes in male reproductive hormones, estrogen receptors (ER), spermatogenesis, and sperm parameters.

Methods: Thirty-six adult male rats were divided into six groups (n = 6): Control, Control EBN, Control E2, Wi-Fi, Wi-Fi+EBN, and Wi-Fi+E2. Control EBN and Wi-Fi+EBN groups received 250 mg/kg/day EBN, while Control E2 and Wi-Fi+E2 groups received 12 µg/kg/day E2 for 10 days. Wi-Fi exposure and EBN supplementation lasted eight weeks. Assessments included organ weight, hormone levels (FSH, LH, testosterone, and E2), ERα/ERβ mRNA and protein expression, spermatogenic markers (c-KIT and SCF), and sperm quality.

Results: Wi-Fi exposure led to decreased FSH, testosterone, ERα mRNA, and sperm quality (concentration, motility, and viability). EBN supplementation restored serum FSH and testosterone levels, increased serum LH levels, and the testosterone/E2 ratio, and normalized mRNA ERα expression. Additionally, EBN increased sperm concentration in Wi-Fi-exposed rats without affecting motility or viability.

Conclusions: EBN plays a crucial role in regulating male reproductive hormones and spermatogenesis, leading to improved sperm concentration. This could notably benefit men experiencing oligospermia due to excessive Wi-Fi exposure.

Excerpts

Wi-Fi exposure setting: For Wi-Fi exposure, this study utilized the TP-LINK AC750 Wireless Dual Band Wi-Fi Router Archer C20 (Shenzhen, China). This router features three external antennas, emitting signals at a frequency of 2.45 GHz using the IEEE 802.11n standard. The router was positioned 20 cm away from the rat cages and constantly exchanged data with a Raspberry Pi device through a ping protocol.3 The router was selected for its minimal vibration and noise output, which is typical for standard Wi-Fi routers used in laboratory settings. Additionally, the rats were housed in a controlled environment designed to minimize external disturbances, ensuring the reliability of our findings related to Wi-Fi exposure effects on male reproductive health.

Conclusion: This study highlights the negative impact of eight weeks of Wi-Fi exposure on sperm quality, including decreased concentration, motility, and viability, which can be ascribed to changes in male reproductive hormones. EBN supplementation appears to be a preventive intervention, significantly increasing gonadotrophin and testosterone levels, as well as sperm concentration in Wi-Fi-exposed rats, but not influencing sperm motility or viability. Furthermore, it increases the T/E2 ratio and restores estrogenic activity in the testes, resulting in enhanced sperm concentration. The study also reveals a discrepancy between the impacts of EBN supplementation and E2 treatment on sperm concentration in a Wi-Fi-exposed setting, emphasizing EBN's unique protective properties without adverse effects on male reproduction. In conclusion, EBN supplementation effectively restores spermatogenesis capabilities that are affected by Wi-Fi-induced damage. This is achieved through the modulation of male reproductive hormones, with a primary influence on sperm concentration. Nevertheless, further research is necessary to fully understand the mechanisms and establish safe usage limits for maximizing the benefits of EBN while minimizing potential risks.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/rmb2.12606

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Spots with Extremely High Radiofrequency Radiation After Deployment of 5G Base Stations in Stockholm, Sweden

Hardell L, Koppel T. Spots with Extremely High Radiofrequency Radiation After Deployment of 5G Base Stations in Stockholm, Sweden. Ann Clin Med Case Rep. 2024; V14(4): 1-8.

Abstract

During recent years there is an on-going deployment of 5G base stations for radiofrequency [RF] communication in Sweden as well in many other countries. This is made without investigations on risks to human health and the environment. Since 2016 we have made several measurements of environmental exposure to RF radiation in Stockholm, Sweden, including previous generations and now also 5G. In the current study, performed in October 2023, the broadband meter Narda-550 with the probe EF-1891 was used. It gives results in the root mean square [RMS] mode, thus not peak levels. Both the International Commission on Non-Ionizing Radiation Protection [ICNIRP] and the US Federal Communications Commission [FCC] base their guidelines on RMS levels of RF radiation. Measurements were made in similar city areas as in our previous studies. Results show that the RF radiation has increased substantially. High maximum levels were found at e.g. the Central Railway Station [3 637 191

µW/m2], and popular walking streets such as Mäster Samuelsgatan [11 613 976 µW/m2], and Drottninggatan [5 271 555 µW/m2]. The peak values would be much higher. These levels are in the same magnitude or even higher than those measured in homes of persons that rapidly developed symptoms of the microwave syndrome after installation of 5G, usually in combination with 4G+, in the neighborhood. They are also substantially higher than levels that have previously been linked to cancer and the microwave syndrome in studies of people living near base stations and masts from previous generations of telecommunications.

Open access paper: https://acmcasereport.org/wp-content/uploads/2024/09/ACMCR-v14-2262-3-1.pdf

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Mobile Phone Emissions in 5G FR1: Using Statistic Inferences and Deep Learning for Empiric Features Extraction

Miclaus S, Deaconescu DB, Vatamanu D, Buda AM. Mobile Phone Emissions in 5G FR1: Using Statistic Inferences and Deep Learning for Empiric Features Extraction. *2024 IEEE International Symposium on Measurements & Networking (M&N)*, Rome, Italy, 2024, pp. 01-06, doi: 10.1109/MN60932.2024.10615263.

Abstract

As the primary source of human exposure to electromagnetic fields, the emission of a 5G mobile phone is quantified for several mobile applications use. Following the time variability of the exposure, its peak levels and their statistic distributions, together with the time-frequency change in the spectrograms, we emphasize the peculiarities of the exposure in connection to modulation scheme used and to the application. The results show notable differences in amplitude probability densities, in complementary cumulative density functions and in repeatability of time-frequency features of the emissions.

Excerpts

It has been recently proved that the main exposure source of a person is the mobile phone itself [5], [6]. The study results of [7] confirmed that the human exposure in a 5G network is dominated by the uplink, and can be ten times larger than the downlink exposure....

Conducting measurements in real-life situations contributes to true assessment of the field exposure impact. It is essential to interpret all the findings on the background of dosimetric determinations and based on present regulatory guidelines [16], [17]. However, studies like [18] - [20] clearly pointed out that “cell phones emit a succession of pulse trains of different durations, the instantaneous fields of such signals allow activation of molecular, electronic, and protonic components within cells that have different thresholds and relaxation times, enriching the non-thermal effects of radiofrequency fields”.

In the current work we aimed to analyze the exposure situation generated by a 5G mobile phone in a static position, while emitting signals in a 100 MHz bandwidth centered on 3.58 GHz. While using four different mobile applications running on the phone ...

An Iphone 14pro (model A 2890, Apple, Zhengzhou, China) was the source of the emissions. It was maintained in a stationary position and connected to the 5G mobile network - Orange Romania

operator. The central frequency was f=3.58 GHz, the bandwidth was 100 MHz and Time Division Multiple Access (TDMA) scheme was used....

... the phone was situated at the cell edge and it received a good downlink signal.

The receiving system was composed of a signal analyzer model FSW from Rhode & Schwarz, with a real time bandwidth of 160 MHz connected to a receiving antenna model Aaronia Omnilog 30800 (Fig. 1)....

... video streaming conducted to the highest mean emitted powers, while upload provokes the highest peak powers. Crest factors are the largest when a file is uploaded, and they can exceed 20 dB....

Variations of 19 dB around mean power is equivalent to a factor of approximately 8 x 10**3. Such a large variability during so short time (ms), may pose challenging biological response. The trends in the excessive exceedance of the mean power depend at least on mobile application type and on the modulation scheme. From this perspective, the tail features of time-variability of the exposure level may trigger unexpected consequences....

CONCLUSIONS

A mobile phone connected to a 5G-NR network in FR1 band was investigated for its emitted EMF level and the associated time-variability characterization (during 250 ms), in four situations of usage: during file-upload, file-download, video call and Internet streaming. The measurement set-up consisted in a receiving antenna mostly planar and parallel to the phone’s display connected to a vector signal analyzer with a capability of analysing bandwidth larger than the communication bandwidth (100 MHz). The antenna collected the field of the phone at 30 cm distance from it, and had an omnidirectional pattern in azimuth....

All the results showed that the uplink EMF level is far below the safe limit based on thermal effects of human exposure. However, other important features evolved and they may be further linked to the non-thermal/specific effects of microwaves....

When it comes to the prevalence of peaks in the exposure, it resulted that crest factors varied mostly in function of the mobile application used but also, in a lower measure, in function on the modulation scheme. The largest crest factors were more than one order of magnitude higher than the smallest ones, overall. Mean and peak powers of emissions could deviate from each other with approximately two orders of magnitude, for the same mobile application. Such short and pronounced extremes should be carefully investigated from the biological endpoint of view.

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Estimates and measurements of radiofrequency exposures in smart-connected homes

Joyner K, Milligan M, Knipe P. Estimates and measurements of radiofrequency exposures in smart-connected homes. Bioelectromagnetics. 2024 Jul 18. doi: 10.1002/bem.22518.

Abstract

The aim of this research was to quantify the levels of radiofrequency electromagnetic energy (RF-EME) in a residential home/apartment equipped with a range of wireless devices, often referred to as internet of things (IoT) devices or smart devices and subsequently develop a tool that could be useful for

estimating the levels of RF-EME in a domestic environment. Over the course of 3 years measurements were performed in peoples' homes on a total of 43 devices across 16 device categories. Another 12 devices were measured in detail in a laboratory setup. In all a total of 55 individual devices across 23 device categories were measured. Based on this measurement data we developed predictive software that showed that even with a single device in 23 device categories operating near maximum they would, in total, produce exposures at a distance of 1 m of 0.17% of the ICNIRP (2020) public exposure limits. Measurements were also made in two separate smart apartments—one contained over 50 IoT devices and a second with over 100 IoT devices with the devices driven as hard as could reasonably be achieved. The respective 6-min average exposure level recorded were 0.0077% and 0.44% of the ICNIRP (2020) 30-min average public exposure limit.

Excerpts

.... Based on all of these measurements, we have developed predictive software that can be used to estimate exposure levels on a conservative basis by incorporating a 3 dB enhancement to produce a realistic upper bound for the exposure estimation. The RF estimator tool, which is available from the Mobile & Wireless Forum (MWF) website (www.mwfai.org), has a drop-down menu that allows the selection of multiple IoT devices and separation distances and returns an estimate of the exposure level that could be expected in the home environment. Devices in neighboring rooms can be included in the software by selecting the appropriate device and distance. However, because of the inverse square dependence with distance and the attenuation through walls, the majority contribution in a particular room is determined by the proximity of devices in that room. Future work will include the expansion of the device categories and the inclusion of wall/window attenuation to account for neighboring homes and apartments.

CONFLICT OF INTEREST STATEMENT This work was fully funded by the Mobile and Wireless Forum (www.mwfai.org) and that KJ and MM are contractored by the MWF.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/bem.22518

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Review Antenna Design for Modern Mobile Phones: A Review

Wang Y, Sun L, Du Z, Zhang Z. Review Antenna Design for Modern Mobile Phones: A Review. Electromagnetic Science, 2(2):1-36. June 2024, doi: 10.23919/emsci.2023.0052.

Abstract

Due to limited antenna space, high communication requirements, and strict regulatory constraints, the design of antennas for modern mobile phones has become an exceedingly challenging task. In recent years, numerous studies have been conducted in this area, leading to significant advancements. This review paper comprehensively summarizes recent progress made in antenna design for modern mobile phones. Firstly, the challenges faced in antenna design for modern mobile phones are described, including bandwidth enhancement, integration and decoupling techniques, mm-wave array antennas, satellite communication antennas, as well as interactions between mobile antennas and the human body. Secondly, the basic antenna types (such as inverted-F, slot, loop, and planar inverted-F antennas) commonly used in modern metal-bezel mobile phones along with their key characteristics are briefly

summarized. Thirdly, the commonly employed methods used in practical applications for designing wideband antennas within compact sizes and achieving decoupling among multiple antennas with wide bandwidths are collected. Fourthly, recent advances in the design of compact, wideband, and wide-angle scanning mm-wave arrays for modern mobile phones are summarized. Fifthly, recent progress made in satellite communication antenna designs for modern mobile phones, including broadside and end-fire radiation patterns, is presented. Sixthly, recent studies on the interaction between mobile antennas and the human body are briefly concluded. Finally, the future challenge of antenna design for mobile phones is briefly discussed. It is our hope that this comprehensive review will provide readers with a systematic understanding of antenna design principles applicable to modern mobile phones.

Excerpts

"Currently, with the improvement of communication requirements and the evolution of communication specifications, the number of antennas in smartphones has reached 20–30 (as depicted in Figure 3), including the following antennas:

- Four antennas for LB (low band): 698–960 MHz;
- Four antennas for MHB (mid- and high-band) MIMO operation: 1710–2690 MHz;
- Four antennas for 5G New Radio (NR) band MIMO operation: 3300–4200 MHz & 4400–5000 MHz;
- Two or more dual-band millimeter-wave AiP antennas: 24.25-29.50 GHz and 37.00-43.50 GHz;
- One or more satellite communication antennas: the operating band is the L- or S-band;
- Two GNSS (global navigation satellite system) antennas: GPS L5 at 1176 MHz and GPS L1 at 1575 MHz;
- Two to four tri-band WiFi (wireless fidelity) and BT (Bluetooth) antennas: 2400–2484 MHz, 5150–5350 MHz, and 5725–5825 MHz;
- One NFC (near field communication) antenna: 13.56 MHz;
- Three UWB (ultra-wideband) antennas: 6240–6740 MHz and 7750–8250 MHz."

"In [199], the interaction principle of antenna radiation fields with nearby human bodies are analyzed by using electromagnetic boundary conditions. Under these boundary conditions, the horizontal E-field penetrates human tissue more easily than the vertical E-field does [199], as shown in Figure 49. Thus, mobile antennas with a vertical E-field have a higher on-body efficiency and lower SAR. As shown in Figure 50, a smartwatch antenna with a vertical E-field has a weak E-field in the human body, thus, the performance of an antenna with a vertical E-field is approximately 4 dB greater than that of an antenna with a horizontal E-field [200], [201]. Additionally, the vertical E-field method can also be applied to ear-bar TWS earphones, which can improve the antenna performance from 19.1% to 30.9% with a vertical E-field [202]."

Open access paper: https://ieeexplore.ieee.org/document/10636175

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High Frequency Electromagnetic Field Exposure in Paediatric and Female Patients with Implanted Cardiac Pacemaker

Bacova F, Benova M, Psenakova Z, Smetana M, Pacek M, Ochodnicky J. High Frequency Electromagnetic Field Exposure in Paediatric and Female Patients with Implanted Cardiac Pacemaker. *Applied Sciences*. 2024; 14(16):7198. doi: 10.3390/app14167198.

Abstract

This article investigates the effects of electromagnetic field (EMF) from mobile phones on human tissues and implanted medical devices. The intensity of the electric field (E) is evaluated based on simulations and measurements of various exposure scenarios. An area of interest is the case of a person with an implanted device (heart pacemaker) who may be affected by this exposure. Due to the rapid development of communication technologies and the growing awareness of the potential health risks of radio frequency (RF) EMF, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) has established exposure limits within the European Union. Our study models and analyses EMF values in human tissues in an ideal environment, in a situation where a person uses a mobile phone in the DCS (Digital Cellular System) band, including the case of a person with an implanted pacemaker. Pilot simulations were verified by experimental measurements. Based on them, specific human models with the best matching results were selected for modelling other possible interactions of exogenous EMF and cardiac pacemaker in the same situations and locations

Excerpt

Based on our simulations and experimental measurements, we found that maintaining a minimum distance of 15 cm between the mobile phone and the pacemaker is not sufficient to ensure patient safety. Our results show that even at a distance of 30 cm, the E values for the models were: MM—54.96 V/m, for Child—65.34 V/m, for Laura—62.81 V/m, and measurements—52.72 In M. In the case of the Child and Laura complex models, the E values still exceeded the exposure limit of 58 V/m for a frequency of 1800 MHz. Our recommendation is to push this limit up to more than 30 cm.

Another recommendation is protective equipment that reduces the exposure of parts of the human body to EMF. However, these aids must have a certificate of satisfactory EM compatibility.

Open access paper: https://www.mdpi.com/2076-3417/14/16/7198

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Importance of magnetic information for neuronal plasticity in desert ants

Grob R, Müller VL, Grübel K, Fleischmann PN. Importance of magnetic information for neuronal plasticity in desert ants. PNAS. 2024. 121 (8) e2320764121. doi: pnas.2320764121.

Significance

The Earth's magnetic field is an essential navigational cue for many animal species. However, where in the brain magnetic information is processed is still little understood. In this paper, we analyzed structural neuronal plasticity in the brain of Cataglyphis desert ants following sky-compass calibration under permanently manipulated magnetic field conditions. Our results demonstrate that information from the Earth's magnetic field is integrated into the ants' internal compass (central complex) and into

the learning and memory centers (mushroom bodies). Together with our behavioral analyses, the results show that the ants use magnetic information both as a navigational compass and as a reference system for visual compass calibration.

Abstract

Many animal species rely on the Earth's magnetic field during navigation, but where in the brain magnetic information is processed is still unknown. To unravel this, we manipulated the natural magnetic field at the nest entrance of Cataglyphis desert ants and investigated how this affects relevant brain regions during early compass calibration. We found that manipulating the Earth's magnetic field has profound effects on neuronal plasticity in two sensory integration centers. Magnetic field manipulations interfere with a typical look-back behavior during learning walks of naive ants. Most importantly, structural analyses in the ants' neuronal compass (central complex) and memory centers (mushroom bodies) demonstrate that magnetic information affects neuronal plasticity during early visual learning. This suggests that magnetic information does not only serve as a compass cue for navigation but also as a global reference system crucial for spatial memory formation. We propose a neural circuit for integration of magnetic information into visual guidance networks in the ant brain. Taken together, our results provide an insight into the neural substrate for magnetic navigation in insects.

https://www.pnas.org/doi/10.1073/pnas.2320764121

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A critical appraisal of the WHO 2024 systematic review of the effects of RF-EMF exposure on tinnitus, migraine/headache, and non-specific symptoms (WHO SR 7)

Frank J, Melnick R, Moskowitz J, on behalf of the International Commission on the Biological Effects of Electromagnetic Fields (ICBE-EMF). A critical appraisal of the WHO 2024 systematic review of the effects of RF-EMF exposure on tinnitus, migraine/headache, and non-specific symptoms. Reviews on Environmental Health. 2024. doi: 10.1515/reveh-2024-0069.

Abstract

The World Health Organization (WHO) in 2012 initiated an expert consultation about research on the health effects of radio-frequency electromagnetic fields (RF-EMF) for a WHO monograph that was last updated in 1993. The project was abandoned over concerns about the quality of the commissioned review papers. The WHO restarted the project in 2019 by commissioning ten systematic reviews (SRs) of the research on RF-EMF exposure and adverse biological and health outcomes in laboratory animals, cell cultures, and human populations. The second of these SRs, published in 2024, addresses human observational studies of RF-EMF exposure and non-specific symptoms, including tinnitus, migraine/headache, and sleep disturbance. The present commentary is a critical appraisal of the scientific quality of this SR (SR7) employing criteria developed by the Oxford Centre for Evidence-Based Medicine. Based upon our review, we call for a retraction of SR7 and an impartial investigation by unconflicted experts of the currently available evidence and future research priorities.

Conclusion

To summarize, the way in which any epidemiologically unsophisticated reader is likely to be misled by this SR is clear. It appears to conclude unequivocally that the body of scientific evidence reviewed supports the safety of current (e.g. ICNIRP-based) population exposure limits for RF-EMF [10]. We reiterate that, on the contrary, this body of evidence is not adequate to either support or refute the safety of current exposure limits – largely due to the very small number and low methodological quality of the relevant primary studies to date, and the fundamental inappropriateness of meta-analysis for the handful of very heterogeneous primary studies identified by Röösli et al. [3] for each of the exposure/outcome combinations analysed.

We therefore call for a retraction of the SR by Röösli et al., and an impartial international investigation, by unconflicted experts, of both the currently available evidence base on these issues, as well as related research priorities for the future. That investigation should particularly address, above and beyond the topic of priority health outcomes to be researched (which was already assessed in the international expert consultation by WHO in 2018) [2], and the need for improved methods of accurately measuring RF-EMF exposures, suitable for large human observational studies in the general population – the Achilles heel of the current literature.

Open access paper: https://www.degruyter.com/document/doi/10.1515/reveh-2024-0069/html

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WHO to build neglect of RF-EMF exposure hazards on flawed EHC reviews? Case study demonstrates how "no hazards" conclusion is drawn from data showing hazards (WHO SR 3)

Nordhagen E, Flydal E. WHO to build neglect of RF-EMF exposure hazards on flawed EHC reviews? Case study demonstrates how "no hazards" conclusion is drawn from data showing hazards. *Reviews on Environmental Health*. 2024. doi: 10.1515/reveh-2024-0089.

Abstract

We examined one of the first published of the several systematic reviews being part of WHO's renewed initiative to assess the evidence of associations between man-made radiofrequency electromagnetic radiation (RF-EMF) and adverse health effects in humans. The examined review addresses experimental studies of pregnancy and birth outcomes in non-human mammals. The review claims that the analyzed data did not provide conclusions certain enough to inform decisions at a regulatory level. Our objective was to assess the quality of this systematic review and evaluate the relevance of its conclusions to pregnant women and their offspring. The quality and relevance were checked on the review's own premises: e.g., we did not question the selection of papers, nor the chosen statistical methods. While the WHO systematic review presents itself as thorough, scientific, and relevant to human health, we identified numerous issues rendering the WHO review irrelevant and severely flawed. All flaws found skew the results in support of the review's conclusion that there is no conclusive evidence for nonthermal effects. We show that the underlying data, when relevant studies are cited correctly, support the opposite conclusion: There are clear indications of detrimental nonthermal effects from RF-EMF exposure. The many identified flaws uncover a pattern of systematic skewedness aiming for uncertainty hidden behind complex scientific rigor. The skewed methodology and low quality of this review is highly concerning, as it threatens to undermine the trustworthiness and professionalism of the WHO in the area of human health hazards from man-made RF-EMF.

Conclusions

The rigorous protocol and extensive analyses presented in EHC2023 and its protocol, convey an impression of serious science, credibility, and reliability. However, we have shown that this is not the case.

We found EHC2023 to be a massive work with a rigorous and complex protocol and extensive and complex statistical analyses. A consequence of the complexity is that it can be assumed that no average reader – not even professionals – will check the results of the review, if not for other reasons, because of the major effort needed. Thereby, scientific exchange, debate and control is impeded and reduced to a matter of trust.

We had the opportunity to spend time on an in-depth analysis of representative parts of EHC2023 to assess its quality based to the extent possible on the review's own premises – that is, independent of our opinion about the professional premises chosen.

We cannot prove that the flaws and omissions are deliberately added to reach wanted conclusions, as we have next to no information about the authors, neither of the process behind the authoring EHC2023 or its protocol. Anyhow, and whatever the cause, the EHC2023 review is clearly of such a low quality, also when evaluated within the thermal only tradition, that its conclusions are without scientific value.

Our findings show that the conclusion of EHC2023 is not well-founded, and therefore the final conclusions of EHC2023 that no conclusion can be drawn that are (EHC2023, p. 31) "certain enough to inform decisions at a regulatory level" cannot be trusted. The errors, flaws and omissions are grave enough to render EHC2023 unscientific and unethical, and it should therefore be retracted.

As it now stands, the conclusion of ECH2023 stands out as what appears to be a manufactured argument for current regulations being adequate to protect the health of human mothers and their offspring. Manipulating and skewing research results in order to manufacture a wanted conclusion is a well-known strategy to avoid stricter regulations [11], [12], [13], [14], [15]. Further investigations and better sources would be needed to prove such an assault on humanity to be the case as to EHC2023.

EHC2023 is just one of several studies commissioned by the same organization (WHO EHC no. 137) and states clearly that consistency has been assured in the protocols for these studies. Our analysis of EHC2023 may in this view be seen as a case study of the results of the entire WHO EHC undertaking: Since many of our concerns are related to core elements of the protocol, there are good reasons also to question the quality of all present and forthcoming results being part of the WHO EHC undertaking unless a thorough revision of its course is made.

Open access paper: https://www.degruyter.com/document/doi/10.1515/reveh-2024-0089/html

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A comprehensive review of 5G NR RF-EMF exposure assessment technologies: fundamentals, advancements, challenges, niches, and implications

Korkmaz E, Aerts S, Coesoij R, Bhatt CR, Velghe M, Colussi L, Land D, Petroulakis N, Spirito M, Bolte J. A comprehensive review of 5G NR RF-EMF exposure assessment technologies: fundamentals, advancements, challenges, niches, and implications. Environ Res. 2024 Jul 6;260:119524. doi: 10.1016/j.envres.2024.119524.

Highlights

- Monitoring exposure to radiofrequency electromagnetic fields (RF-EMF) is crucial for environmental health and risk assessment
- A comprehensive review of the diverse landscape of RF-EMF assessment tools was missing.
- There is a definite need for cost-effective and long-lasting EMF sensors.
- Custom-developed RF-EMF measurement tools lack a standardized framework for comparison and validation.

Abstract

This review offers a detailed examination of the current landscape of radio frequency (RF) electromagnetic field (EMF) assessment tools, ranging from spectrum analyzers and broadband field meters to area monitors and custom-built devices. The discussion encompasses both standardized and non-standardized measurement protocols, shedding light on the various methods employed in this domain. Furthermore, the review highlights the prevalent use of mobile apps for characterizing 5G NR radio network data. A growing need for low-cost measurement devices is observed, commonly referred to as “sensors” or “sensor nodes”, that are capable of enduring diverse environmental conditions. These sensors play a crucial role in both microenvironmental surveys and individual exposures, enabling stationary, mobile, and personal exposure assessments based on body-worn sensors, across wider geographical areas. This review revealed a notable need for cost-effective and long-lasting sensors, whether for individual exposure assessments, mobile (vehicle-integrated) measurements, or incorporation into distributed sensor networks. However, there is a lack of comprehensive information on existing custom-developed RF-EMF measurement tools, especially in terms of measuring uncertainty. Additionally, there is a need for real-time, fast-sampling solutions to understand the highly irregular temporal variations EMF distribution in next-generation networks. Given the diversity of tools and methods, a comprehensive comparison is crucial to determine the necessary statistical tools for aggregating the available measurement data.

Conclusions

The objective of this review was to establish a groundwork for progress in the field of RF-EMF exposure assessment, ultimately contributing to a more thorough and efficient assessment. This review provides a comprehensive overview of the current state-of-the-art concerning RF-EMF measuring instruments. It covers a wide array of tools, such as spectrum analyzers, broadband field meters, area monitors, personal exposimeters, and custom-built instruments, as well as the existing measurement protocols, encompassing both standardized and non-standardized methods. In addition, we also have presented some of the most commonly used mobile apps for collecting 5G NR radio network data, which have also been used in RF-EMF exposure assessments. However, it is not yet clear on how accurate the measurement results of these apps are and how they compare among themselves and to more sophisticated tools.

Most importantly, this review revealed the need for cost-effective and long-lasting measurement devices or sensors that are capable of collecting data at a high time resolution in various frequency bands, as well as withstanding various environmental conditions. These sensors are essential for conducting stationary, mobile, and personal exposure assessments across larger geographical areas, time intervals, and populations than current capabilities allow. Additionally, it is important to recognize that the specific requirements for these sensors differ based on their intended usage, e.g., on-body measurement devices need to take into account the influence of the body, vehicle-integrated sensors the influence of the speed and the relative position of the sensor on the vehicle, and sensors on infrastructure the influence of the height and the building materials. Furthermore, there exists a demand for real-time, fast-sampling solutions to comprehend the highly irregular temporal variations in EMF distribution within next-generation networks.

Moreover, there is a notable absence of extensive information regarding currently employed custom-developed RF-EMF measurement tools, particularly with respect to measuring uncertainty. Considering the diversity of tools and methodologies in use, conducting a thorough comparison becomes crucial to identify the necessary statistical tools for aggregating the available measurement data.

A more in-depth discussion relating the current 5G NR assessment methods to measurement equipment is intended for a follow-up study, which will describe more in detail the requirements, opportunities, and priorities for new, low-cost, custom-built measurement equipment.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0013935124014294

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The effect of exposure to radiofrequency electromagnetic fields on cognitive performance in human experimental studies: Systematic review and meta-analyses (SR 6)

Pophof B, Kuhne J, Schmid G, Weiser E, Dorn H, Henschenmacher B, Burns J, Danker-Hopfe H, Sauter C, Pophof B. The effect of exposure to radiofrequency electromagnetic fields on cognitive performance in human experimental studies: Systematic review and meta-analyses. Environment International (2024). doi: 10.1016/j.envint.2024.108899.

Abstract

Background The objective of this review is to evaluate the associations between short-term exposure to radiofrequency electromagnetic fields (RF-EMF) and cognitive performance in human experimental studies.

Methods Online databases (PubMed, Embase, Scopus, Web of Science and EMF-Portal) were searched for studies that evaluated effects of exposure to RF-EMF on seven domains of cognitive performance in human experimental studies. The assessment of study quality was based on the Risk of Bias (RoB) tool developed by the Office of Health Assessment and Translation (OHAT). Random effects meta-analyses of Hedges's g were conducted separately for accuracy- and speed-related performance measures of various cognitive domains, for which data from at least two studies were available. Finally, the certainty of evidence for each identified outcome was assessed according to Grading of Recommendations Assessment, Development, and Evaluation (GRADE).

Results 57,543 records were identified and 76 studies (80 reports) met the inclusion criteria. The included 76 studies with 3846 participants, consisting of humans of different age, sex and health status from 19 countries, were conducted between 1989 and 2021. Quantitative data from 50 studies (52 reports) with 2433 participants were included into the meta-analyses. These studies were performed in 15 countries between 2001 and 2021. The majority of the included studies used head exposure with GSM 900 uplink.

None of the meta-analyses observed a statistically significant effect of RF-EMF exposure compared to sham on cognitive performance as measured by the confidence interval surrounding the Hedges's g or the significance of the z-statistic.

For the domain Orientation and Attention, subclass Attention – Attentional Capacity RF-EMF exposure results in little to no difference in accuracy (Hedges's g 0.024, 95 % CI [-0.10; 0.15], I2 = 28 %, 473 participants).

For the domain Orientation and Attention, subclass Attention – Concentration / Focused Attention RF-EMF exposure results in little to no difference in speed (Hedges's g 0.005, 95 % CI [-0.17; 0.18], I2 = 7 %, 132 participants) and probably results in little to no difference in accuracy; it does not reduce accuracy (Hedges's g 0.097, 95 % CI [-0.05; 0.24], I2 = 0 %, 217 participants).

For the domain Orientation and Attention, subclass Attention – Vigilance RF-EMF exposure probably results in little to no difference in speed and does not reduce speed (Hedges's g 0.118, 95 % CI [-0.04; 0.28], I2 = 41 %, 247 participants) and results in little to no difference in accuracy (Hedges's g 0.042, 95 % CI, [-0.09; 0.18], I2 = 0 %, 199 participants).

For the domain Orientation and Attention, subclass Attention – Selective Attention RF-EMF exposure probably results in little to no difference in speed and does not reduce speed (Hedges's g 0.080, 95 % CI [-0.09; 0.25], I2 = 63 %, 452 participants); it may result in little to no difference in accuracy, but it probably does not reduce accuracy (Hedges's g 0.178, 95 % CI [-0.02; 0.38], I2 = 68 %, 480 participants).

For the domain Orientation and Attention, subclass Attention – Divided Attention RF-EMF exposure results in little to no difference in speed (Hedges's g −0.010, 95 % CI [-0.14; 0.12], I2 = 5 %, 307 participants) and may result in little to no difference in accuracy (Hedges's g −0.089, 95 % CI [-0.35; 0.18], I2 = 53 %, 167 participants).

For the domain Orientation and Attention, subclass Processing Speed − Simple Reaction Time Task RF-EMF exposure results in little to no difference in speed (Hedges's g 0.069, 95 % CI [-0.02; +0.16], I2 = 29 %, 820 participants).

For the domain Orientation and Attention, subclass Processing Speed – 2-Choice Reaction Time Task RF-EMF exposure results in little to no difference in speed (Hedges's g −0.023, 95 % CI [-0.13; 0.08], I2 = 0 %, 401 participants), and may result in little to no difference in accuracy (Hedges's g −0.063, 95 % CI [-0.38; 0.25], I2 = 63 %, 117 participants).

For the domain Orientation and Attention, subclass Processing Speed – >2-Choice Reaction Time Task RF-EMF exposure results in little to no difference in speed (Hedges's g −0.054, 95 % CI [-0.14; 0.03],

I2 = 0 %, 544 participants) and probably results in little to no difference in accuracy (Hedges's g −0.129, 95 % CI [-0.30; 0.04], I2 = 0 %, 131 participants).

For the domain Orientation and Attention, subclass Processing Speed – Other Tasks RF-EMF exposure probably results in little to no difference in speed and does not reduce speed (Hedges's g 0.067, 95 % CI [-0.12; 0.26], I2 = 38 %, 249 participants); it results in little to no difference in accuracy (Hedges's g 0.036, 95 % CI [-0.08; 0.15], I2 = 0 %, 354 participants).

For the domain Orientation and Attention, subclass Working Memory – n-back Task (0–3-back) we found Hedges's g ranging from −0.090, 95 % CI [-0.18; 0.01] to 0.060, 95 % CI [-0.06; 0.18], all I2 = 0 %, 237 to 474 participants, and conclude that RF-EMF exposure results in little to no difference in both speed and accuracy.

For the domain Orientation and Attention, subclass Working Memory – Mental Tracking RF-EMF exposure results in little to no difference in accuracy (Hedges's g −0.047, 95 % [CI −0.15; 0.05], I2 = 0 %, 438 participants). For the domain Perception, subclass Visual and Auditory Perception RF-EMF exposure may result in little to no difference in speed (Hedges's g −0.015, 95 % CI [-0.23; 0.195], I2 = 0 %, 84 participants) and probably results in little to no difference in accuracy (Hedges's g 0.035, 95 % CI [-0.13; 0.199], I2 = 0 %, 137 participants).

For the domain Memory, subclass Verbal and Visual Memory RF-EMF exposure probably results in little to no difference in speed and does not reduce speed (Hedges's g −0.042, 95 % CI [-0.15; 0.21], I2 = 0 %, 102 participants); it may result in little to no difference in accuracy (Hedges's g −0.087, 95 % CI [-0.38; 0.20], I2 = 85 %, 625 participants).

For the domain Verbal Functions and Language Skills, subclass Verbal Expression, a meta-analysis was not possible because one of the two included studies did not provide numerical values. Results of both studies did not indicate statistically significant effects of RF-EMF exposure on both speed and accuracy.

For the domain Construction and Motor Performance, subclass Motor Skills RF-EMF exposure may reduce speed, but the evidence is very uncertain (Hedges's g −0.919, 95 % CI [-3.09; 1.26], I2 = 96 %, 42 participants); it probably results in little to no difference in accuracy and does not reduce accuracy (Hedges's g 0.228, 95 % CI [-0.01; 0.46], I2 = 0 %, 109 participants).

For the domain Concept Formation and Reasoning, subclass Reasoning RF-EMF exposure results in little to no difference in speed (Hedges's g 0.010, 95 % CI [-0.11; 0.13], I2 = 0 %, 263 participants) and probably results in little to no difference in accuracy and does not reduce accuracy (Hedges's g 0.051, 95 % CI [-0.14; 0.25], I2 = 0 %, 100 participants).

For the domain Concept Formation and Reasoning, subclass Mathematical Procedures RF-EMF exposure results in little to no difference in speed (Hedges's g 0.033, 95 % CI [-0.12; 0.18], I2 = 0 %, 168 participants) and may result in little to no difference in accuracy but probably does not reduce accuracy (Hedges's g 0.232, 95 % CI [-0.12; +0.59], I2 = 86 %, 253 participants).

For the domain Executive Functions there were no studies.

Discussion Overall, the results from all domains and subclasses across their speed- and accuracy-related outcome measures according to GRADE provide high to low certainty of evidence that short-term RF-EMF exposure does not reduce cognitive performance in human experimental studies. For 16 out of 35

subdomains some uncertainty remains, because of limitations in the study quality, inconsistency in the results or imprecision of the combined effect size estimate. Future research should focus on construction and motor performance, elderly, and consideration of both sexes.

Other This review was partially funded by the WHO radioprotection programme. The protocol for this review was registered in Prospero reg. no. CRD42021236168 and published in Environment International (Pophof et al. 2021).

4.9. Implications of practice and policy

The present systematic review provides mostly moderate to high certainty of evidence that short-term RF-EMF exposure at SAR levels within the recommended limits (ICNIRP 2010) does not negatively affect the investigated domains of cognitive function.

4.10. Implications for research

Although the number of studies and participants is low for several domains / subclasses, the certainty of evidence for lack of an effect is very low only for the speed category of D5 *Construction and Motor Performance*. Only two small studies with a total number of 42 participants contribute to the result with substantial heterogeneity and the body of evidence suggests a large negative effect with very low certainty. Further studies are needed to confirm or refute this effect. In particular, all outcome measures used in both studies should be considered and reported numerically.

The number of studies that provide age-specific information on RF-EMF effects on cognitive performance is small. In particular, only five of the included studies were performed in children and only one in the elderly. Since children are generally considered to be a sensitive group, and the cognitive performance tends to decline with age, studies in children /adolescents and in elderly subjects are recommended to investigate whether these both age groups are more affected by RF-EMF exposure than young adults. Since the subgroup analyses (Supplementary Data 11) provide weak indications for a possible effect of sex, analyses stratified for sex of the participants are recommended.

In general, any new study should be designed in a way that any potential RoB is minimized. The criteria for definitely low RoB are summarized in Supplementary Data 7 of the protocol (Pophof et al. 2021). Furthermore, power calculations should be conducted prior to the final study design and study power should be sufficient for detecting even small effects. A comprehensive list of further issues that should be considered when conducting studies on possible effects of RF-EMF on cognitive performance, are published in Regel and Achermann (2011).

Authors of future studies are encouraged to make the original individual data publicly available in appropriate data repositories to avoid missing data due to incomplete reporting.

5.2. Deviations from the protocol

In the protocol, we did not describe how the ratings of the individual RoB questions for a given study would be used to define an overall quality rating for that study. This admission could be considered as a potential risk of bias for this systematic review if, for example, certain studies were selectively included/excluded from subgroup analyses based on the quality rating. However, given that the heterogeneity of effects across studies was low for most outcome measures, such selective analysis

would in principle have little to no impact. The GRADE assessment, however, strongly depends on the overall study quality assessment. Thus, in order to be as transparent as possible, we have explained and justified the chosen method for allocating studies to quality tiers in detail in Methods − Risk of Bias assessment.

We did not conduct separate analyses for individuals with and without IEI-EMF, because there were only seven studies including subjects with IEI. Only six of the seven studies provided numerical data (for only some domains / subclasses) to be used to calculate effect sizes. The data of these six studies do not allow a detailed analysis following the approach pursued in this paper.

Because there was only one study investigating females, heterogeneity could not be assessed for this subgroup. Therefore, we performed subgroup analyses stratified by studies investigating only males, and studies investigating males and females together. However, the explanatory power of this approach should not be overestimated.

We did not evaluate a potential dose–response relationship or perform subgroup analyses regarding exposure levels, because independently from the exposure level there was predominantly no effect of RF-EMF, and the exposure assessment in most studies did not provide spatially resolved exposure levels in the brain. For similar reasons we did not analyse the exposure category D separately from A, B and C (see Protocol, Pophof et al. 2021), but combined all exposure categories in analyses.

Due to the huge amount of data available for the domains D1 and to a lesser extent for D6, and due to the fact that some studies reported results for a large number of different subclasses of domains, a problem with the unit of analysis would have resulted in a huge amount of original data that could not be used for a *meta*-analysis if we had kept the outcome categories defined in the protocol. Therefore, we defined more detailed outcome categories according to the domain subclasses (Table 2) as defined by Lezak et al. (2012, Part II The Compendium of Tests and Assessment Techniques, p. 391 ff.). This enables a better differentiation of different cognitive abilities, and increases the number of possible *meta*-analyses and a higher proportion of original data included in the *meta*-analyses.

In order to explore possible sources of heterogeneity, we additionally included a stratification according to sample sizes (<30; ≥ 30). Studies with small sample sizes are likely to have a higher variability than studies with larger sample sizes.

Deviating from the protocol, we did not conduct subgroup analyses for the exposure-related categories of signals with different modulation, time course of exposure, different frequencies, for the nine outcome measures of subclasses with results with at least moderate heterogeneity (Table 3). This is because a large number of studies falls in the category “continuous GSM-modulated near-field exposure with frequency lower than 1 GHz” (in six out of these nine outcome measures at least half of results include this exposure category) and most of the outlier studies that strongly contribute to heterogeneity of the results also fall into this category (five studies).

5.3. Support

This review was partly funded by the World Health Organization (contracts 2020/1028371–0, 2022/1276784–0). WHO provided the basis for the protocol and methodological support throughout the review process.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: [The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. BP is member of the ICNIRP Scientific Expert Group (SEG) on environment, BfS observer in the working group SSK-A630 of the German Commission on Radiological Protection and was German delegate of European Cost Actions BM0704 and BM1309 “EMF-MED”. GS is member of the Committee “Non-Ionizing Radiation” (SSK-A6) and member of the working group SSK-A630 of the German Commission on Radiological Protection. GS is chair of the Austrian Standardization Sub-Committee TSK-EMV-EMF “Electromagnetic Fields”. HDHs research is entirely funded by public or not-for-profit foundations. She has served as advisor to a number of national and international public advisory groups concerning the potential health effects of exposure to non-ionizing radiation, including the World Health Organization, the German Commission on Radiological Protection (member of the committee “Non-Ionizing Radiation” (SSK-A6) and member of the working group 5G (SSK-A630)) and the Independent Expert Group of the Swedish Radiation Safety Authority. JK is member of the ICNIRP Scientific Expert Group (SEG) on ultrasound and BfS observer in the working group SSK-A630 of the German Commission on Radiological Protection].

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Literature review: potential non-thermal molecular effects of external radiofrequency electromagnetic fields on cancer

Dieper A, Scheidegger S, Füchslin RM, Veltsista PD, Stein U, Weyland M, Gerster D, Beck M, Bengtsson O, Zips D, Ghadjar P. Literature review: potential non-thermal molecular effects of external radiofrequency electromagnetic fields on cancer. Int J Hyperthermia. 2024;41(1):2379992. doi: 10.1080/02656736.2024.2379992.

Abstract

Introduction: There is an ongoing scientific discussion, that anti-cancer effects induced by radiofrequency (RF)-hyperthermia might not be solely attributable to subsequent temperature elevations at the tumor site but also to non-temperature-induced effects. The exact molecular mechanisms behind said potential non-thermal RF effects remain largely elusive, however, limiting their therapeutical targetability.

Objective: Therefore, we aim to provide an overview of the current literature on potential non-temperature-induced molecular effects within cancer cells in response to RF-electromagnetic fields (RF-EMF).

Material and methods: This literature review was conducted following the PRISMA guidelines. For this purpose, a MeSH-term-defined literature search on MEDLINE (PubMed) and Scopus (Elsevier) was conducted on March 23rd, 2024. Essential criteria herein included the continuous wave RF-EMF nature

(3 kHz - 300 GHz) of the source, the securing of temperature-controlled circumstances within the trials, and the preclinical nature of the trials.

Results: Analysis of the data processed in this review suggests that RF-EMF radiation of various frequencies seems to be able to induce significant non-temperature-induced anti-cancer effects. These effects span from mitotic arrest and growth inhibition to cancer cell death in the form of autophagy and apoptosis and appear to be mostly exclusive to cancer cells. Several cellular mechanisms were identified through which RF-EMF radiation potentially imposes its anti-cancer effects. Among those, by reviewing the included publications, we identified RF-EMF-induced ion channel activation, altered gene expression, altered membrane potentials, membrane oscillations, and blebbing, as well as changes in cytoskeletal structure and cell morphology.

Conclusion: The existent literature points toward a yet untapped therapeutic potential of RF-EMF treatment, which might aid in damaging cancer cells through bio-electrical and electro-mechanical molecular mechanisms while minimizing adverse effects on healthy tissue cells. Further research is imperative to definitively confirm non-thermal EMF effects as well as to determine optimal cancer-type-specific RF-EMF frequencies, field intensities, and exposure intervals.

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Exposure to Electromagnetic Fields from Mobile Phones and Fructose Consumption Coalesce to Perturb Metabolic Regulators AMPK/SIRT1-UCP2/FOXO1 in Growing Rats

Tripathi R, Banerjee SK, Nirala JP, Mathur R. Exposure to Electromagnetic Fields from Mobile Phones and Fructose Consumption Coalesce to Perturb Metabolic Regulators AMPK/SIRT1-UCP2/FOXO1 in Growing Rats[J]. Biomedical and Environmental Sciences, 2023, 36(11): 1045-1058. doi: 10.3967/bes2023.134

Abstract

Objective In this study, the combined effect of two stressors, namely, electromagnetic fields (EMFs) from mobile phones and fructose consumption, on hypothalamic and hepatic master metabolic regulators of the AMPK/SIRT1-UCP2/FOXO1 pathway were elucidated to delineate the underlying molecular mechanisms of insulin resistance.

Methods Weaned Wistar rats (28 days old) were divided into 4 groups: Normal, Exposure Only (ExpO), Fructose Only (FruO), and Exposure and Fructose (EF). Each group was provided standard laboratory chow ad libitum for 8 weeks. Additionally, the control groups, namely, the Normal and FruO groups, had unrestricted access to drinking water and fructose solution (15%), respectively. Furthermore, the respective treatment groups, namely, the ExpO and EF groups, received EMF exposure (1,760 MHz, 2 h/day x 8 weeks). In early adulthood, mitochondrial function, insulin receptor signaling, and oxidative stress signals in hypothalamic and hepatic tissues were assessed using western blotting and biochemical analysis.

Result In the hypothalamic tissue of EF, SIRT1, FOXO 1, p-PI3K, p-AKT, Complex III, UCP2, MnSOD, and catalase expressions and OXPHOS and GSH activities were significantly decreased (P < 0.05) compared

to the Normal, ExpO, and FruO groups. In hepatic tissue of EF, the p-AMPKα, SIRT1, FOXO1, IRS1, p-PI3K, Complex I, II, III, IV, V, UCP2, and MnSOD expressions and the activity of OXPHOS, SOD, catalase, and GSH were significantly reduced compared to the Normal group (P < 0.05).

Conclusion The findings suggest that the combination of EMF exposure and fructose consumption during childhood and adolescence in Wistar rats disrupts the closely interlinked and multi-regulated crosstalk of insulin receptor signals, mitochondrial OXPHOS, and the antioxidant defense system in the hypothalamus and liver.

Open access paper: https://www.besjournal.com/en/article/doi/10.3967/bes2023.134

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Upper bound for broadband radiofrequency field disruption of magnetic compass orientation in night-migratory songbirds

Leberecht B, Wong SY, Satish B, Döge S, Hindman J, Venkatraman L, Apte S, Haase K, Musielak I, Dautaj G, Solov'yov IA, Winklhofer M, Mouritsen H, Hore PJ. Upper bound for broadband radiofrequency field disruption of magnetic compass orientation in night-migratory songbirds. Proc Natl Acad Sci U S A. 2023 Jul 11;120(28):e2301153120. doi: 10.1073/pnas.2301153120. Epub 2023 Jul 3. PMID: 37399422; PMCID: PMC10334787.

Abstract

Night-migratory songbirds have a light-dependent magnetic compass sense, the mechanism of which is thought to depend on the photochemical formation of radical pairs in cryptochrome (Cry) proteins located in the retina. The finding that weak radiofrequency (RF) electromagnetic fields can prevent birds from orienting in the Earth's magnetic field has been regarded as a diagnostic test for this mechanism and as a potential source of information on the identities of the radicals. The maximum frequency that could cause such disorientation has been predicted to lie between 120 and 220 MHz for a flavin-tryptophan radical pair in Cry. Here we show that the magnetic orientation capabilities of Eurasian blackcaps (*Sylvia atricapilla*) are not affected by RF noise in the frequency bands 140 to 150 MHz and 235 to 245 MHz. From a consideration of its internal magnetic interactions, we argue that RF field effects on a flavin-containing radical-pair sensor should be approximately independent of frequency up to 116 MHz and that birds' sensitivity to RF disorientation should fall by about two orders of magnitude when the frequency exceeds 116 MHz. Taken together with our earlier finding that 75 to 85 MHz RF fields disrupt the magnetic orientation of blackcaps, these results provide compelling evidence that the magnetic compass of migratory birds operates by a radical pair mechanism.

Open access paper: https://www.pnas.org/doi/abs/10.1073/pnas.2301153120

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Impact of high (1950 MHz) and extremely low (50 Hz) frequency electromagnetic fields on DNA damage caused by occupationally relevant exposures in human derived cell lines

Worel N, Mišík M, Kundi M, Ferk F, Hutter HP, Nersesyan A, Wultsch G, Krupitza G, Knasmueller S. Impact of high (1950 MHz) and extremely low (50 Hz) frequency electromagnetic fields on DNA damage caused by occupationally relevant exposures in human derived cell lines. Toxicol In Vitro. 2024 Jul 16:105902. doi: 10.1016/j.tiv.2024.105902.

Highlights

- Mobile phone-specific (HF) and low-frequency (LF) electromagnetic fields (EMF) may cause cancer.
- We investigated the impact of these fields on DNA damage in human-derived cells.
- The cells were exposed to the EMF in combination with occupationally related carcinogens.
- We found no evidence for synergistic effects.
- In neural cells, we observed a significant reduction of DNA damage after exposure to the HF field.

Abstract

Epidemiological studies indicate that electromagnetic fields are associated with cancer in humans. Exposure to mobile phone specific high frequency fields (HF-EMF) may lead to increased glioma risks, while low frequency radiation (LF-EMF) is associated with childhood leukemia. We studied the impact of HF-EMF (1950 MHz, UMTS signal) on DNA stability in an astrocytoma cell line (1321N1), and the effect of LF-EMF (50 Hz) in human derived lymphoma (Jurkat) cells. To find out if these fields affect chemically induced DNA damage, co-exposure experiments were performed. The cells were exposed to HF-EMF or LF-EMF and treated simultaneously and sequentially with mutagens. The compounds cause DNA damage via different molecular mechanisms, i.e. pyrimidine dimers which are characteristic for UV light (4-nitroquinoline 1-oxide, 4NQO), bulky base adducts (benzo[a]pyrene diolepoxide, BPDE), DNA-DNA and DNA-protein cross links and oxidative damage ($NiCl_2$, CrO_3). DNA damage was measured in single cell gel electrophoresis (comet) assays. We found a moderate reduction of basal and 4NQO-induced DNA damage in the astrocytoma line, but no significant alterations of chemically induced DNA migration by the HF and LF fields under all other experimental series. The biological consequences of the moderate reduction remain unclear, but our findings indicate that acute mobile phone and power line specific EMF exposures do not enhance genotoxic effects caused by occupationally relevant chemical exposures.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0887233324001322

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Estimates and measurements of radiofrequency exposures in smart-connected homes

Joyner K, Milligan M, Knipe P. Estimates and measurements of radiofrequency exposures in smart-connected homes. Bioelectromagnetics. 2024 Jul 18. doi: 10.1002/bem.22518.

Abstract

The aim of this research was to quantify the levels of radiofrequency electromagnetic energy (RF-EME) in a residential home/apartment equipped with a range of wireless devices, often referred to as internet

of things (IoT) devices or smart devices and subsequently develop a tool that could be useful for estimating the levels of RF-EME in a domestic environment. Over the course of 3 years measurements were performed in peoples' homes on a total of 43 devices across 16 device categories. Another 12 devices were measured in detail in a laboratory setup. In all a total of 55 individual devices across 23 device categories were measured. Based on this measurement data we developed predictive software that showed that even with a single device in 23 device categories operating near maximum they would, in total, produce exposures at a distance of 1 m of 0.17% of the ICNIRP (2020) public exposure limits. Measurements were also made in two separate smart apartments-one contained over 50 IoT devices and a second with over 100 IoT devices with the devices driven as hard as could reasonably be achieved. The respective 6-min average exposure level recorded were 0.0077% and 0.44% of the ICNIRP (2020) 30-min average public exposure limit.

Conclusions

We have presented measurements of Wi-Fi signals from 55 individual IoT devices across 23 device categories, which showed that the respective 6-min average exposure levels recorded ranged from 0.0077% to 0.44% of the ICNIRP (2020) 30-min average public exposure limit. These results were corroborated by measurements made in two separate smart apartments—one contained over 50 IoT devices and a second with over 100 IoT devices with the devices driven as hard as could reasonably be achieved. Based on all of these measurements, we have developed predictive software that can be used to estimate exposure levels on a conservative basis by incorporating a 3 dB enhancement to produce a realistic upper bound for the exposure estimation. The RF estimator tool, which is available from the Mobile & Wireless Forum (MWF) website (www.mwfai.org), has a drop-down menu that allows the selection of multiple IoT devices and separation distances and returns an estimate of the exposure level that could be expected in the home environment. Devices in neighboring rooms can be included in the software by selecting the appropriate device and distance. However, because of the inverse square dependence with distance and the attenuation through walls, the majority contribution in a particular room is determined by the proximity of devices in that room. Future work will include the expansion of the device categories and the inclusion of wall/window attenuation to account for neighboring homes and apartments.

CONFLICT OF INTEREST STATEMENT

This work was fully funded by the Mobile and Wireless Forum (www.mwfai.org) and that KJ and MM are contractored by the MWF.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/bem.22518

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Maternal linalool treatment protects against radiofrequency wave-induced deteriorations in adolescent rats: A behavioral and electrophysiological study

Azimzadeh M, Noorbakhshnia M. Maternal linalool treatment protects against radiofrequency wave-induced deteriorations in adolescent rats: A behavioral and electrophysiological study. Sci Rep. 2024 Jul 27;14(1):17257. doi: 10.1038/s41598-024-68103-5.

Abstract

Recent years, the rapid advancement of technology has raised concerns. We studied the effects of prenatal exposure to 900 MHz radiofrequency (RF) from mobile phones and the protective effects of linalool on learning and memory, and anxiety in adolescent male and female offspring rats. Pregnant rats were divided into four groups: control, wave, wave + linalool, and linalool. Rats received linalool (25mg/kg) by gavage for 21 days. Irradiation was conducted from day 0 to day 21 of pregnancy. Offsprings underwent behavioral and electrophysiological tests on days 50 and 60 after birth. Exposure to RF during pregnancy caused anxiety-like behavior in the EPM test and impairment of learning and memory in the Morris water maze and shuttle box tests. Electrophysiological properties and synaptic plasticity of the dorsal hippocampal CA3-CA1 synapse showed a decrease in fEPSP amplitude and slope. The trace element levels in both male and female offspring were consistent across all groups compared to their respective controls. In the hippocampus tissue, the levels of Fe, Cu, and Mn, as well as the Cu/Zn ratio, were significantly higher in the exposed groups (wave groups) compared to their controls. Moreover, Zn levels were significantly lower in the hippocampus tissue of the exposed groups. Linalool administration mitigated the excessive increase in Fe, Cu, Mn, and Cu/Zn ratio and normalized the disrupted levels of trace elements, except for Zn levels in both male and female offspring. Sex differences were observed in the EPM and shuttle box tests, females were more sensitive than males. In summary, our study demonstrates that prenatal exposure to mobile phone radiation induces stress-like behaviors, disrupts learning and memory, alters hippocampal electrophysiological properties and trace element balance in offspring. Treatment with linalool mitigates these deleterious effects, highlighting its potential as a therapeutic intervention. These findings contribute to our understanding of the impact of prenatal environmental exposures on neurodevelopment and offer insights into potential strategies for neuroprotection.

https://www.nature.com/articles/s41598-024-68103-5

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Sulforaphane Effects on Neuronal-like Cells and Peripheral Blood Mononuclear Cells Exposed to 2.45 GHz Electromagnetic Radiation

Bertuccio MP, Saija C, Acri G, Ientile R, Caccamo D, Currò M. Sulforaphane Effects on Neuronal-like Cells and Peripheral Blood Mononuclear Cells Exposed to 2.45 GHz Electromagnetic Radiation. Int J Mol Sci. 2024 Jul 18;25(14):7872. doi: 10.3390/ijms25147872.

Abstract

Exposure to 2.45 GHz electromagnetic radiation (EMR) emitted from commonly used devices has been reported to induce oxidative stress in several experimental models. Our study aims to evaluate the efficacy of sulforaphane, a well-known natural product, in preventing radiation-induced toxic effects caused by a 24 h exposure of SH-SY5Y neuronal-like cells and peripheral blood mononuclear cells (PBMCs) to 2.45 GHz EMR. Cells were exposed to radiation for 24 h in the presence or absence of sulforaphane at different concentrations (5-10-25 µg/mL). Cell viability, mitochondrial activity alterations, the transcription and protein levels of redox markers, and apoptosis-related genes were investigated. Our data showed a reduction in cell viability of both neuronal-like cells and PBMCs caused by EMR exposure and a protective effect of 5 µg/mL sulforaphane. The lowest sulforaphane

concentration decreased ROS production and increased the Mitochondrial Transmembrane Potential ($\Delta\psi m$) and the NAD+/NADH ratio, which were altered by radiation exposure. Sulforaphane at higher concentrations displayed harmful effects. The hormetic behavior of sulforaphane was also evident after evaluating the expression of genes coding for Nrf2, SOD2, and changes in apoptosis markers. Our study underlined the vulnerability of neuronal-like cells to mitochondrial dysfunction and oxidative stress and the possibility of mitigating these effects by supplementation with sulforaphane. To our knowledge, there are no previous studies about the effects of SFN on these cells when exposed to 2.45 GHz electromagnetic radiation.

Open access paper: https://www.mdpi.com/1422-0067/25/14/7872

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Ubiquitous extremely low frequency electromagnetic fields induces anxiety-like behavior: mechanistic perspectives

Hosseini E. Ubiquitous extremely low frequency electromagnetic fields induces anxiety-like behavior: mechanistic perspectives. Electromagn Biol Med. 2024 Jul 29:1-16. doi: 10.1080/15368378.2024.2380305.

Abstract

Anxiety is an adaptive condition characterized by heightened uneasiness, which in the long term can cause complications such as reducing the quality of life and problems related to the mental and physical health. Concerns have been raised regarding the potential dangers of extremely low frequency electromagnetic fields (ELF-EMF) ranging from 3 to 3000 Hz, which are omnipresent in our daily lives and there have been studies about the anxiogenic effects of these fields. Studies conducted in this specific area has revealed that ELF-EMF can have an impact on various brain regions, such as the hippocampus. In conclusion, studies have shown that ELF-EMF can interfere with hippocampus-prefrontal cortex pathway, inducing anxiety behavior. Also, ELF-EMF may initiate anxiety behavior by generating oxidative stress in hypothalamus and hippocampus. Moreover, ELF-EMF may induce anxiety behavior by reducing hippocampus neuroplasticity and increasing the $NMDA2_A$ receptor expression in the hippocampus. Furthermore, supplementation with antioxidants could serve as an effective protective measure against the adverse effects of ELF-EMF in relation to anxiety behavior.

Conclusion

In the present study, it was found out that:

1. ELF-EMF by creating oxidative stress in different regions of brain involved in anxiety behavior, results in an increase of stress hormones and also excitability subsequently.
2. ELF-EMF by decreasing in neuroplasticity and modulation of some receptors in the hippocampus may have a key role in initiating anxiety behavior.

https://pubmed.ncbi.nlm.nih.gov/39074042/

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Characterizing parameters and incorporating action potentials via the Hodgkin-Huxley model in a novel electric model for living cells

Bougandoura O, Achour Y, Zaoui A, Starzyński J. Characterizing parameters and incorporating action potentials via the Hodgkin-Huxley model in a novel electric model for living cells. Electromagn Biol Med. 2024 Jul 2;43(3):187-203. doi: 10.1080/15368378.2024.2372107.

Abstract

To enhance our understanding of electroporation and optimize the pulses used within the frequency range of 1 kHz to 100 MHz, with the aim of minimizing side effects such as muscle contraction, we introduce a novel electrical model, structured as a 2D representation employing exclusively lumped elements. This model adeptly encapsulates the intricate dynamics of living cells' impedance variation. A distinguishing attribute of the proposed model lies in its capacity to decipher the distribution of transmembrane potential across various orientations within living cells. This aspect bears critical importance, particularly in contexts such as electroporation and cellular stimulation, where precise knowledge of potential gradients is pivotal. Furthermore, the augmentation of the proposed electrical model with the Hodgkin-Huxley (HH) model introduces an additional dimension. This integration augments the model's capabilities, specifically enabling the exploration of muscle cell stimulation and the generation of action potentials. This broader scope enhances the model's utility, facilitating comprehensive investigations into intricate cellular behaviors under the influence of external electric fields.

https://pubmed.ncbi.nlm.nih.gov/38990565/

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Risk Assessment for Workers with Wearable Medical Devices Exposed to Electromagnetic Fields

Vivarelli C, Censi F, Calcagnini G, Falsaperla R, Mattei E. Risk Assessment for Workers with Wearable Medical Devices Exposed to Electromagnetic Fields. Health Physics 127(2):p 269-275, August 2024. doi: 10.1097/HP.0000000000001798.

Abstract

The exponential diffusion of wearable medical devices (WMD) in recent years has involved people of all ages, including workers. Workers who use WMDs should be considered at a particular risk from electromagnetic fields, and in accordance with EU Directive 2013/35/EU, they require an individual risk assessment. Currently, there is no international standard that provides specific guidance on how to perform such a risk assessment. This paper focuses on the effects of electromagnetic fields on WMDs and does not consider the direct effects on human body tissues. It aims to offer practical recommendations to employers and/or health physicists for the risk assessment of workers with WMDs. Focusing on EU countries, we first describe the requirements outlined by the technical standard for the electromagnetic compatibility (EMC) of medical electrical equipment EN 60601-1-2. Then, some general guidelines on how to perform the risk assessment are provided. The assessment can be conducted by comparing the field values measured in the workplace with the immunity test levels specified in the technical standards of medical electrical equipment. If the measured values are lower than the immunity test levels indicated in the standard and the distance from the electromagnetic source is

greater than the distance used by the manufacturer during the EMC (electromagnetic compatibility) tests (typically 30 cm), the risk for the worker may be considered acceptable. However, if the measured values exceed the immunity test levels or the distance criteria, a specific evaluation based on a case-by-case analysis is required.

https://journals.lww.com/health-physics/abstract/2024/08000/risk_assessment_for_workers_with_wearable_medical.1.aspx

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Health risks for medical personnel due to magnetic fields in magnetic resonance imaging

König AM, Pöschke A, Mahnken AH. Health risks for medical personnel due to magnetic fields in magnetic resonance imaging. Rofo. 2024 Jul 19. English, German. doi: 10.1055/a-2296-3860.

Abstract

The current state of medical and scientific knowledge on the effects of exposure to electromagnetic fields on workers in the field of clinical magnetic resonance imaging (MRI) is summarized here.A systematic literature search was conducted to analyze the health risks to medical personnel from magnetic fields in MRI. A total of 7273 sources were identified, with 7139 being excluded after screening of the title and abstract. After full-text screening, 34 sources remained and were included in this paper. There are a number of scientific publications on the occurrence of short-term sensory effects such as vertigo, metallic taste, phosphenes as well as on the occurrence of neurocognitive and neurobehavioral effects. For example, short-term exposure to clinical magnetic fields has been reported to result in a 4% reduction in speed and precision and a 16% reduction in visual contrast sensitivity at close range. Both eye-hand precision and coordination speed are affected. The long-term studies concern, among other things, the influence of magnetic fields on sleep quality, which could be linked to an increased risk of accidents. The data on the exposure of healthcare workers to magnetic fields during pregnancy is consistently outdated. However, it has been concluded that there are no particular deviations with regard to the duration of pregnancy, premature births, miscarriages, and birth weight. Epidemiological studies are lacking. With a focus on healthcare personnel, there is a considerable need for high-quality data, particularly on the consequences of long-term exposure to electromagnetic fields from clinical MRI and the effects on pregnancy.

Key points

- Short-term sensory effects such as vertigo, metallic taste, phosphenes as well as neurocognitive and neurological behavioral effects may occur upon exposure to magnetic fields.
- Long-term effects mainly concern quality of sleep, which can be associated with an increased risk of accidents.
- When pregnant women were exposed to magnetic fields, no particular deviations were found with regard to the duration of pregnancy, premature births, miscarriages, and birth weight.

Open access paper: https://www.thieme-connect.com/products/ejournals/html/10.1055/a-2296-3860?articleLanguage=en

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A Reexamination of Peto's Paradox: Insights Gained from Human Adaptation to Varied Levels of Ionizing and Non-ionizing Radiation

Mortazavi SMJ, Zare O, Ghasemi L, Taghizadeh P, Faghani P, Arshadi M, Mortazavi SAR, Sihver L. A Reexamination of Peto's Paradox: Insights Gained from Human Adaptation to Varied Levels of Ionizing and Non-ionizing Radiation. J Biomed Phys Eng. 2024 Jun 1;14(3):309-314. doi: 10.31661/jbpe.v0i0.2402-1729.

Abstract

Humans have generally evolved some adaptations to protect against UV and different levels of background ionizing radiation. Similarly, elephants and whales have evolved adaptations to protect against cancer, such as multiple copies of the tumor suppressor gene p53, due to their large size and long lifespan. The difference in cancer protection strategies between humans and elephants/whales depends on genetics, lifestyle, environmental exposures, and evolutionary pressures. In this paper, we discuss how the differences in evolutionary adaptations between humans and elephants could explain why elephants have evolved a protective mechanism against cancer, whereas humans have not. Humans living in regions with high levels of background radiation, e.g. in Ramsar, Iran where exposure rates exceed those on the surface of Mars, seem to have developed some kind of protection against the ionizing radiation. However, humans in general have not developed cancer-fighting adaptations, so they instead rely on medical technologies and interventions. The difference in cancer protection strategies between humans and elephants/whales depends on genetics, lifestyle, environmental exposures, and evolutionary pressures. In this paper, we discuss how the differences in evolutionary adaptations between humans and elephants could explain why elephants have evolved a protective mechanism against cancer, whereas humans have not. Studying elephant adaptations may provide insights into new cancer prevention and treatment strategies for humans, but further research is required to fully understand the evolutionary disparities.

Open access paper: https://jbpe.sums.ac.ir/article_50037.html

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A review on point mutations via proton transfer in DNA base pairs in the absence and presence of electric fields

Pushkaran AC, Arabi AA. A review on point mutations via proton transfer in DNA base pairs in the absence and presence of electric fields. Int J Biol Macromol. 2024 Jul 26:134051. doi: 10.1016/j.ijbiomac.2024.134051.

Abstract

This is a comprehensive review that focuses on spontaneous mutations that may occur during DNA replication, the fundamental process responsible for transferring genetic information. In 1963, Löwdin postulated that these mutations are primarily a result of proton transfer reactions within the hydrogen-bonded DNA base pairs. The single and double proton transfer reactions within the base pairs result in

zwitterions and rare tautomers, respectively. For persistent mutations, these products must be generated at high rates and should be thermodynamically stable. This review covers the proton transfer reactions studied experimentally and computationally. The review also examines the influence of externally applied electric fields on the thermodynamics and kinetics of proton transfer reactions within DNA base pairs, and their biological implications.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0141813024048566

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Corrigendum to "The effects of radiofrequency electromagnetic fields exposure on human self-reported symptoms: A systematic review of human experimental studies"

Bosch-Capblanch X, Esu E, Moses Oringanje C, Dongus S, Jalilian H, Eyers J, Auer C, Meremikwu M, Röösli M. Corrigendum to "The effects of radiofrequency electromagnetic fields exposure on human self-reported symptoms: A systematic review of human experimental studies" [Environ. Int. 187 (2024) 108612]. Environ Int. 2024 Jul 20:108892. doi: 10.1016/j.envint.2024.108892. Epub ahead of print. Erratum for: Environ Int. 2024 May;187:108612. doi: 10.1016/j.envint.2024.108612. PMID: 39034214.

No abstract

Open access paper:
https://www.sciencedirect.com/science/article/pii/S0160412024004781?via%3Dihub

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Investigating the impact of anthropogenic radiofrequency electromagnetic fields on animals and plants in the environment: analysis from a systematic map

Brzozek C, Mate R, Bhatt CR, Loughran S, Wood AW, Karipidis K. (2024). Investigating the impact of anthropogenic radiofrequency electromagnetic fields on animals and plants in the environment: analysis from a systematic map. *International Journal of Environmental Studies*, 1–16. doi: 10.1080/00207233.2024.2375861.

Abstract

Radiofrequency electromagnetic fields (RF EMF) from anthropogenic sources have become ubiquitous in the environment. International guidelines have been set by expert scientific bodies to protect human health from excessive exposure. There are no specifically established exposure guidelines to protect plants and animals. A previous systematic map identified 334 studies investigating the effects of RF EMF exposure from anthropogenic sources on animals and plants. This study aimed to analyse the effect of RF EMF and its relationship to different exposure parameters and the quality of those studies. Statistically significant inverse relationships were found between effect size and exposure-level parameters for studies investigating effects in animals. The results indicated that quality score is more indicative of the magnitude of the effect size than exposure-level parameters or exposure duration. This highlights the need for further, high-quality research on the effects of RF EMF exposure on plants and animals.

Quality score

A risk of bias assessment for each study was not conducted as this is more appropriate for a systematic review rather than a systematic map [Citation22]. Instead an assessment of the quality of the studies included in the systematic map was conducted with separate methods used for assessing experimental and observational studies. This was considered important to describe the distribution of quality of evidence across the research in this field. For experimental studies, the method of Vijayalaxmi and Prihoda was used which assessed five quality criteria including adequate dosimetry, use of controls, use of positive controls, use of blinding, use of temperature monitoring [Citation24]. For observational studies, the five quality criteria used in the assessment were as follows: appropriate exposure assessment, appropriate subject selection/comparison groups, consideration of confounders, follow-up assessment, and appropriate outcome assessment. A quality score (QS) was given for each study by two assessors independently, with the final quality score being the average of the two scores. Pearson correlation coefficients were used to assess the reliability and consistency between assessors. The QS was derived by scoring each of the five quality criteria; a score of 1 was awarded when the criterion was adequately addressed, 0.5 awarded when it was partially addressed and a score of 0 when the criterion was not addressed. This resulted in the QS for each study ranging between 0 and 5 with a higher value indicating higher quality for that study. The quality score results were further categorised as studies with QS ≤ 2 being 'poor quality', studies with QS > 2 - < 3.5 as 'average quality' and studies with QS ≥ 3.5 as 'good quality'.

Effect size

Studies investigating the impact of RF EMF on animals and plants have reported a range in the magnitude of effects including no effect and from small effects to large effects. It is therefore important to map the distribution of the effect size (ES) across the different studies, noting that ES = 0 denotes no statistically significant effect and ES > 0 denotes an effect size with a larger number corresponding to a larger effect. We extracted the ES for every study in the systematic map where this could be gleaned from the information provided. The ES was estimated using a number of different methods available in Thalheimer and Cook and according to the type of data provided by each study [Citation23]. Thalheimer and Cook include calculating the effect size from t-test (with and without the standard deviation or standard error) and from F-tests (with and without the mean squared error). Studies that used other statistics did not receive an effect size score. In many of the included studies more than one frequency and exposure intensity was investigated, and in some studies, several endpoints were investigated (and occasionally, more than one animal/plant). In these cases, the largest statistically significant effect was selected to represent that study. For effects that were not statistically significant the ES was set to zero.

Conclusion

The analysis of the systematic map dataset has identified that quality score is more indicative of the magnitude of the effect size than exposure-level parameters or exposure duration in fauna. Similar trends are seen in flora studies; but, these results were not found to be statistically significant. This highlights the need for further, high-quality research.

An investigation of the effect size in relation to different exposure characteristics, as well as the quality of the studies, raises doubts on whether animals and plants are truly affected at levels below human

exposure limits. There are distinct evidence clusters on insect and bird reproduction, development and behaviour for animals, and grain and legume germination and growth for plants that would benefit from specific systematic reviews, with appropriate risk of bias assessments and pooling of the data in meta-analyses. Our review also highlights the need for studies of additional animal and plant species and additional effects that are yet to be investigated. Further, there is a particular need for more observational studies and for an improvement in the quality of all studies.

Disclosure statement

KK, CBr, CBh, RM and SL as part of their employment at ARPANSA provide advice to the Australian Government, Australian States and Territories and the general public on the effects and risks of exposure to ionising and non-ionising radiation. KK and SL are also members of the main commission and scientific expert group, respectively, of the International Commission on Non-Ionising Radiation Protection where they contribute in the development and dissemination of science-based advice on limiting exposure to non-ionising radiation. KK, AW and CBr are members of systematic review teams into the WHO assessment of health effects of exposure to radiofrequency electromagnetic fields. SL is a member of the WHO Task Group on Radiofrequency Fields and Health Risks. No member of the mapping team screened or extracted data from any study in which he or she is an author.

https://www.tandfonline.com/doi/full/10.1080/00207233.2024.2375861

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Electrostatic pollination by butterflies and moths

England SJ, Robert D. Electrostatic pollination by butterflies and moths. J R Soc Interface. 2024 Jul;21(216):20240156. doi: 10.1098/rsif.2024.0156.

Abstract

Animals, most notably insects, generally seem to accumulate electrostatic charge in nature. These electrostatic charges will exert forces on other charges in these animals' environments and therefore have the potential to attract or repel other objects, for example, pollen from flowers. Here, we show that butterflies and moths (Lepidoptera) accumulate electrostatic charge while in flight. Then, using finite element analysis, we demonstrate that when within millimetres of a flower, the electrostatic charge of a lepidopteran generates an electric field in excess of 5 kV m^{-1}, and that an electric field of this magnitude is sufficient to elicit contactless pollen transfer from flowers across air gaps onto the body of a butterfly or moth. Furthermore, we see that phylogenetic variations exist in the magnitude and polarity of net charge between different species and families and Lepidoptera. These phylogenetic variations in electrostatic charging correlate with morphological, biogeographical and ecological differences between different clades. Such correlations with biogeographical and ecological differences may reflect evolutionary adaptations towards maximizing or minimizing charge accumulation, in relation to pollination, predation and parasitism, and thus we introduce the idea that electrostatic charging may be a trait upon which evolution can act.

Open access paper: https://royalsocietypublishing.org/doi/10.1098/rsif.2024.0156

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COSMOS. A methodologically-flawed cohort study of the health effects from exposure to radiofrequency radiation from mobile phone use

Moskowitz JM, Frank JW, Melnick RL, Hardell L, Belyaev I, Héroux P, Kelley E, Lai H, Maisch D, Mallery-Blythe E, Philips A; International Commission on the Biological Effects of Electromagnetic Fields. COSMOS: A methodologically-flawed cohort study of the health effects from exposure to radiofrequency radiation from mobile phone use. Environ Int. 2024 Jun 21;190:108807. doi: 10.1016/j.envint.2024.108807.

No abstract

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024003933

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Response to the letter to the editor regarding "Mobile phone use and brain tumour risk – COSMOS, a prospective cohort study"

Feychting M, Schüz J, Toledano MB, Vermeulen R, Auvinen A, Poulsen AH, Deltour I, Smith RB, Heller J, Kromhout H, Huss A, Johansen C, Tettamanti G, Elliott P. Response to the Letter to the Editor regarding "Mobile phone use and brain tumour risk - COSMOS, a prospective cohort study". Environ Int. 2024 May;187:108664. doi: 10.1016/j.envint.2024.108664.

No abstract

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024003945

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Summary of seven Swedish case reports on the microwave syndrome associated with 5G radiofrequency radiation

Hardell L, Nilsson M. Summary of seven Swedish case reports on the microwave syndrome associated with 5G radiofrequency radiation. Rev Environ Health. 2024 Jun 19. doi: 10.1515/reveh-2024-0017.

Abstract

The fifth generation, 5G, for wireless communication is currently deployed in Sweden since 2019/2020, as well as in many other countries. We have previously published seven case reports that include a total of 16 persons aged between 4 and 83 years that developed the microwave syndrome within a short time after being exposed to 5G base stations close to their dwellings. In all cases high radiofrequency (RF) radiation from 4G/5G was measured with a broadband meter. RF radiation reached >2,500,000 to >3,180,000 $\mu W/m^2$ in peak maximum value in three of the studies. In total 41 different health issues were assessed for each person graded 0 (no complaint) to 10 (worst symptoms). Most prevalent and severe were sleeping difficulty (insomnia, waking night time, early wake-up), headache, fatigue, irritability, concentration problems, loss of immediate memory, emotional distress, depression tendency, anxiety/panic, dysesthesia (unusual touched based sensations), burning and lancinating skin, cardiovascular symptoms (transitory high or irregular pulse), dyspnea, and pain in muscles and joints. Balance disorder and tinnitus were less prevalent. All these symptoms are included in the microwave syndrome. In most cases the symptoms declined and disappeared within a short time period after the studied persons had moved to a place with no 5G. These case histories are classical examples of

provocation studies. They reinforce the urgency to inhibit the deployment of 5G until more safety studies have been performed.

Open access paper: https://www.degruyter.com/document/doi/10.1515/reveh-2024-0017/html

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Follow-Up Research on NTP's Clear Evidence on RF Causing Malignant Tumors in Rats

Lin JC. Follow-Up Research on NTP's Clear Evidence on RF Causing Malignant Tumors in Rats [Health Matters]. *IEEE Microwave Magazine*. 25(6):16-18. June 2024. doi: 10.1109/MMM.2024.3378608.

Abstract

The recent disclosure of the U.S. National Toxicology Program (NTP) closing down its RF radiation research program on how RF radiation causes cancer was a surprise [1], [2], [3]. NTP is a part of the National Institutes of Health and reports to the U.S. Department of Health and Human Services. NTP's mandates are to provide the scientific basis for programs, activities, and policies that promote health or lead to the prevention of disease.

Excerpts

In 2018, NTP published the final report on its US$30 million laboratory research showing "clear evidence" that lifelong exposure to low-level RF radiation caused cancers in rats [6], [7], [8]. The statistically significant findings showed that both GSM- and CDMA-modulated 900-MHz RF radiation had led to the development of malignant schwannoma, a rare form of tumor in the hearts of male rats. Furthermore, an independent analysis of the NTP data for overall cancer incidence detected in any organ or tissue inside the animal showed that rats exposed to GSM and CDMA cellphone RF radiation had significantly higher overall or total primary tumor incidence than the concurrent controls....

The NTP findings of clear evidence that RF radiation can cause cancer was already reaffirmed by the Ramazzini Institute study from Italy [10]....

In 2019, NTP announced a new genotoxicology project designed to examine how RF radiation causes cancer....

Apparently, now, close to five years later, the new project has never progressed beyond the feasibility studies with the compact exposure chambers. Moreover, the NTP located in Research Triangle Park, NC, USA, no longer plans to study biological effects from cellphone RF radiation. NTP has decided that "the research was technically challenging and more resource-intensive than expected." This effectively marks the end of the nonmilitary governmental project in the United States to study the biological effects of cellphone or RF radiation. Any future NTP publications on the topic would come from the feasibility studies only [3].

Unfortunately, whether the U.S. civilian government halts doing the important research on mechanistic causes for cancer from low-level chronic exposure to RF radiation or not, nearly 100% of all Americans are being cast as subjects in a massive health experiment without a formal protocol. Furthermore, billions of people worldwide, including the young and older adults, are being exposed to unnecessary levels of human-made wireless RF radiation.

The obvious question is, what happened? Should we all forget about NTP's findings of clear scientific evidence that lifelong exposure to low-level RF radiation causes cancer from a federal government health agency that prides itself in telling the nation that its product is "science you can depend on for decisions that matter"?

Postscript: It is interesting to recall that the recently announced termination of NTP's RF research program on how RF radiation causes cancer practically halts most, if not all, biological research of RF radiation supported by the civilian U.S. government. In contrast, the military arm of the U.S. government through its Defense Advanced Research Projects Agency (DARPA) has initiated a new research program on the roles RF radiation may have in biological systems [11]. DARPA's historical and contemporary contributions to scientific and technological advancements are widely known. Thus, it poses the question, what does DARPA know about RF radiation on biological systems?

https://ieeexplore.ieee.org/document/10523054

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Epidemiological exploration of the impact of bluetooth headset usage on thyroid nodules using Shapley additive explanations method

Zhou N, Qin W, Zhang JJ, Wang Y, Wen JS, Lim YM. Epidemiological exploration of the impact of bluetooth headset usage on thyroid nodules using Shapley additive explanations method. Sci Rep. 2024 Jun 21;14(1):14354. doi: 10.1038/s41598-024-63653-0.

Abstract

With an increasing prevalence of thyroid nodules globally, this study investigates the potential correlation between the use of Bluetooth headsets and the incidence of thyroid nodules, considering the cumulative effects of non-ionizing radiation (NIR) emitted by these devices. In this study, we analyzed 600 valid questionnaires from the WenJuanXing platform using Propensity Score Matching (PSM) and the XGBOOST model, supplemented by SHAP analysis, to assess the risk of thyroid nodules. PSM was utilized to balance baseline characteristic differences, thereby reducing bias. The XGBOOST model was then employed to predict risk factors, with model efficacy measured by the area under the Receiver Operating Characteristic (ROC) curve (AUC). SHAP analysis helped quantify and explain the impact of each feature on the prediction outcomes, identifying key risk factors. Initially, 600 valid questionnaires from the WenJuanXing platform underwent PSM processing, resulting in a matched dataset of 96 cases for modeling analysis. The AUC value of the XGBOOST model reached 0.95, demonstrating high accuracy in differentiating thyroid nodule risks. SHAP analysis revealed age and daily Bluetooth headset usage duration as the two most significant factors affecting thyroid nodule risk. Specifically, longer daily usage durations of Bluetooth headsets were strongly linked to an increased risk of developing thyroid nodules, as indicated by the SHAP analysis outcomes. Our study highlighted a significant impact relationship between prolonged Bluetooth headset use and increased thyroid nodule risk, emphasizing the importance of considering health impacts in the use of modern technology, especially for devices like Bluetooth headsets that are frequently used daily. Through precise model predictions and variable importance analysis, our research provides a scientific basis for the formulation of public health policies and personal health habit choices, suggesting that attention should be paid to the duration of Bluetooth headset use in daily life to reduce the potential risk of thyroid nodules. Future

research should further investigate the biological mechanisms of this relationship and consider additional potential influencing factors to offer more comprehensive health guidance and preventive measures.

Open access paper: https://www.nature.com/articles/s41598-024-63653-0

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The effects of radiofrequency exposure on male fertility: A systematic review of human observational studies with dose–response meta-analysis (SR 3--male)

Kenny RPW, Johnson EE, Adesanya AM, Richmond C, Beyer F, Calderon C, Rankin J, Pearce MS, Toledano M, Craig D, Pearson F. The effects of radiofrequency exposure on male fertility: A systematic review of human observational studies with dose–response meta-analysis. Environment International, 2024. doi: 10.1016/j.envint.2024.108817.

Abstract

Background The World Health Organization (WHO) is bringing together evidence on radiofrequency electromagnetic field (RF-EMF) exposure in relation to health outcomes, previously identified as priorities for research and evaluation by experts in the field, to inform exposure guidelines. A suite of systematic reviews have been undertaken by a network of topic experts and methodologists to collect, assess and synthesise data relevant to these guidelines. Following the WHO handbook for guideline development and the COSTER conduct guidelines, we systematically reviewed the evidence on the potential effects of RF-EMF exposure on male fertility in human observational studies.

Methods We conducted a broad and sensitive search for potentially relevant records within the following bibliographic databases: MEDLINE; Embase; Web of Science and EMF Portal. We also conducted searches of grey literature through relevant databases including OpenGrey, and organisational websites and consulted RF-EMF experts. We hand searched reference lists of included study records and for citations of these studies. We included quantitative human observational studies on the effect of RF-EMF exposure in adult male participants on infertility: sperm concentration; sperm morphology; sperm total motility; sperm progressive motility; total sperm count; and time to pregnancy. Titles and abstracts followed by full texts were screened in blinded duplicate against pre-set eligibility criteria with consensus input from a third reviewer as required. Data extraction from included studies was completed by two reviewers, as was risk of bias assessment using the Office of Health Assessment and Translation (OHAT) tool. We conducted a dose–response meta-analysis as possible and appropriate. Certainty of the evidence was assessed by two reviewers using the OHAT GRADE tool with input from a third reviewer as required.

Results We identified nine studies in this review; seven were general public studies (with the general public as the population of interest) and two were occupational studies (with specific workers/workforces as the population of interest). General public studies. Duration of phone use: The evidence is very uncertain surrounding the effects of RF-EMF on sperm concentration (10/6 mL) (MD (mean difference) per hour of daily phone use 1.6 106/mL, 95 % CI −1.7 to 4.9; 3 studies), sperm morphology (MD 0.15 percentage points of deviation of normal forms per hour, 95 % CI −0.21 to 0.51; 3 studies), sperm progressive motility (MD −0.46 percentage points per hour, 95 % CI −1.04 to 0.13; 2 studies) and total sperm count (MD per hour −0.44 106/ejaculate, 95 % CI −2.59 to 1.7; 2 studies) due to

very low-certainty evidence. Four additional studies reported on the effect of mobile phone use on sperm motility but were unsuitable for pooling; only one of these studies identified a statistically significant effect. All four studies were at risk of exposure characterisation and selection bias; two of confounding, selective reporting and attrition bias; three of outcome assessment bias and one used an inappropriate statistical method. Position of phone: There may be no or little effect of carrying a mobile phone in the front pocket on sperm concentration, total count, morphology, progressive motility or on time to pregnancy. Of three studies reporting on the effect of mobile phone location on sperm total motility and, or, total motile count, one showed a statistically significant effect. All three studies were at risk of exposure characterisation and selection bias; two of confounding, selective reporting and attrition bias; three of outcome assessment bias and one used inappropriate statistical method. RF-EMF Source: One study indicates there may be little or no effect of computer or other electric device use on sperm concentration, total motility or total count. This study is at probably high risk of exposure characterisation bias and outcome assessment bias. Occupational studies. With only two studies of occupational exposure to RF-EMF and heterogeneity in the population and exposure source (technicians exposed to microwaves or seamen exposed to radar equipment), it was not plausible to statistically pool findings. One study was at probably or definitely high risk of bias across all domains, the other across domains for exposure characterisation bias, outcome assessment bias and confounding.

Discussion

The majority of evidence identified was assessing localised RF-EMF exposure from mobile phone use on male fertility with few studies assessing the impact of phone position. Overall, the evidence identified is very uncertain about the effect of RF-EMF exposure from mobile phones on sperm outcomes. One study assessed the impact of other RF-EMF sources on male fertility amongst the general public and two studies assessed the impact of RF-EMF exposure in occupational cohorts from different sources (radar or microwave) on male fertility. Further prospective studies conducted with greater rigour (in particular, improved accuracy of exposure measurement and appropriate statistical method use) would build the existing evidence base and are required to have greater certainty in any potential effects of RF-EMF on male reproductive outcomes.

Prospero Registration: CRD42021265401 (SR3A)

Excerpts

Conclusions Overall, the evidence is very uncertain about the effect of RF-EMF on male fertility outcomes. Where dose–response *meta*-analysis was possible, the evidence was rated as very low-certainty on OHAT GRADE, while the majority of included studies were at risk of bias and only a small number of studies reported on each outcome of interest. Given this, we cannot be confident in what the current body of research concludes about the effect of RF-EMF on male fertility.

Further prospective studies conducted with greater rigour (in particular, improved accuracy of exposure measurement and appropriate statistical method use) are required to build on the existing evidence base and provide greater certainty in any potential effects of RF-EMF on male reproductive outcomes.

Competing interests Carolina Calderon was involved in both MOBI-Kids (risk of brain cancer from exposure to radiofrequency fields in childhood and adolescence) and GERoNIMO, Tsarna et al. 2019 was

one of the outcomes of this project. Although Carolina was not involved in the publication, with her involvement being in the intermediate frequency exposure assessment.

Mireille Toledano has been involved in funded research assessing mobile phone and other wireless technologies usage on health outcomes. The SCAMP (study cognition adolescents and mobile phones) prospective cohort study which is currently ongoing (2015–2021). The COSMOS (cohort study of mobile phone use and health) a longitudinal cohort study which is completed (2019).

Declaration of competing interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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The effects of radiofrequency exposure on adverse female reproductive outcomes: A systematic review of human observational studies with dose–response meta-analysis (SR 3--female)

Johnson EE, Kenny RPW, Adesanya AM, Richmond C, Beyer F, Calderon C, Rankin J, Pearce MS, Toledano M, Craig D, Pearson F. The effects of radiofrequency exposure on adverse female reproductive outcomes: A systematic review of human observational studies with dose–response meta-analysis. Environment International, 2024. doi: 10.1016/j.envint.2024.108816.

Abstract

Background To inform radiofrequency electromagnetic field (RF-EMF) exposure guidelines the World Health Organization (WHO) is bringing together evidence on RF-EMF in relation to health outcomes prioritised for evaluation by experts in this field. Given this, a network of topic experts and methodologists have conducted a series of systematic reviews collecting, assessing, and synthesising data of relevance to these guidelines. Here we present a systematic review of the effect of RF-EMF exposure on adverse pregnancy outcomes in human observational studies which follows the WHO handbook for guideline development and the COSTER conduct guidelines.

Methods We conducted a broad, sensitive search for potentially relevant records within the following bibliographic databases: MEDLINE; Embase; and the EMF Portal. Grey literature searches were also conducted through relevant databases (including OpenGrey), organisational websites and via consultation of RF-EMF experts. We included quantitative human observational studies on the effect of RF-EMF exposure in adults' preconception or pregnant women on pre-term birth, small for gestational age (SGA; associated with intrauterine growth restriction), miscarriage, stillbirth, low birth weight (LBW) and congenital anomalies. In blinded duplicate, titles and abstracts then full texts were screened against eligibility criteria. A third reviewer gave input when consensus was not reached. Citation chaining of included studies was completed. Two reviewers' data extracted and assessed included studies for risk of

bias using the Office of Health Assessment and Translation (OHAT) tool. Random effects meta-analyses of the highest versus the lowest exposures and dose–response meta-analysis were conducted as appropriate and plausible. Two reviewers assessed the certainty in each body of evidence using the OHAT GRADE tool.

Results We identified 18 studies in this review; eight were general public studies (with the general public as the population of interest) and 10 were occupational studies (with the population of interest specific workers/workforces). General public studies. From pairwise meta-analyses of general public studies, the evidence is very uncertain about the effects of RF-EMF from mobile phone exposure on preterm birth risk (relative risk (RR) 1.14, 95% confidence interval (CI): 0.97–1.34, 95% prediction interval (PI): 0.83–1.57; 4 studies), LBW (RR 1.14, 95% CI: 0.96–1.36, 95% PI: 0.84–1.57; 4 studies) or SGA (RR 1.13, 95% CI: 1.02–1.24, 95% PI: 0.99–1.28; 2 studies) due to very low-certainty evidence. It was not feasible to meta-analyse studies reporting on the effect of RF-EMF from mobile phone exposure on congenital anomalies or miscarriage risk. The reported effects from the studies assessing these outcomes varied and the studies were at some risk of bias. No studies of the general public assessed the impact of RF-EMF exposure on stillbirth. Occupational studies. In occupational studies, based on dose–response meta-analyses, the evidence is very uncertain about the effects of RF-EMF amongst female physiotherapists using shortwave diathermy on miscarriage due to very low-certainty evidence (OR 1.02 95% CI 0.94–1.1; 2 studies). Amongst offspring of female physiotherapists using shortwave diathermy, the evidence is very uncertain about the effects of RF-EMF on the risk of congenital malformations due to very low-certainty evidence (OR 1.4, 95% CI 0.85 to 2.32; 2 studies). From pairwise meta-analyses, the evidence is very uncertain about the effects of RF-EMF on the risk of miscarriage (RR 1.06, 95% CI 0.96 to 1.18; very low-certainty evidence), pre-term births (RR 1.19, 95% CI 0.32 to 4.37; 3 studies; very low-certainty evidence), and low birth weight (RR 2.90, 95% CI: 0.69 to 12.23; 3 studies; very low-certainty evidence). Results for stillbirth and SGA could not be pooled in meta-analyses. The results from the studies reporting these outcomes were inconsistent and the studies were at some risk of bias.

Discussion Most of the evidence identified in this review was from general public studies assessing localised RF-EMF exposure from mobile phone use on female reproductive outcomes. In occupational settings, each study was of heterogenous whole-body RF-EMF exposure from radar, short or microwave diathermy, surveillance and welding equipment and its effect on female reproductive outcomes. Overall, the body of evidence is very uncertain about the effect of RF-EMF exposure on female reproductive outcomes. Further prospective studies conducted with greater rigour (particularly improved accuracy of exposure measurement and using appropriate statistical methods) are required to identify any potential effects of RF-EMF exposure on female reproductive outcomes of interest.

Excerpts

Summary of the evidence and interpretation of the results In total, 18 studies were identified for this review: in eight the general public was the population of interest and in 10 the populations of interest were occupational. Within the general population, the evidence is very uncertain about the effects of RF-EMF on pre-term birth, SGA and low birth weight. It was not possible to conduct meta-analyses for miscarriage and congenital anomalies due to significant heterogeneity between studies. Within the occupational studies, the evidence is very uncertain about the effects of RF-EMF on miscarriage and the effects of maternal RF-EMF exposure on pre-term birth, congenital anomalies and low birth weight.

Limitations of the evidence The are multiple limitations with the evidence base of human observational studies assessing the effect of localised and whole-body RF-EMF exposure on pre-term birth; SGA; miscarriage; still birth and, or, congenital anomalies compared to no or low level exposure in preconception or pregnant adults.

Risk of bias was often apparent in both general public and occupational studies; all but one of the included studies were rated as probably or definitely high risk for at least two domains on the OHAT risk of bias tool. Nine studies were at probably or definitely high risk of exposure characterisation bias (Allam, 2016, Baste et al., 2012, Cromie et al., 2002, Källén et al., 1982, Karuserci et al., 2019, Lu et al., 2017, Taskinen et al., 1990, Tsarna et al., 2019, Zhao et al., 2021), while another nine were at risk of outcome assessment bias (Baste et al., 2012, Cromie et al., 2002, Källén et al., 1982, Karuserci et al., 2019, Lu et al., 2017, Mahmoudabadi et al., 2015, Tsarna et al., 2019, Xu et al., 2016, Zhao et al., 2021). In 10 studies, issues surrounding the identification and handling of confounders was present (Allam, 2016, Baste et al., 2012, Baste et al., 2015, Brizzi and Marinelli, 2018, Cromie et al., 2002, Källén et al., 1982, Karuserci et al., 2019, Kolmodin-Hedman et al., 1988, Mahmoudabadi et al., 2015, Xu et al., 2016), while three were also at risk of selective reporting (Cromie et al., 2002, Källén et al., 1982, Kolmodin-Hedman et al., 1988).

More generally, reporting of exposures across studies was often inconsistent and lacking in detail (see Table 1, Table 2). Most studies in the general population used a proxy exposure, such as time spent on mobile phone or mobile phone usage, with heterogeneity between how these were measured.

One of the main issues of the evidence base is a lack of confounding assessment in studies (Baste et al., 2015, Allam, 2016, Brizzi and Marinelli, 2018, Karuserci et al., 2019, Kolmodin-Hedman et al., 1988, Baste et al., 2012, Källén et al., 1982, Cromie et al., 2002, Mahmoudabadi et al., 2015, Xu et al., 2016) and inconsistency regarding the method of exposure measurement. All analyses were downgraded to either low-certainty or very low-certainty evidence on OHAT GRADE, with risk of bias, indirectness and imprecision causing concerns. Indirectness was an issue for occupational studies measuring congenital anomalies. Many of the studies only stated that they were assessing the risk of any congenital anomalies rather than identifying and assessing the risk of specific congenital anomalies (e.g. the effect of RF-EMF could potentially affect different congenital anomalies in different ways). This limits our ability to assess the risk of different kinds of congenital anomalies following RF-EMF exposure.

Conclusions Overall, the majority of evidence suggest that there is little to no effect of RF-EF on female reproductive outcomes. The evidence was rated as low to very low certainty, was at risk of bias and only a small number of studies reported on each outcome of interest. Given this we cannot be confident in what the body of research is indicating about the effect of RF-EMF on female reproductive outcomes. The *meta*-analyses that were possible suggest no increased relative risk for female reproductive outcomes due to RF-EMF exposure in the general public or occupational settings. This is further supported by the dose–response *meta*-analysis in female physiotherapists using SWD. For studies that were not *meta*-analysed, there was variation in effect. Most included studies were at risk of bias.

Overall, while we observe a lack of effect, further prospective studies conducted with greater rigour would build the existing evidence base and are required to have greater certainty in any potential effects of RF-EMF on female reproductive outcomes.

Registration and protocol The protocol was published in Environment International (Kenny et al., 2022) and an abridged version is also available on PROSPERO (CRD42021265401; referred to as SR3B).

Declaration of competing interest The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: [Mireille Toledano has been involved in funded research assessing mobile phone and other wireless technologies usage on health outcomes: the SCAMP (study cognition adolescents and mobile phones) prospective cohort study which is currently ongoing (2015–2021), and the COSMOS (cohort study of mobile phone use and health) a longitudinal cohort study which is completed (2019). Carolina Calderon has been involved in MOBI-Kids (risk of brain cancer from exposure to radiofrequency fields in childhood adolescence) and GERoNIMO, of which the Tsarna 2019 study was one of the outcomes. However, they were not directly involved in the Tsarna 2019 paper and was not involved in the selection, data extraction or risk of bias assessment for this study.].

Acknowledgements We would like to thank Jos Verbeek, Emilie Van Deventer and Maria Feychting for their expertise and support throughout the systematic review.

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Detrimental impact of cell phone radiation on sperm DNA integrity

Koohestanidehaghi Y, Khalili MA, Dehghanpour F, Seify M. Detrimental impact of cell phone radiation on sperm DNA integrity. Clinical and Experimental Reproductive Medicine 2024;51(1):13-19.

Abstract

Radiofrequency electromagnetic radiation (RF-EMR) from various sources may impact health due to the generation of frequency bands. Broad pulses emitted within frequency bands can be absorbed by cells, influencing their function. Numerous laboratory studies have demonstrated that mobile phones—generally the most widely used devices—can have harmful effects on sex cells, such as sperm and oocytes, by producing RF-EMR. Moreover, some research has indicated that RF-EMR generated by mobile phones can influence sperm parameters, including motility, morphology, viability, and (most critically) DNA structure. Consequently, RF-EMR can disrupt both sperm function and fertilization. However, other studies have reported that exposure of spermatozoa to RF-EMR does not affect the functional parameters or genetic structure of sperm. These conflicting results likely stem from differences among studies in the duration and exposure distance, as well as the species of animal used. This report was undertaken to review the existing research discussing the effects of RF-EMR on the DNA integrity of mammalian spermatozoa.

Conclusion

EMW can induce oxidative stress, which subsequently leads to disorders such as reduced mobility, morphological changes, acrosome disturbances, and ultimately, damage to the nucleus and genetic material. This oxidative damage to DNA can result in the breakdown of both single-stranded and double-stranded DNA structures, culminating in fragmentation. If the DNA is not repaired and the damage accumulates, the sperm may undergo apoptosis. Damage to the sperm genome can ultimately impact

fertility, potentially leading to infertility. Therefore, it is advisable to limit daily exposure to these sources to prevent irreversible damage caused by EMWs. Many men carry their cell phones in their trouser pockets or clipped to their belts, and the use of Bluetooth can increase their susceptibility to RF-EMR exposure. This exposure can induce changes in sperm quality through oxidative stress, potentially leading to infertility. Agarwal et al. [11] suggested that carrying a cell phone in a pocket could lead to a decline in sperm quality. However, it is important to note that the phone and male reproductive organs are separated by multiple tissue layers. Therefore, extrapolating these in vitro effects to real-life conditions requires further studies [11].

In July 2021, the European Parliament commissioned a research report titled “Health impact of 5G.” The report concluded that the commonly used RF-EMFs are likely carcinogenic to humans and have a definitive impact on male fertility. It also suggested potential adverse effects on the development of embryos, fetuses, and newborns. To mitigate these adverse effects, the organization proposed several strategies. These include favoring non-wireless connections, increasing distance from the source of RF-EMFs, switching off devices when not in use, and practicing safe phone usage [55].

Open access paper: https://ecerm.org/journal/view.php?doi=10.5653/cerm.2023.06121

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A comprehensive review of 5G NR RF-EMF exposure assessment technologies: fundamentals, advancements, challenges, niches, and implications

Korkmaz E, Aerts S, Coesoij R, Bhatt CR, Velghe M, Colussi L, Land D, Petroulakis N, Spirito M, Bolte J. A comprehensive review of 5G NR RF-EMF exposure assessment technologies: fundamentals, advancements, challenges, niches, and implications. Environ Res. 2024 Jul 5:119524. doi: 10.1016/j.envres.2024.119524.

Abstract

This review offers a detailed examination of the current landscape of radio frequency (RF) electromagnetic field (EMF) assessment tools, ranging from spectrum analyzers and broadband field meters to area monitors and custom-built devices. The discussion encompasses both standardized and non-standardized measurement protocols, shedding light on the various methods employed in this domain. Furthermore, the review highlights the prevalent use of mobile apps for characterizing 5G-NR radio network data. A growing need for low-cost measurement devices is observed, commonly referred to as ”sensors” or ”sensor nodes,” that are capable of enduring diverse environmental conditions. These sensors play a crucial role in both microenvironmental surveys and individual exposures, enabling stationary, mobile, and personal exposure assessments based on body-worn sensors, across wider geographical areas. This review revealed a notable need for cost-effective and long-lasting sensors, whether for individual exposure assessments, mobile (vehicle-integrated) measurements, or incorporation into distributed sensor networks. However, there is a lack of comprehensive information on existing custom-developed RF-EMF measurement tools, especially in terms of measuring uncertainty. Additionally, there is a need for real-time, fast-sampling solutions to understand the highly irregular temporal variations EMF distribution in next-generation networks.

Given the diversity of tools and methods, a comprehensive comparison is crucial to determine the necessary statistical tools for aggregating the available measurement data.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0013935124014294

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Under the Hood of Electromagnetic Field Estimation and Evaluation in 5G Networks

Estrada-Jimenez JC, Pardo E, Roth U, L. Selmane L, Faye S. Under the Hood of Electromagnetic Field Estimation and Evaluation in 5G Networks. *IEEE Access*, doi: 10.1109/ACCESS.2024.3418301.

Abstract

The estimation of Electromagnetic Field (EMF) exposure is critical for evaluating the potential health risks associated with wireless network implementation. With the advent of new communication technologies, such as 5G and 6G, new methodologies are required. Indeed, higher frequency ranges are being studied, necessitating an increased number of base stations for service provision. In this paper, we introduce a novel methodology for EMF estimation in 5G mobile networks. We also evaluate common scenarios that mobile network operators frequently encounter, resulting in additional exposure, such as interference, overpropagation, and the presence of other users. Our approach is validated through a combination of simulated values and real data collected from sensors deployed in the field. Finally, a digital twin approach is proposed to combine the simulated values with the real data obtained from radio frequency sensors. The scenario is deployed in Belval, Luxembourg.

Open access paper: https://ieeexplore.ieee.org/document/10568919

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Demonstration of Safe Electromagnetic Radiation Emitted by 5G Active Antenna Systems

Kumar S, Sheemar CK, Astro A, Querol J, Chatzinotas S. Demonstration of Safe Electromagnetic Radiation Emitted by 5G Active Antenna Systems. arXiv:2406.07910v1 [cs.ET] 12 Jun 2024.

Abstract

The careful planning and safe deployment of 5G technologies will bring enormous benefits to society and economy. Higher frequency, beamforming and small-cells are key technologies that will provide unmatched throughput and seamless connectivity to the 5G users. Superficial knowledge of these technologies has raised concerns among the general public about the harmful effects of radiation. Several standardization bodies are active to put limits on the emissions which are based on a defined set of radiation measurement methodologies. However, due to the peculiarity of 5G such as dynamicity of the beams, network densification, Time Division Duplexing mode of operation, etc, using existing EMF measurement methods may provide inaccurate results. In this context, we discuss our experimental studies aimed towards the measurement of radiation caused by beam-based transmissions from 5G base-station equipped with an Active Antenna System (AAS). We elaborate on the shortcomings of current measurement methodologies and address several open questions. Next, we demonstrate that using user-specific downlink beamforming, not only better performance is achieved compared to non-beamformed downlink, but also the radiation in the vicinity of the intended user is significantly

decreased. Further, we show that under weak reception conditions, an uplink transmission can cause significantly high radiation in the vicinity of the user-equipment. We believe that our work will help in clearing several misleading concepts about the 5G EMF radiation effects. We conclude the work by providing guidelines to improve the methodology of EMF measurement by considering the spatio-temporal dynamicity of the 5G transmission.

Open access paper: https://arxiv.org/html/2406.07910v1

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Smartphone-Based Methodology Applied to Electromagnetic Field Exposure Assessment

López-Espí PL, Sánchez-Montero R, Guillén-Pina J, Castro-Sanz R, Chocano-Del-Cerro R, Martínez-Rojas JA. Smartphone-Based Methodology Applied to Electromagnetic Field Exposure Assessment. Sensors (Basel). 2024 May 31;24(11):3561. doi: 10.3390/s24113561.

Abstract

This study presents the measurements of exposure to electromagnetic fields, carried out comparatively following standard methods from fixed sites using a broadband meter and using a smartphone on which an App designed for this purpose has been installed. The results of two measurement campaigns carried out on the campus of the University of Alcalá over an area of 1.9 km^2 are presented. To characterize the exposure, 20 fixed points were measured in the first case and 860 points along the route made with a bicycle in the last case. The results obtained indicate that there is proportionality between the two methods, making it possible to use the smartphone for comparative measurements. The presented methodology makes it possible to characterize the exposure in the area under study in four times less time than that required with the traditional methodology

Open access paper: https://www.mdpi.com/1424-8220/24/11/3561

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A boundary element method of bidomain modeling for predicting cellular responses to electromagnetic fields

Czerwonky DM, Aberra AS, Gomez LJ. A boundary element method of bidomain modeling for predicting cellular responses to electromagnetic fields. J Neural Eng. 2024 Jun 11. doi: 10.1088/1741-2552/ad5704.

Abstract

Objective: Commonly used cable equation approaches for simulating the effects of electromagnetic fields on excitable cells make several simplifying assumptions that could limit their predictive power. Bidomain or “whole” finite element methods have been developed to fully couple cells and electric fields for more realistic neuron modeling. Here, we introduce a novel bidomain integral equation designed for determining the full electromagnetic coupling between stimulation devices and the intracellular, membrane, and extracellular regions of neurons.

Methods: Our proposed boundary element formulation offers a solution to an integral equation that connects the device, tissue inhomogeneity, and cell membrane-induced E-fields. We solve this integral equation using first-order nodal elements and an unconditionally stable Crank-Nicholson time-stepping

scheme. To validate and demonstrate our approach, we simulated cylindrical Hodgkin-Huxley axons and spherical cells in multiple brain stimulation scenarios.

Main Results: Comparison studies show that a boundary element approach produces accurate results for both electric and magnetic stimulation. Unlike bidomain finite element methods, the bidomain boundary element method does not require volume meshes containing features at multiple scales. As a result, modeling cells, or tightly packed populations of cells, with microscale features embedded in a macroscale head model, is simplified, and the relative placement of devices and cells can be varied without the need to generate a new mesh.

Significance: Device-induced electromagnetic fields are commonly used to modulate brain activity for research and therapeutic applications. Bidomain solvers allow for the full incorporation of realistic cell geometries, device E-fields, and neuron populations. Thus, multi-cell studies of advanced neuronal mechanisms would greatly benefit from the development of fast-bidomain solvers to ensure scalability and the practical execution of neural network simulations with realistic neuron morphologies.

Conclusion

We introduced a novel bidomain integral equation for modeling the electric response of neuron cells to device-induced E-fields. Our study includes several canonical test cases with unmyelinated cells, including scenarios with multiple cells, transverse polarization, DBS electrodes at varying proximity to multiple axon geometries, and TMS with a spherical head model. The study results indicate that (1) the hybrid cable-equation approach is a sufficient choice for most simulations, (2) longitudinal stimulation serves as the primary activation mechanism for electromagnetic brain stimulation, and (3) multi-cell studies of advanced mechanisms would greatly benefit from further development of fast-bidomain or hybrid cable-bidomain solvers. Our future efforts will focus on developing fast bidomain solvers to fully incorporate realistic neuron morphologies.

Acknowledgements

Preliminary results for this work have been presented at the Applied Computational Electromagnetics Society (ACES) 2023 conference (March 2023, Monterey, California, USA)[67], the 2023 IEEE MTTS International Conference on Numerical Electromagnetic and Multiphysics Modeling and Optimization (NEMO'2023, June 2023, Winnipeg, Canada), the IEEE International Symposium on Antennas and Propagation Society and USNC-URSI Radio Science Meeting (IEEE-AP-S 2023, July 2023, Portland, Oregon, USA), and the Brain and Human Body Modeling conference 2023 (BHBM 2023, August 2023, Boston, Massachusetts, USA). Additionally, a preprint of this manuscript has been uploaded to https://www.biorxiv.org.

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Open access paper: https://iopscience.iop.org/article/10.1088/1741-2552/ad5704

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(In)accuracy and convergent validity of daily end-of-day and single-time self-reported estimations of smartphone use among adolescents

Tkaczyk M, Tancoš M, Smahel D, Elavsky S, Plhák J. (In)accuracy and convergent validity of daily end-of-day and single-time self-reported estimations of smartphone use among adolescents. Computers in Human Behavior. Vol. 158, 2024, doi: 10.1016/j.chb.2024.108281.

Abstract

Understanding the measurement inaccuracy and bias introduced by self-reports of smartphone use is essential for making meaningful inferences about smartphone use and its effects. Evidence for the self-reports of smartphone use in intensive longitudinal studies is largely missing. Based on self-reported and digital trace data from 137 Czech adolescents (41% girls, Mage = 14.95 years), this study examined the accuracy, directional bias, and convergent validity of daily end-of-day and single-time reports of screen time and phone-checking behavior. Overall, the study found considerable discrepancies between self-reported smartphone use and digital trace and low between-person convergent validity for all self-reports considered for the study. Respondents usually reported shorter screen time and lower frequency of phone-checking behavior as compared to digital trace, both in daily and single-time self-reports. The within-person convergent validity between daily reports and digital tracking was low, indicating poor self-reports ability to capture the actual day-to-day fluctuations in smartphone use. This study adds to the existing evidence showing that self-reports based insights into how people use smartphones differ considerably from digital trace data and shows that both person and situational levels contribute to explaining the discrepancy between digital trace and self-report data among adolescents.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0747563224001493

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Fuzzy-Based Bioengineering System for Predicting and Diagnosing Diseases of the Nervous System Triggered by the Interaction of Industrial Frequency Electromagnetic Fields

Korenevskiy NA, Al-Kasasbeh RT, Krikunova EA, Rodionova SN, Shaqdan A, Al-Habahbeh OM, Filist S, Alshamasin MS, Khrisat MS, Ilyash M. Fuzzy-Based Bioengineering System for Predicting and Diagnosing Diseases of the Nervous System Triggered by the Interaction of Industrial Frequency Electromagnetic Fields. Crit Rev Biomed Eng. 2024;52(5):1-16. doi: 10.1615/CritRevBiomedEng.2024053240.

Abstract

The study aims to enhance the standard of medical care for individuals working in the electric power industry who are exposed to industrial frequency electromagnetic fields and other relevant risk factors. This enhancement is sought through the integration of fuzzy mathematical models with contemporary information and intellectual technologies. The study addresses the challenges of forecasting and diagnosing illnesses within a specific demographic characterized by a combination of poorly formalized issues with interconnected conditions. To tackle this complexity, a methodological framework was developed for synthesizing hybrid fuzzy decision rules. This approach combines clinical expertise with artificial intelligence methodologies to promote innovative problem-solving strategies. Additionally, the researchers devised an original method to evaluate the body's protective capacity, which was integrated into these decision rules to enhance the precision and efficacy of medical decision-making processes. The research findings indicate that industrial frequency electromagnetic fields contribute to illnesses of societal significance. Additionally, it highlights that these effects are worsened by other risk factors such as adverse microclimates, noise, vibration, chemical exposure, and psychological stress. Diseases of the neurological, immunological, cardiovascular, genitourinary, respiratory, and digestive systems are caused by these variables in conjunction with unique physical traits. The development of mathematical models in this study makes it possible to detect and diagnose disorders in workers exposed to electromagnetic fields early on, especially those pertaining to the autonomic nervous system and heart rhythm regulation. The results can be used in clinical practice to treat personnel in the electric power industry since expert evaluation and modeling showed high confidence levels in decision-making accuracy.

https://pubmed.ncbi.nlm.nih.gov/38884210/

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Exposure assessment and cytogenetic biomonitoring study of workers occupationally exposed to extremely low-frequency magnetic fields

Nguyen H, Vandewalle G, Mertens B, Collard JF, Hinsenkamp M, Verschaeve L, Feipel V, Magne I, Souques M, Beauvois V, Ledent M. Exposure assessment and cytogenetic biomonitoring study of workers occupationally exposed to extremely low-frequency magnetic fields. Bioelectromagnetics. 2024 Jun 11. doi: 10.1002/bem.22506.

Abstract

Human cytogenetic biomonitoring (HCB) has long been used to evaluate the potential effects of work environments on the DNA integrity of workers. However, HCB studies on the genotoxic effects of occupational exposure to extremely low-frequency electromagnetic fields (ELF-MFs) were limited by the quality of the exposure assessment. More specifically, concerns were raised regarding the method of exposure assessment, the selection of exposure metrics, and the definition of exposure group. In this study, genotoxic effects of occupational exposure to ELF-MFs were assessed on peripheral blood lymphocytes of 88 workers from the electrical sector using the comet and cytokinesis-block micronucleus assay, considering workers' actual exposure over three consecutive days. Different methods were applied to define exposure groups. Overall, the summarized ELF-MF data indicated a low exposure level in the whole study population. It also showed that relying solely on job titles might misclassify 12 workers into exposure groups. We proposed combining hierarchical agglomerative clustering on personal exposure data and job titles to define exposure groups. The final results showed

that occupational MF exposure did not significantly induce more genetic damage. Other factors such as age or past smoking rather than ELF-MF exposure could affect the cytogenetic test outcomes.

Highlights

- The study results indicated that exposure assessment had better rely on the workers' actual exposure data.
- Electrical workers in this study were exposed on average to quite low levels of 50 Hz magnetic fields at work. But there was wide variability between workers. This highlights the value of using cluster analysis on workers' actual exposure data to define exposure groups.
- Occupational exposure to 50 Hz magnetic fields did not significantly increase the level of DNA or chromosomal damage on workers' blood samples.

Open access paper: https://pubmed.ncbi.nlm.nih.gov/38862415/

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Thoughts on the entanglement of electromagnetism and life: A theoretical study

Zsarnovszky A. Thoughts on the entanglement of electromagnetism and life: A theoretical study. Acta Vet Hung. 2024 Jun 18. doi: 10.1556/004.2023.00976. Epub ahead of print. PMID: 38888962.

Abstract

Dissection of the matter into its constituents leads us to the smallest particles that we know. These particles form a material structure that is determined by the electromagnetic field generated and carried by those particles. Changes in any of the two major constituents leads to changes in that material system, be it a living organism or a lifeless object. The latter statement carries the mystery of life that is born from a continuous and programmed series of system changes fuelled by an energy source with a yet unknown functioning mechanism. The present work is a theoretical approach towards the understanding and potential discovery of the aforementioned, not-yet-known cellular energetic mechanism. Understanding the energetic basis of intracellular biochemistry is equally important in human and animal therapeutics. Additionally, as all such discoveries offer novel solutions in various fields of the global industry, the final outcome of this theoretical work also brings about the idea of a new discovery in electronics industry.

Open access paper: https://akjournals.com/view/journals/004/aop/article-10.1556-004.2023.00976/article-10.1556-004.2023.00976.xml

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Investigation of genetic stress parameters in brain tissues of rats exposed to 1.8 GHz cell phone radiofrequency electromagnetic field

Arslan B, Aras N, Yaman S, Comelekoglu U. Investigation of genetic stress parameters in brain tissues of rats exposed to 1.8 GHz cell phone radiofrequency electromagnetic field. Med Science. 2024;13(1):78-82.

Abstract

Heat Shock Proteins (HSPs) may induce various cellular processes, including replication, apoptosis, cell-cycle progression. Mitogen-activated protein kinase (MAPK) cascades are the primary mechanism that mediates the cellular stress response to extracellular stimuli and regulates transcriptional activity. It has been shown that mobile phone exposure can stimulate the Hsp27/p38MAPK stress pathway. In this study, twenty-seven mature female Wistar albino rats were exposed to 1.8 GHz radiofrequency electromagnetic field (RF-EMF) 2h/day for 8 weeks (SAR: 0.06 W/kg). Hsp27 and p38MAPK gene expressions were investigated in rat brains. Rats were divided into groups sham-exposed, cage control, and 1.8 GHz RF-EMF exposed. Hsp27 and p38MAPK gene expression levels were investigated from the brain. p38MAPK expression was found to be upregulated in RF-EMF exposed group (p=0.018) Hsp27 expressions were not altered (p=0.897). In conclusion, long-term exposure to 1.8 GHz cell phone radiation can activate the Hsp27/p38MAPK stress pathway. It may cause several cellular disorders and can affect brain function.

Open access paper: https://www.medicinescience.org/article/4261

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Critical role of model organism selection in assessing weak urban electromagnetic field effects: Implications for human health

Sincak M, Adamkova P, Demeckova V, Smelko M, Lipovsky P, Oravec M, Luptakova A, Sedlakova-Kadukova J. Critical role of model organism selection in assessing weak urban electromagnetic field effects: Implications for human health. Bioelectrochemistry. 2024 Jun 29;160:108756. doi: 10.1016/j.bioelechem.2024.108756.

Highlights

- Real urban electromagnetic field present a combination 50 and 150 Hz in ratio 4:1.
- Macrophages shifted from M2 to M1 phenotype in 2 h in urban magnetic field.
- Urban magnetic fields can induce pro-inflammatory macrophage phenotype.
- Yeast showed only one change: 17 h exponential growth phase extension.
- Is crucial to choose proper organism for study of urban magnetic field perception.

Abstract

The impact of electromagnetic fields on human health has been investigated in recent years using various model organisms, yet the findings remain unclear. In our work, we examined the effect of less-explored, weak electromagnetic fields commonly found in the urban environments we inhabit. We studied different impacts of electromagnetic fields with a frequency of 50 Hz and a combination of 50 Hz and 150 Hz, on both yeasts (Saccharomyces cerevisiae) and human macrophages. We determined growth, survival, and protein composition (SDS-PAGE) (Saccharomyces cerevisiae) and morphology of macrophages (human monocytic cell line). In yeast, the sole observed change after 24 h of exposure was the extension of the exponential growth phase by 17 h. Conversely, macrophages exhibited morphological transformations from the anti-inflammatory to the pro-inflammatory type within just 2 h of exposure to the electromagnetic field. Our results suggest that effects of electromagnetic field largely depend on the model organism. The selection of an appropriate model organism proves essential for the study of the specific impacts of electromagnetic fields. The potential risk associated with the presence of

pro-inflammatory M1 macrophages in everyday urban environments primarily arises from the continual promotion of inflammatory reactions within a healthy organism and deserves further investigation.

https://pubmed.ncbi.nlm.nih.gov/38959750/

Conclusion

Based on our observations, macrophages appear to be more responsive to the presence of an electromagnetic field, making them a more proper model organism for describing the influence of the urban electromagnetic environment on humans compared to yeasts. Our results demonstrate that while yeasts did not exhibit changes in growth, pH, and redox potential within 24 h under low-intensity fields (20 µT and 50 or 50/150 Hz), immune system cells detected a magnetic field alteration within just 2 h, manifested in a shift in their phenotype.

Though these changes were temporary, the transformation of macrophages into pro-inflammatory M1 macrophages raises concerns about the potential risks associated with prolonged exposure to the weak urban electromagnetic fields that surround us daily. Continuous exposure to electromagnetic fields in our daily lives may have adverse effects on our health, as demonstrated through the use of macrophages as model organisms.

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On the origin of the biological effects of time varying magnetic fields: quantitative insights

Ravikumar K, Roy Choudury AN, Dubey AK, Kumaran V, Basu B. On the origin of the biological effects of time varying magnetic fields: quantitative insights. J Mater Chem B. 2024 Jul 3. doi:10.1039/d4tb00362d.

Abstract

In a number of recently published experimental studies from our research group, the positive impact of magnetic stimuli (static/pulsed) on cell functionality modulation or bactericidal effects, *in vitro*, has been established. In order to develop a theoretical understanding of such magnetobiological effects, the present study aimed to present two quantitative models to determine magnetic Maxwell stresses as well as pressure acting on the cell membrane, under the influence of a time varying magnetic field. The model predicts that magnetic field-induced stress on the cell/bacteria is dependent on the conductivity properties of the extracellular region, which is determined to be too low to cause any significant effect. However, the force on the cell/bacteria due to the induced electric field is more influential than that of the magnetic field, which has been used to determine the membrane tension that can cause membrane poration. With a known critical membrane tension for cells, the field parameters necessary to cause membrane rupture have been estimated. Based on the experimental results and theoretically predicted values, the field parameters can be classified into three regimes, wherein the magnetic fields cause no effect or result in biophysical stimulation or induce cell death due to membrane damage. Taken together, this work provides some quantitative insights into the impact of magnetic fields on biological systems.

https://pubmed.ncbi.nlm.nih.gov/38958687/

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Do non-ionizing radiation concerns affect people's choice between hybrid and traditional cars?

Anat Tchetchik, Sigal Kaplan, Orit Rotem-Mindali O. Do non-ionizing radiation concerns affect people's choice between hybrid and traditional cars? Transportation Research Part D: Transport and Environment, Volume 131, 2024, doi: 10.1016/j.trd.2024.104226.

Abstract

The growing market for hybrid electric vehicles (HEV) has raised concerns about the long-term impacts of non-ionizing radiation (NIR) exposure. This study is the first to address the impact of NIR on consumer choice between HEV and internal combustion engine (ICE) vehicles. We explore the hypothesis that NIR is associated with a lower probability of HEV choice in the presence of NIR information and the relative effect of NIR-health concerns versus environmental attitudes and driving norms. The data are collected from a stated choice experiment and estimated via a hybrid choice model. The results show that i NIR is associated with a lower choice probability of HEV, ii NIR-dread is associated with a higher probability of choosing ICE vehicles, while skepticism about NIR is associated with a higher probability of choosing HEV, iii prompting positively or negatively framed information about NIR discourages HEV choice compared to providing no information.

Conclusions and policy recommendations

The results show the effect of NIR-associated barriers on the choice of HEV versus ICE and highlight the following policy recommendations.

First, the massive production of EVs combined with the lack of regulatory frameworks can lead to the introduction of low-cost car models with low NIR safety standards (Trentadue et al., 2020). The European Union recommends a clear regulatory framework and international standards to promote the transition toward EVs. This study showed that NIR levels negatively affect the choice of HEV, signaling to car manufacturers and policymakers that consumers are concerned about NIR levels. Accordingly, setting NIR safety standards and maintaining low NIR levels are important goals for the transition toward autonomous, connected, electric vehicles.

Second, this study showed that while NIR dread was a discouraging factor, NIR skepticism was a strong choice motivator. Thus, perceived occurrence probability is as important as NIR risk dread. As with other health issues, prevalence across the population is an important decision-making factor that, in the absence of information, may lead to self-exemption beliefs. Scientific evidence from large-scale studies regarding both short- and long-term NIR effects and their prevalence in the population and among risk groups will enable informed decision-making, help mitigate NIR dread, and establish meaningful guidelines for in-vehicle NIR levels. With climate goals requiring the transition toward EV by 2030 and with the rapid technological advancement of autonomous, connected, electric vehicles, establishing the prevalence of NIR short- and long-term health effects is important for the future of the industry.

Third, better information quality strengthens the relationship between the depiction of new vehicle technologies and perceived purchase value (Zhang et al., 2022). Our study showed that both positive and negative framing can lead to a lower choice probability when an NIR safety threshold is provided. In this study, the information that “Studies show that long-term exposure to NIR levels below 4 mG is safe”

was associated with lower choice probabilities, similar to the case of negative framing, “Studies show that long-term exposure to NIR levels below 4 mG increases the health risks to health concerns.” Policymakers and manufacturers must consider information quality in terms of accuracy, clarity, ambiguity, and potential sources of confusion and decision bias. In this study, consumers used the provided threshold of 4 mG as a decision anchor, which means that consumers in some cultural contexts seek clear, “fast and frugal” evaluation criteria without engaging in complex exposure evaluations.

Finally, the model shows that travel with children is negatively associated with HEV leasing. Nevertheless, while NIR dread is negatively associated with HEV leasing, an additional interaction effect between NIR levels and travel with children was not statistically significant. These results indicate that while NIR dread is important, there is no additional health concerns particularly asso- ciated with travel with children. Hence, the decrease in the HEV leasing propensity when traveling with children may be associated with other reasons, such as vehicle reliability or other concerns that were not investigated in the current study. Notably, previous studies found a particular concern for children’s health-related to NIR from mobile phones and cellular stations. Leach and Bromwich (2018) found that two-thirds of the participants believed that mobile technology use should be restricted due to possible health risks to children’s health. P¨olzl (2011) added that 30 % of the population had strong or considerable concerns regarding NIR health risks to children, and noted that adults can be motivated to adjust their behavior to protect their children. Further research is important in other regions and contexts, to understand more thoroughly the issue of HEV leasing or purchase when traveling with children.

https://www.sciencedirect.com/science/article/pii/S1361920924001834

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50 Hz magnetic field influences caspase-3 activity and cell cycle distribution in ionizing radiation exposed SH-SY5Y neuroblastoma cells

Nieminen V, Martikainen MV, Kalliomäki S, Virén T, Seppälä J, Juutilainen J, Naarala J, Luukkonen J. 50 Hz magnetic field influences caspase-3 activity and cell cycle distribution in ionizing radiation exposed SH-SY5Y neuroblastoma cells. Int J Radiat Biol. 2024 Jun 26:1-10. doi: 10.1080/09553002.2024.2369105.

Abstract

Purpose: Earlier evidence suggests that extremely low frequency magnetic fields (ELF MFs) can modify the effects of carcinogenic agents. However, the studies conducted so far with ionizing radiation as the co-exposure agent are sparse and have provided inconclusive results. We investigated whether 50 Hz MFs alone, or in combination with ionizing radiation alter cell biological variables relevant to cancer and the biological effects of ionizing radiation.

Materials and methods: Human SH-SY5Y neuroblastoma cells were sham exposed or exposed to 100 or 500 µT MF for 24 h either before or after ionizing radiation exposure (0, 0.4 or 2 Gy). After the exposures, cells were assayed for viability, clonogenicity, reactive oxygen species, caspase-3 activity, and cell cycle distribution. Cell cycle distribution was assayed with propidium iodide staining followed by flow cytometry analysis and ROS levels were assayed together with cell viability by double staining with DeepRed and Sytox Blue followed by flow cytometry analysis.

Results: Increased caspase-3 activity was observed in cells exposed to 500 µT MF before or after ionizing radiation. Furthermore, exposure to the 500 µT MF after the ionizing radiation decreased the percentage of cells in S-phase. No changes in the ROS levels, clonogenicity, or viability of the cells were observed in the MF exposed groups compared to the corresponding sham exposed groups, and no MF effects were observed in cells exposed at 100 µT.

Conclusions: Only the 500 µT magnetic flux density affected SH-SY5Y cells significantly. The effects were small but may nevertheless help to understand how MFs modify the effects of ionizing radiation. The increase in caspase-3 activity may not reflect effects on apoptosis, as no changes were observed in the subG1 phase of the cell cycle. In contrast to some earlier findings, 50 Hz MF exposure after ionizing radiation was not less effective than MF treatment given prior to ionizing radiation.

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Electromagnetic field-induced adaptive response in Schwann cells through DNA methylation, histone deacetylation, and oxidative stress

Colciago A, Mohamed T, Colleoni D, Melfi V, Magnaghi V. Electromagnetic field-induced adaptive response in Schwann cells through DNA methylation, histone deacetylation, and oxidative stress. J Cell Physiol. 2024 Jun 30:e31365. doi: 10.1002/jcp.31365.

Abstract

Schwannomas are benign tumors of the peripheral nervous system arising from the transformation of Schwann cells (SCs). On the whole, these tumors are related to alterations of the neurofibromin type 2 gene, coding for the oncosuppressor merlin, a cytoskeleton-associated protein belonging to the ezrin-radixin-moesin family. However, the underlying mechanisms of schwannoma onset and progression are not fully elucidated, whereas one of the challenges might be the environment. In this light, the exposure to electromagnetic field (EMF), generated by the use of common electrical devices, has been defiantly suggested as the cause of SCs transformation even if the evidence was mostly epidemiologic. Indeed, insubstantial mechanisms have been so far identified to explain SCs oncotransformation. Recently, some in vitro evidence pointed out alterations in proliferation and migration abilities in SCs exposed to EMF (0.1 T, 50 Hz, 10 min). Here, we used the same experimental paradigma to discuss the involvement of putative epigenetic mechanisms in SCs adaptation to EMF and to explain the occurrence of hypoxic alterations after the exposure. Our findings indicate a set of environmental-induced changes in SCs, toward a less-physiological state, which may be pathologically relevant for the SCs differentiation and the schwannoma development.

https://pubmed.ncbi.nlm.nih.gov/38946084/

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The Slowest Shared Resonance: A Review of Electromagnetic Field Oscillations Between Central and Peripheral Nervous Systems

Young A, Hunt T, Ericson M. The Slowest Shared Resonance: A Review of Electromagnetic Field Oscillations Between Central and Peripheral Nervous Systems. Front Hum Neurosci. 2022 Feb 16;15:796455. doi: 10.3389/fnhum.2021.796455.

Abstract

Electromagnetic field oscillations produced by the brain are increasingly being viewed as causal drivers of consciousness. Recent research has highlighted the importance of the body's various endogenous rhythms in organizing these brain-generated fields through various types of entrainment. We expand this approach by examining evidence of extracerebral shared oscillations between the brain and other parts of the body, in both humans and animals. We then examine the degree to which these data support one of General Resonance Theory's (GRT) principles: the Slowest Shared Resonance (SSR) principle, which states that the combination of micro- to macro-consciousness in coupled field systems is a function of the slowest common denominator frequency or resonance. This principle may be utilized to develop a spatiotemporal hierarchy of brain-body shared resonance systems. It is predicted that a system's SSR decreases with distance between the brain and various resonating structures in the body. The various resonance relationships examined, including between the brain and gastric neurons, brain and sensory organs, and brain and spinal cord, generally match the predicted SSR relationships, empirically supporting this principle of GRT.

Open access paper:
https://www.frontiersin.org/journals/human-neuroscience/articles/10.3389/fnhum.2021.796455/full

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Brain structure alterations following neonatal exposure to low-frequency electromagnetic fields: A histological analysis

Sissons SM, Dotta BT. Brain structure alterations following neonatal exposure to low-frequency electromagnetic fields: A histological analysis. Int J Dev Neurosci. 2024 Jul 5. doi: 10.1002/jdn.10361.

Abstract

Nitric oxide (NO) and electromagnetic fields (EMF) have been extensively studied for their roles in neurobiology, particularly in regulating cerebral functions and synaptic plasticity. This study investigates the impact of EMFs on NO modulation and its subsequent effects on neurodevelopment, building upon prior research examining EMF exposure's consequences on Wistar albino rats. Rats were exposed perinatally to either tap water, 1 g/L of L-arginine (LA) or 0.5 g/L of N-methylarginine (NMA). Half of the rats in each group were also exposed to a 7-Hz square-wave EMF at three separate intensities (5, 50 and 500 nT) for 2-14 days following birth. Animals were allowed to develop, and their brains were harvested later in adulthood (mean age = 568.17 days, SD = 162.73). Histological analyses were used to elucidate structural changes in key brain regions. All brains were stained with Toluidine Blue O (TBO), enabling the visualization of neurons. Neuronal counts were then conducted in specific regions of interest (e.g. hippocampus, cortices, amygdala and hypothalamus). Histological analyses revealed significant alterations in neuronal density in specific brain regions, particularly in response to EMF exposure and pharmacological interventions. Notable findings include a main EMF exposure effect where increased neuronal counts were observed in the secondary somatosensory cortex under low EMF intensities ($p <$

0.001) and sex-specific responses in the hippocampus, where a significant increase in neuronal counts was observed in the left CA3 region in female rats exposed to EMF compared to unexposed females ($t(18) = 2.371$, $p = 0.029$). Additionally, a significant increase in neuronal counts in the right entorhinal cortex was seen in male rats exposed to EMF compared to unexposed males ($t(18) = 2.216$, $p = 0.040$). These findings emphasize the complex interaction among sex, EMF exposure and pharmacological agents on neuronal dynamics across brain regions, highlighting the need for further research to identify underlying mechanisms and potential implications for cognitive function and neurological health in clinical and environmental contexts.

https://pubmed.ncbi.nlm.nih.gov/38967459/

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Electromagnetic Exposure Levels of Electric Vehicle Drive Motors to Passenger Wearing Cardiac Pacemakers

Dong X, Qian Y, Lu M. Electromagnetic Exposure Levels of Electric Vehicle Drive Motors to Passenger Wearing Cardiac Pacemakers. *Sensors*. 2024; 24(13):4395. doi: 10.3390/s24134395

Abstract

The number of individuals wearing cardiac pacemakers is gradually increasing as the population ages and cardiovascular disease becomes highly prevalent. The safety of pacemaker wearers is of significant concern because they must ensure that the device properly functions in various life scenarios. Electric vehicles have become one of the most frequently used travel tools due to the gradual promotion of low-carbon travel policies in various countries. The electromagnetic environment inside the vehicle is highly complex during driving due to the integration of numerous high-power electrical devices inside the vehicle. In order to ensure the safety of this group, the paper takes passengers wearing cardiac pacemakers as the object and the electric vehicle drive motors as the exposure source. Calculation models, with the vehicle body, human body, heart, and cardiac pacemaker, are built. The induced electric field, specific absorption rate, and temperature changes in the passenger's body and heart are calculated by using the finite element method. Results show that the maximum value of the induced electric field of the passenger occurs at the ankle of the body, which is 60.3 mV/m. The value of the induced electric field of the heart is greater than that of the human trunk, and the maximum value (283 mV/m) is around the pacemaker electrode. The maximum specific absorption rate of the human body is 1.08×10^{-6} W/kg, and that of heart positioned near the electrode is 2.76×10^{-5} W/kg. In addition, the maximum temperature increases of the human torso, heart, and pacemaker are 0.16×10^{-5} °C, 0.4×10^{-6} °C, and 0.44×10^{-6} °C within 30 min, respectively. Accordingly, the induced electric field, specific absorption rate, and temperature rise in the human body and heart are less than the safety limits specified in the ICNIRP. The electric field intensity at the pacemaker electrode and the temperature rise of the pacemaker meet the requirements of the medical device standards of ICNIRP and ISO 14708-2. Consequently, the electromagnetic radiation from the motor operation in the electric vehicle does not pose a safety risk to the health of passengers wearing cardiac pacemakers in this paper. This study also contributes to advancing research on the electromagnetic environment of electric vehicles and provides guidance for ensuring the safe travel of individuals wearing cardiac pacemakers.

Open access paper: https://www.mdpi.com/1424-8220/24/13/4395

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Personal light exposure patterns and incidence of type 2 diabetes: analysis of 13 million hours of light sensor data and 670,000 person-years of prospective observation

Daniel P. Windred, Angus C. Burns, Martin K. Rutter, Chris Ho Ching Yeung, Jacqueline M. Lane, Qian Xiao, Richa Saxena, Sean W. Cain, Andrew J. K. Phillips. Personal light exposure patterns and incidence of type 2 diabetes: analysis of 13 million hours of light sensor data and 670,000 person-years of prospective observation. Lancet. 2024. doi: 10.1016/j.lanepe.2024.100943.

Abstract

Background Light at night disrupts circadian rhythms, and circadian disruption is a risk factor for type 2 diabetes. Whether personal light exposure predicts diabetes risk has not been demonstrated in a large prospective cohort. We therefore assessed whether personal light exposure patterns predicted risk of incident type 2 diabetes in UK Biobank participants, using ∼13 million hours of light sensor data.

Methods Participants (N = 84,790, age (M ± SD) = 62.3 ± 7.9 years, 58% female) wore light sensors for one week, recording day and night light exposure. Circadian amplitude and phase were modeled from weekly light data. Incident type 2 diabetes was recorded (1997 cases; 7.9 ± 1.2 years follow-up; excluding diabetes cases prior to light-tracking). Risk of incident type 2 diabetes was assessed as a function of day and night light, circadian phase, and circadian amplitude, adjusting for age, sex, ethnicity, socioeconomic and lifestyle factors, and polygenic risk.

Findings Compared to people with dark nights (0–50th percentiles), diabetes risk was incrementally higher across brighter night light exposure percentiles (50–70th: multivariable-adjusted HR = 1.29 [1.14–1.46]; 70–90th: 1.39 [1.24–1.57]; and 90–100th: 1.53 [1.32–1.77]). Diabetes risk was higher in people with lower modeled circadian amplitude (aHR = 1.07 [1.03–1.10] per SD), and with early or late circadian phase (aHR range: 1.06–1.26). Night light and polygenic risk independently predicted higher diabetes risk. The difference in diabetes risk between people with bright and dark nights was similar to the difference between people with low and moderate genetic risk.
Interpretation Type 2 diabetes risk was higher in people exposed to brighter night light, and in people exposed to light patterns that may disrupt circadian rhythms. Avoidance of light at night could be a simple and cost-effective recommendation that mitigates risk of diabetes, even in those with high genetic risk.

Open access paper: https://www.thelancet.com/pdfs/journals/lanepe/PIIS2666-7762(24)00110-8.pdf

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IEC/IEEE Draft International Standard - Assessment methods of the human exposure to electric and magnetic fields from wireless power transfer systems

IEC/IEEE Draft International Standard - Assessment methods of the human exposure to electric and magnetic fields from wireless power transfer systems - models, instrumentation, measurement and numerical methods and procedures (Frequency range of 1 kHz to 30 MHz). *IEC/IEEE P63184/FDIS, June 2024* , vol., no., pp.1-153, 26 June 2024.

Abstract

The objective of this document is to specify the assessment methods to evaluate compliance of stationary and dynamic wireless power transfer (WPT) systems with electromagnetic human exposure guidelines (specific absorption rate (SAR), internal electric fields, or current density including contact currents). The frequency range covered by this document is from 1 kHz to 30 MHz. This version of the standard focuses on exposures from inductive WPT systems. Future versions will consider extended guidance for assessments of exposure from capacitive WPT systems.

https://ieeexplore.ieee.org/document/10576682

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Evaluation of oxidative stress and genetic instability among residents near mobile phone base stations in Germany

Gulati S, Mosgoeller W, Moldan D, Kosik P, Durdik M, Jakl L, Skorvaga M, Markova E, Kochanova D, Vigasova K, Belyaev I. Evaluation of oxidative stress and genetic instability among residents near mobile phone base stations in Germany. Ecotoxicology and Environmental Safety, Volume 279, 2024, doi: 10.1016/j.ecoenv.2024.116486.

Highlights

- Residents exposed to RF-EMR from base stations were tested for genetic instability.
- The years long exposure had no measurable effect on specific cancer related genes.
- We found high level of lipid peroxidation and DNA-lesions but not significant.
- Chromosomal aberrations were significantly more pronounced in highly exposed group.

Abstract

Human exposure to radiofrequency electromagnetic fields (RF-EMF) is restricted to prevent thermal effects in the tissue. However, at very low intensity exposure "non-thermal" biological effects, like oxidative stress, DNA or chromosomal aberrations, etc. collectively termed genomic-instability can occur after few hours. Little is known about chronic (years long) exposure with non-thermal RF-EMF. We identified two neighboring housing estates in a rural region with residents exposed to either relatively low (control-group) or relatively high (exposed-group) RF-EMF emitted from nearby mobile phone base stations (MPBS). 24 healthy adults that lived in their homes at least for 5 years volunteered. The homes were surveyed for common types of EMF, blood samples were tested for oxidative status, transient DNA alterations, permanent chromosomal damage, and specific cancer related genetic markers, like MLL gene rearrangements. We documented possible confounders, like age, sex, nutrition, life-exposure to ionizing radiation (X-rays), occupational exposures, etc. The groups matched well, age, sex, lifestyle and occupational risk factors were similar. The years long exposure had no measurable effect on MLL gene rearrangements and c-Abl-gene transcription modification. Associated with higher exposure, we found higher levels of lipid oxidation and oxidative DNA-lesions, though not statistically significant. DNA double strand breaks, micronuclei, ring chromosomes, and acentric chromosomes were not significantly different between the groups. Chromosomal aberrations like dicentric chromosomes ($p=0.007$), chromatid gaps ($p=0.019$), chromosomal fragments ($p<0.001$) and the total of chromosomal aberrations ($p<0.001$) were significantly higher in the exposed group. No potential confounder interfered with these

findings. Increased rates of chromosomal aberrations as linked to excess exposure with ionizing radiation may also occur with non-ionizing radiation exposure. Biological endpoints can be informative for designing exposure limitation strategies. Further research is warranted to investigate the dose-effect-relationship between both, exposure intensity and exposure time, to account for endpoint accumulations after years of exposure. As established for ionizing radiation, chromosomal aberrations could contribute to the definition of protection thresholds, as their rate reflects exposure intensity and exposure time.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0147651324005621

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Analysis of the metabolic profile of humans naturally exposed to RF-EM radiation

Rangesh NM, Malaisamy AK, Kumar N, Kumar S. Analysis of the metabolic profile of humans naturally exposed to RF-EM radiation. Metabolomics. 2024 May 18;20(3):55. doi: 10.1007/s11306-024-02121-2.

Abstract

Introduction: The world is experiencing exponential growth in communication, especially wireless communication. Wireless connectivity has recently become a part of everyone's daily life. Recent developments in low-cost, low-power, and miniature devices contribute to a significant rise in radiofrequency-electromagnetic field (RF-EM) radiation exposure in our environment, raising concern over its effect on biological systems. The inconsistent and conflicting research results make it difficult to draw definite conclusions about how RF-EM radiation affects living things.

Objectives: This study identified two micro-environments based on their level of exposure to cellular RF-EM radiation, one with significantly less exposure and another with very high exposure to RF-EM radiation. Emphasis is given to studying the metabolites in the urine samples of humans naturally exposed to these two different microenvironments to understand short-term metabolic dysregulations.

Methods: Untargeted 1H NMR spectroscopy was employed for metabolomics analyses to identify dysregulated metabolites. A total of 60 subjects were recruited with 5 ml urine samples each. These subjects were divided into two groups: one highly exposed to RF-EM (n = 30) and the other consisting of low-exposure populations (n = 30).

Results: The study found that the twenty-nine metabolites were dysregulated. Among them, 19 were downregulated, and 10 were upregulated. In particular, Glyoxylate and dicarboxylate and the TCA cycle metabolism pathway have been perturbed. The dysregulated metabolites were validated using the ROC curve analysis.

Conclusion: Untargeted urine metabolomics was conducted to identify dysregulated metabolites linked to RF-EM radiation exposure. Preliminary findings suggest a connection between oxidative stress and gut microbiota imbalance. However, further research is needed to validate these biomarkers and understand the effects of RF-EM radiation on human health. Further research is needed with a diverse population.

Conclusion

The purpose of this study was to initiate an exploration using urine metabolomics and ^{1}H NMR spectroscopy to identify specific dysregulated metabolites associated with RF-EM radiation exposure. The objective was to pinpoint potential biomarkers for future validation. Based on these preliminary findings, there appears to be a possible connection between RF-EM radiation exposure, oxidative stress, and disruptions in the gut microbiota balance. Nevertheless, it's imperative to stress that additional investigations with a larger and more diverse population are necessary to validate these identified biomarkers and gain a more comprehensive understanding of the effects of RF-EM radiation exposure on human health. Furthermore, individuals with lower levels of radiation exposure exhibited metabolite signatures of a healthier gut microbiota system, indicating a potential association between radiation exposure and microbiota health. However, it is crucial to emphasize that further research is essential for confirmation. Future studies involve conducting a comprehensive study involving individuals with substantial RF-EM radiation exposure alongside a control group of unexposed individuals.

https://pubmed.ncbi.nlm.nih.gov/38762651/

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Investigation of the Adverse Health Effects of Cell Phone Radiation and Propose Solutions to Minimize Them: A Systematic Review

Elyasi H, Ghanbari M, Nadri F. Investigation of the Adverse Health Effects of Cell Phone Radiation and Propose Solutions to Minimize Them: A Systematic Review. Indian J Occup Environ Med. 2024 Jan-Mar;28(1):18-22. doi: 10.4103/ijoem.ijoem_89_23.

Abstract

Today, mobile phones are one of the most common devices emitting electromagnetic radiation and are available to more than seven billion people in different age groups around the world. The effects of electromagnetic radiation on biological systems have been studied for several years. In this systematic review to find relevant articles, international databases such as Google Scholar, PubMed, Scopus, Science Direct, Web of Science, and Cochrane were used since 2007-2022 by selecting appropriate keywords. The result revealed that exposure to cell phone radiation can lead to disturb in the metabolic activity of the cerebellum by increasing the migration of granulosa cells, decrease the water around the fetus in pregnant women, decrease in the number of blood plates, increasing levels of ALT and AST that they are the key biomarkers of liver damage, decrease of phagocytosis and induced apoptosis of neutrophils, changes at the level of glucose and even at the microscopic level of pancreas this may be a predisposing factor for diabetes, increment in tissue temperature in all depth of the brain tissue, EMF increase the volume, weight, and atresia follicles of the ovaries of the children, also it can cause oxidative stress, DNA fragmentation, etc. Mobile phone radiation is harmful and depends on its intensity, frequency, wave type, and exposure duration. It can cause different biological effects in humans. Due to the uncertainty of the results and mechanism of the effect of these waves, research in this field is still ongoing.

Open access paper: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11111148/

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Evaluation of neonatal outcomes according to the specific absorption rate values of phones used during pregnancy

Büyükeren M, Karanfil Yaman F. Evaluation of neonatal outcomes according to the specific absorption rate values of phones used during pregnancy. J Turk Ger Gynecol Assoc. 2024 Mar 6;25(1):7-12. doi: 10.4274/jtgga.galenos.2023.2022-10-1.

Abstract

Objective: The aim was to compare neonatal outcomes according to cell phone specific absorption rate (SAR) levels and daily time spent on cell phones by pregnant women.

Material and Methods: Women who gave birth at Konya City Hospital between September 2020 and February 2021 were included in this retrospective study. Gestational ages, birth weight, birth length, head circumference, sex, 5-minute APGAR scores, neonate postpartum resuscitation requirement, delivery type, the model of phone used by the pregnant women, and the average time spent on the phone during a day were recorded. To determine the relation between the SAR values of the phones used and delivering a small for gestational age (SGA) baby, receiver operating characteristic curve analysis was performed.

Results: In total 1495 pregnant women were included. The rate of delivering a SGA fetus was significantly higher in women who used phones with higher SAR values (p=0.001). The cut-off value for the SAR level was 1.23 W/kg with 69.3% sensitivity and 73.0% specificity (area under the curve: 0.685; 95% confidence interval: 0.643-0.726). No correlation was found between time spent on the phone and SGA birth rate. Although both phone SAR values and time spent on the phone were higher in the symmetrical SGA group compared to the asymmetrical SGA group, the difference was not significant (p>0.05). Although the women who had preterm delivery had higher phone SAR values and had spent more time on the phone compared to those who had term deliveries, the difference was again not significant (p>0.05).

Conclusion: As the SAR values of cell phones used during pregnancy increased, there was a trend towards delivering a SGA baby.

Open access paper: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10921072/

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1.7 GHz LTE radiofrequency EMF with stable power monitoring and efficient thermal control has no effect on the proliferation of various human cell types

My note: The study employed a Western blot analysis which is less likely to detect DNA damage than a comet assay.

Goh J, Suh D, Park G, Jeon S, Lee Y, Kim N, Song K. 1.7 GHz long-term evolution radiofrequency electromagnetic field with stable power monitoring and efficient thermal control has no effect on the proliferation of various human cell types. PLoS One. 2024 May 7;19(5):e0302936. doi: 10.1371/journal.pone.0302936.

Abstract

Long-term evolution (LTE) radiofrequency electromagnetic field (RF-EMF) is widely used in communication technologies. Thus, the influence of RF-EMF on biological systems is a major public concern and its physiological effects remain controversial. In our previous study, we showed that continuous exposure of various human cell types to 1.7 GHz LTE RF-EMF at a specific absorption rate (SAR) of 2 W/Kg for 72 h can induce cellular senescence. To understand the precise cellular effects of LTE RF-EMF, we elaborated the 1.7 GHz RF-EMF cell exposure system used in the previous study by replacing the RF signal generator and developing a software-based feedback system to improve the exposure power stability. This refinement of the 1.7 GHz LTE RF-EMF generator facilitated the automatic regulation of RF-EMF exposure, maintaining target power levels within a 3% range and a constant temperature even during the 72-h-exposure period. With the improved experimental setup, we examined the effect of continuous exposure to 1.7 GHz LTE RF-EMF at up to SAR of 8 W/Kg in human adipose tissue-derived stem cells (ASCs), Huh7, HeLa, and rat B103 cells. Surprisingly, the proliferation of all cell types, which displayed different growth rates, did not change significantly compared with that of the unexposed controls. Also, neither DNA damage nor cell cycle perturbation was observed in the 1.7 GHz LTE RF-EMF-exposed cells. However, when the thermal control system was turned off and the subsequent temperature increase induced by the RF-EMF was not controlled during continuous exposure to SAR of 8 W/Kg LTE RF-EMF, cellular proliferation increased by 35.2% at the maximum. These observations strongly suggest that the cellular effects attributed to 1.7 GHz LTE RF-EMF exposure are primarily due to the induced thermal changes rather than the RF-EMF exposure itself.

Conclusion

To understand the precise cellular effect of 1.7 GHz LTE RF-EMF, we developed an RF-EMF cell exposure system with an improved RF signal generator and control software. With a refined RF-EMF exposure system, we could maintain a consistent target power during the 72-h-exposure period with minimal thermal effects. With this refined experimental setup, exposure to 1.7 GHz LTE RF-EMF at the SAR ranging from 0.4 W/Kg to 8 W/Kg neither affects the proliferation of various human cells with different growth rates nor induces DNA damage and cell cycle perturbation. Before upgrading the exposure system, we observed that the exposure of human cells to 1.7 GHz RF-EMF increased or decreased cell proliferation, depending on the SAR values. In addition, we verified that exposure to 1.7 GHz RF-EMF with this refined system affected cell proliferation when heat was not properly controlled. Altogether, these results suggest that exposure to 1.7 GHz LTE RF-EMF does not directly influence cell proliferation and that the physiological changes induced by RF-EMF might be associated with thermal effects.

Open access paper: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0302936

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The effects of radiofrequency exposure on cognition: A systematic review and meta-analysis of human observational studies

(My note: Systematic reviews require a multitude of macro- and micro-decisions. When conducted by biased investigative teams, systematic reviews generate erroneous conclusions and policy implications. By design, this review excluded most of the relevant research; hence, its conclusion is very limited in scope.)

Benke G, Abramson MJ, Brzozek C, McDonald S, Kelsall H, Sanagou M, Zeleke BM, Kaufman J, Brennan S, Verbeek J, Karipidis K. The effects of radiofrequency exposure on cognition: A systematic review and meta-analysis of human observational studies. Environment International. 2024. doi: 10.1016/j.envint.2024.108779.

Abstract

Background We aimed to assess evidence of long-term effects of exposure to radiofrequency (RF) electromagnetic fields (EMF) on indicators of cognition, including domains of learning and memory, executive function, complex attention, language, perceptual motor ability and social cognition, and of an exposure–response relationship between RF-EMF and cognition.

Methods We searched PubMed, Embase, PsycInfo and the EMF-Portal on September 30, 2022 without limiting by date or language of publication. We included cohort or case-control studies that evaluated the effects of RF exposure on cognitive function in one or more of the cognitive domains. Studies were rated for risk of bias using the OHAT tool and synthesised using fixed effects meta-analysis. We assessed the certainty of the evidence using the GRADE approach and considered modification by OHAT for assessing evidence of exposures.

Results We included 5 studies that reported analyses of data from 4 cohorts with 4639 participants consisting of 2808 adults and 1831 children across three countries (Australia, Singapore and Switzerland) conducted between 2006 and 2017. The main source of RF-EMF exposure was mobile (cell) phone use measured as calls per week or minutes per day. For mobile phone use in children, two studies (615 participants) that compared an increase in mobile phone use to a decrease or no change were included in meta-analyses. Learning and memory. There was little effect on accuracy (mean difference, MD −0.03; 95% CI −0.07 to 0.02) or response time (MD −0.01; 95% CI −0.04 to 0.02) on the one-back memory task; and accuracy (MD −0.02; 95%CI −0.04 to 0.00) or response time (MD −0.01; 95%CI −0.04 to 0.03) on the one card learning task (low certainty evidence for all outcomes). Executive function. There was little to no effect on the Stroop test for the time ratio ((B-A)/A) response (MD 0.02; 95% CI −0.01 to 0.04, very low certainty) or the time ratio ((D-C)/C) response (MD 0.00; 95% CI −0.06 to 0.05, very low certainty), with both tests measuring susceptibility to interference effects. Complex attention. There was little to no effect on detection task accuracy (MD 0.02; 95% CI −0.04 to 0.08), or response time (MD 0.02;95% CI 0.01 to 0.03), and little to no effect on identification task accuracy (MD 0.00; 95% CI −0.04 to 0.05) or response time (MD 0.00;95% CI −0.01 to 0.02) (low certainty evidence for all outcomes). No other cognitive domains were investigated in children. A single study among elderly people provided very low certainty evidence that more frequent mobile phone use may have little to no effect on the odds of a decline in global cognitive function (odds ratio, OR 0.81; 95% CI 0.42 to 1.58, 649 participants) or a decline in executive function (OR 1.07; 95% CI 0.37 to 3.05, 146 participants), and may lead to a small, probably unimportant, reduction in the odds of a decline in complex attention (OR 0.67;95%CI 0.27 to 1.68, 159 participants) and a decline in learning and memory (OR 0.75; 95% CI 0.29 to 1.99, 159 participants). An exposure–response relationship was not identified for any of the cognitive outcomes.

Discussion This systematic review and meta-analysis found only a few studies that provided very low to low certainty evidence of little to no association between RF-EMF exposure and learning and memory, executive function and complex attention. None of the studies among children reported on global cognitive function or other domains of cognition. Only one study reported a lack of an effect for all domains in elderly persons but this was of very low certainty evidence. Further studies are needed to

address all types of populations, exposures and cognitive outcomes, particularly studies investigating environmental and occupational exposure in adults. Future studies also need to address uncertainties in the assessment of exposure and standardise testing of specific domains of cognitive function to enable synthesis across studies and increase the certainty of the evidence.

Other This review was partially funded by the WHO radioprotection programme and prospectively registered on PROSPERO CRD42021257548.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: [Dr Geza Benke reports financial support was provided by World Health Organization. MA declares that he holds a small parcel of Telstra shares. KK, CB and MS as part of their employment are involved in the provision of advice to the Australian Commonwealth Government, Australian States and Territories and the general public on the risks and health effects of exposure to ionising and non-ionising radiation. KK is also a member of the International Commission on Non-Ionizing Radiation Protection where he contributes in the development and dissemination of science-based advice on limiting exposure to non-ionizing radiation. No member of the review team was involved in screening or extracting data from a study in which he or she was an author].

Acknowledgements

We would like to thank Emilie Van Deventer, WHO, Geneva, Switzerland; Martin Röösli, Swiss TPH, Basel, Switzerland and Anke Huss, Utrecht University, Utrecht, The Netherlands; for their contributions to the protocol.

Supplementary files can be downloaded.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024003659

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Effects of recall and selection biases on modeling cancer risk from mobile phone use: Results from a case-control simulation study

(My note: The models tested in this simulation study were based on questionable assumptions.)

Bouaoun L, Byrnes G, Lagorio S, Feychting M, Abou-Bakre A, Beranger R, Schüz J. Effects of recall and selection biases on modeling cancer risk from mobile phone use: Results from a case-control simulation study. Epidemiology. 2024 May 20. doi: 10.1097/EDE.0000000000001749.

Abstract

Background: The largest case-control study (Interphone Study) investigating glioma risk related to mobile phone use showed a J-shaped relationship with reduced relative risks for moderate use and a 40% increased relative risk among the 10% heaviest regular mobile phone users, using a categorical risk model based on deciles of lifetime duration of use among ever regular users.

Methods: We conducted Monte-Carlo simulations examining whether the reported estimates are

compatible with an assumption of no effect of mobile phone use on glioma risk when the various forms of biases present in the Interphone study are accounted for. Four scenarios of sources of error in self-reported mobile phone use were considered, along with selection bias. Input parameters used for simulations were those obtained from Interphone validation studies on reporting accuracy and from using a non-response questionnaire.

Results: We found that the scenario simultaneously modeling systematic and random reporting errors produced a J-shaped relationship perfectly compatible with the observed relationship from the main Interphone study with a simulated spurious increased relative risk among heaviest users (OR = 1.91) compared to never regular users. The main determinant for producing this J shape was higher reporting error variance in cases compared to controls, as observed in the validation studies. Selection bias contributed to the reduced risks as well.

Conclusions: Some uncertainty remains, but the evidence from the present simulation study shifts the overall assessment to making it less likely that heavy mobile phone use is causally related to an increased glioma risk.

Open access paper: https://pubmed.ncbi.nlm.nih.gov/38771708/

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Validation of mobile phone use recall in the multinational MOBI-kids study

van Wel L, Huss A, Kromhout H, Momoli F, Krewski D, Langer CE, Castaño-Vinyals G, Kundi M, Maule M, Miligi L, Sadetzki S, Albert A, Alguacil J, Aragones N, Badia F, Bruchim R, Goedhart G, de Llobet P, Kiyohara K, Kojimahara N, Lacour B, Morales-Suarez-Varela M, Radon K, Remen T, Weinmann T, Vrijheid M, Cardis E, Vermeulen R; MOBI-Kids consortium. Validation of mobile phone use recall in the multinational MOBI-kids study. Bioelectromagnetics. 2024 May 22. doi: 10.1002/bem.22507.

Abstract

Potential differential and non-differential recall error in mobile phone use (MPU) in the multinational MOBI-Kids case-control study were evaluated. We compared self-reported MPU with network operator billing record data up to 3 months, 1 year, and 2 years before the interview date from 702 subjects aged between 10 and 24 years in eight countries. Spearman rank correlations, Kappa coefficients and geometric mean ratios (GMRs) were used. No material differences in MPU recall estimates between cases and controls were observed. The Spearman rank correlation coefficients between self-reported and recorded MPU in the most recent 3 months were 0.57 and 0.59 for call number and for call duration, respectively. The number of calls was on average underestimated by the participants (GMR = 0.69), while the duration of calls was overestimated (GMR = 1.59). Country, years since start of using a mobile phone, age at time of interview, and sex did not appear to influence recall accuracy for either call number or call duration. A trend in recall error was seen with level of self-reported MPU, with underestimation of use at lower levels and overestimation of use at higher levels for both number and duration of calls. Although both systematic and random errors in self-reported MPU among participants were observed, there was no evidence of differential recall error between cases and controls. Nonetheless, these sources of exposure measurement error warrant consideration in interpretation of

the MOBI-Kids case-control study results on the association between children's use of mobile phones and potential brain cancer risk.

Highlights

- Self-reported and operator-registered phone calls were compared among MobiKids participants.
- On average, number of calls was underestimated, and duration overestimated.
- No differential recall error was found between brain tumor cases and controls in MobiKids.

Excerpts

The comparison of self-reported and recorded MPU was conducted separately for the number and duration (in minutes) of calls in the 3 months preceding the date of interview. In addition, a subset of subjects who had data available for 1 year, and a subset for 2 years preceding the date of interview were assessed....

A total of 702 subjects from eight different countries (Canada, France, Germany, Greece, Israel, Italy, Korea, and Spain) had data on both self-reported and recorded MPU in the 3 months preceding the interview date (Table 1)....

The overall GMRs of self-reported versus recorded MPU in the most recent 3 months were 1.59 for call duration and 0.69 for call number, indicating systematic errors in the form of overreporting of call duration of calls and underreporting of the number of calls. Looking at recall over time for subjects with 2 years of data available, there appears to be a lower level of overreporting of duration of calls for both cases (initial GMR 1.62, 1.44 at 1 year) and controls (initial GMR 1.37, 1.08 at 1 year) between recent and 1 year recall. There is however little difference in recall in call duration over time between the 1 and 2 year time points for either cases or controls (1.44 vs. 1.41 and 1.08 vs. 1.07, respectively) (Table 5). Although this same initial decrease can be seen in controls for recall of number of calls, it is less clear for cases (Table 4)....

While not all subjects from the main MOBI-Kids study provided informed consent to obtain their network operator data and not all operators provided data, we managed to include a large proportion of subjects (24.8%) from the MOBI-Kids case–control study in this validation study. The proportion of subjects where longer-term data was available (at 1- and 2-year time periods) was smaller, with no subjects from some of the participating countries....

... it may not always be clear from billing records who the actual user of the phone was when making calls. Therefore, while billing records provide insight into validity and possible calibration of self-reports, they may not represent the gold standard for studies, especially due to the low number of retained study participants, and also because internet-based calling (VoiP) is not included in the records....

Both the COSMOS (Reedijk et al., 2024) as well as the INTERPHONE validation (Vrijheid et al., 2009) studies found significantly differing ratios between countries. In the present study we did see some differences in GMRs among the eight participating countries, but the differences did not achieve statistical significance. In contrast, the MOBI-Expo validation study by Goedhart et al. (2018) did find significant differences among countries with participants from Greece, Israel, and Korea underestimating the duration of calls while in other countries duration was overestimated....

CONCLUSIONS

We compared self-reported MPU with operator data at 3 months, 1 year, and 2 years preceding the interview date. No indication of differential recall error between cases and controls was found. Both non-differential systematic and random errors were observed, with number of calls being underreported and duration of calls being over-reported on average in both cases and controls. If there are true underlying risks, then the observed non-differential random errors may bias risk estimates towards their null values and decrease study power.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/bem.22507

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Micro-environmental personal radio-frequency electromagnetic field exposures in Melbourne: A longitudinal trend analysis

Bhatt CR, Henderson S, Sanagou M, Brzozek C, Thielens A, Benke G, Loughran S. Micro-environmental personal radio-frequency electromagnetic field exposures in Melbourne: A longitudinal trend analysis. Environ Res. 2024 Mar 13;251(Pt 2):118629. doi: 10.1016/j.envres.2024.118629

Highlights

- RF-EMF exposure may be affected by changes in telecommunication technologies.
- Personal RF-EMF exposure assessments were undertaken in 2015/16 and 2022.
- Quantile regression models were used to compare exposure levels and overall trend.
- Median total exposure level at follow-up did not change over time.
- Overall trend of total exposure at follow-up increased.

Abstract

Background A knowledge gap exists regarding longitudinal assessment of personal radio-frequency electromagnetic field (RF-EMF) exposures globally. It is unclear how the change in telecommunication technology over the years translates to change in RF-EMF exposure. This study aims to evaluate longitudinal trends of micro-environmental personal RF-EMF exposures in Australia.

Methods The study utilised baseline (2015-16) and follow-up (2022) data on personal RF-EMF exposure (88 MHz-6 GHz) measured across 18 micro-environments in Melbourne. Simultaneous quantile regression analysis was conducted to compare exposure data distribution percentiles, particularly median (P50), upper extreme value (P99) and overall exposure trends. RF-EMF exposures were compared across six exposure source types: mobile downlink, mobile uplink, broadcast, 5G-New Radio, Others and Total (of the aforementioned sources). Frequency-specific exposures measured at baseline and follow-up were compared. Total exposure across different groups of micro-environment types were also compared.

Results For all micro-environmental data, total (median and P99) exposure levels did not significantly change at follow-up. Overall exposure trend of total exposure increased at follow-up. Mobile downlink contributed the highest exposure among all sources showing an increase in median exposure and overall

exposure trend. Of seven micro-environment types, five of them showed total exposure levels (median and P99) and overall exposure trend increased at follow-up.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0013935124005334

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Evaluating radiofrequency electromagnetic field exposure in confined spaces: a systematic review of recent studies and future directions

Ahsan Ashraf M, Celik T. Evaluating radiofrequency electromagnetic field exposure in confined spaces: a systematic review of recent studies and future directions. Radiat Prot Dosimetry. 2024 Apr 20;200(6):598-616. doi: 10.1093/rpd/ncae045.

Abstract

This study reviews recent research on Radiofrequency Electromagnetic Field (RF-EMF) exposure in confined environments, focusing on methodologies and parameters. Studies typically evaluate RF-EMF exposure using an electric field and specific absorption rate but fail to consider temperature rise in the tissues in confined environments. The study highlights the investigation of RF-EMF exposure in subterranean environments such as subways, tunnels and mines. Future research should evaluate the exposure of communication devices in such environments, considering the surrounding environment. Such studies will aid in understanding the risks and developing effective mitigation strategies to protect workers and the general public.

Conclusion

In this study, we conducted an SLR of 63 articles related to RF-EMF exposure in confined environments. The articles were selected based on a QA and divided into measurement and simulation studies. Our literature analysis demonstrates that RF-EMF exposure is higher in working spaces and transport than in dwellings, largely due to multiple exposure frequencies and excessive users. However, evaluating sub-terrain environments remains limited despite the growing use of wearable wireless devices in these settings. We also identified the different exposimeters and numerical dosimetry software tools commonly used for measuring and simulating RF-EMF exposure in confined environments. Furthermore, we found that the electric field is the most commonly investigated parameter for evaluating RF-EMF exposure using dosimetry simulation and measurement in confined environments. Given the increasing use of wearable wireless devices in sub-terrain and other occupational environments, there is a critical need to evaluate RF-EMF exposure in high-temperature environments, particularly with respect to temperature elevation in tissue. Future studies should evaluate the potential health impacts of long-term exposure to RF-EMF, especially in occupational settings where workers are exposed for extended periods.

Open access paper: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11033578/

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Optimal design of electromagnetic field exposure maps in large areas

López-Espí PL, Sánchez-Montero R, Guillén-Pina J, Chocano-del-Cerro R, Rojas JAM. Optimal design of electromagnetic field exposure maps in large areas. Environmental Impact Assessment Review. Volume 106, 2024, doi: 10.1016/j.eiar.2024.107525.

Abstract

The mapping of electromagnetic field (EMF) exposure over large areas is a very useful tool for the analysis of epidemiological data and risk assessment. Its production requires a costly measurement process. To optimize the effort and ensure the representativeness of the exposure map, criteria for the selection of the sites to be measured must be established. This paper presents a methodology for conducting EMF exposure maps suitable for risk assessment evaluation in large areas. The proposal combines radio wave propagation criteria and GIS methods to optimize the sampling effort. The design criteria are based on the determination of a rectangular grid of 250 m side and the identification of the emitters within the area under study. Both urban and rural sites are analysed in the proposal and line of sight conditions (LOS) are considered to reduce the number of points required and thus optimize the measurement effort. Depending on the extent and regularity of the surface, the density of measurement points has been estimated to be between 8 and 10 points per square kilometre in the urban area. The proposed methodology has been applied to a case study of a 2.8 km2 urban area within a 35.11 km2 municipality, obtaining an average point density of 9.64 points/km2 in the urban area. The differences in exposure depending on the application of the criteria have been analysed by means of the statistical values of the sets and the subtraction of the maps generated using kriging techniques. According to our results, if LOS measurements are not properly incorporated, the mean value of the EMF is underestimated in the area under study.

Conclusions

In this proposal, the methodology for EMF exposure mapping in large areas has been analysed. To optimize the measurement effort over a large area, a division into 250 × 250 m^2 urban grids should be considered, in which the possible sources of radiation should be known. A measurement under LOS conditions must be performed in each of the grids in which any of the emitters is present. The absence of measurements under LOS conditions implies an underestimation of the mean values. To select the rest of the grids to be measured, the viewshed analysis allows to simplify the number of measurements by grouping those grids determined as N-LOS. To achieve optimal interpolation results over the entire surface, sufficient measurements must also be available on its perimeter. Interpolation by ordinary stable kriging obtains adequate results under LOS and N-LOS conditions. The generated maps contribute to a better perception of risk as they provide an objective and simple tool to show the level of EMF. They do not require complex propagation models but are based on interpolations made within a GIS. They can also be combined, using these techniques, for risk assessment and even, if epidemiological data are available, for possible correlations studies.

The proposal considers the differences between urban areas, with the possibility of multipath, and rural (non-urban) areas. For the analysis of urban areas, a grid of 250 × 250 m^2 has been proposed as a guideline for the spatial organisation of the territory in urban areas and 500 × 500 m^2 in rural areas.

Depending on the extent and regularity of the surface, the density of measurement points has been estimated to be between 8 and 10 points per square kilometre in the urban area. Lower point densities

result in IDW representations and higher densities increase the measurement effort excessively. In the case under study, for the urban area, a density of 9.64 points/km^2 has been reached.

The study has been performed following the six-minute averaging criterion and in a bandwidth from 100 kHz to 3 GHz. The latest ICNIRP recommendations modify these values to take into account, among others, the new 5G signals, not yet present in the area. The urban study was carried out in a mainly residential area, where there are no concentrations of the general public, which could lead to areas of greater exposure due to greater use of the network. For future studies, therefore, the measurement and comparison according to the latest ICNIRP recommendations is still pending in areas where the new 5G networks have been incorporated and in urban micro-environments where there is a higher population density or uses significantly different from residential. Another point of continuation of this research is the correlation of the measured values with tumor statistics and other diseases. The opportunity provided by exposure maps created for entire urban environments may allow, where appropriate, to find possible relationships.

https://www.sciencedirect.com/science/article/pii/S0195925524001124

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Electromagnetic field exposure monitoring of commercial 28-GHz band 5G base stations in Tokyo, Japan

Liu S, Tobita K, Onishi T, Taki M, Watanabe S. Electromagnetic field exposure monitoring of commercial 28-GHz band 5G base stations in Tokyo, Japan. Bioelectromagnetics. 2024 May 22. doi: 10.1002/bem.22505.

Abstract

Fifth generation (5G) wireless communication is being rolled out around the world. In this work, the latest radio frequency electromagnetic field (EMF) exposure measurement results on commercial 28-GHz band 5G base stations (BSs) deployed in the urban area of Tokyo, Japan, are presented. The measurements were conducted under realistic traffic conditions with a 5G smartphone and using both omnidirectional and horn antennas. First and foremost, in all cases, the electric-field (E-field) intensity is much lower (<-38 dB) than the exposure limits. The E-field intensities for traffic-off cases do not show any significant difference between the two antennas with the maximum being 3.6 dB. For traffic-on cases, the omnidirectional antenna can undesirably capture the radio wave from the smartphone in some cases, resulting in a 7-13 dB higher E-field intensity than that using the horn antenna. We also present comparative results between 4G long term evolution BSs and sub-6-GHz band and 28-GHz band 5G BSs and provide recommendations on acquiring meaningful EMF exposure data. This work is a further step toward the standardization of the measurement method regarding quasi-millimeter/millimeter wave 5G BSs.

https://pubmed.ncbi.nlm.nih.gov/38778514/

Conclusions

The latest EMF exposure measurement results on commercial 28-GHz band 5G FR2 BSs in Tokyo, Japan, were presented in this paper. The measurements were evaluated under realistic traffic conditions and in an isotropic state using both omnidirectional and horn antennas. In all cases (sites and spots, antennas,

and traffic conditions), the E-field intensity was within the limits established by ICNIRP and IEEE/ICES. The maximal time-averaged E-field intensity (118 dBμV/m) reached only 0.016% of the limit. It was found that the E-field intensity varied with measurement height with a variance in amplitude reaching 10–25 dB over different measurement spots. The E-field intensities for traffic-off cases did not show any significant difference between the two antennas with the maximum being 3.6 dB. However, for traffic-on cases, the omnidirectional antenna may undesirably capture the radio wave from the smartphone in some cases, thus leading to a time-averaged E-field intensity 7–13 dB higher than that in the cases of using the horn antenna. Despite this, an omnidirectional antenna is always preferred as it can detect all the reflections and scatterings of the environment. A horn antenna is preferred only in situations where the reflections and scatterings are negligible. On the other hand, the distance between the smartphone and the antenna (50 cm in this study) may be increased to avoid the capture of the irradiation from the smartphone. For the horn antenna, there is generally a 23–27 dB rise in the time-averaged E-field intensity of traffic-on cases compared with that of traffic-off cases. The rise for the omnidirectional antenna is 19–37 dB.

5G, especially 5G FR2, is being continuously deployed. The measurements in this work were mainly limited to the urban area of Tokyo, Japan. With the expansion of the 5G service coverage, measurements in suburban and rural areas will be conducted in the future. Comparative studies between 5G FR1 and FR2 will also be of considerable interest and will be a future target. In summary, investigations will be successively conducted following the deployment of 5G.

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The exposure of nonhuman living organisms to mobile communication emissions: A survey to establish European stakeholders' policy option preferences

Recuero Virto L, Thielens A, Czerwiński M, Froidevaux J. (2024). The exposure of nonhuman living organisms to mobile communication emissions: A survey to establish European stakeholders' policy option preferences. *Risk Analysis*, 1–15. doi: 10.1111/risa.14322.

Abstract

There is an unprecedented exposure of living organisms to mobile communications radiofrequency electromagnetic field (RF-EMF) emissions. Guidelines on exposure thresholds to limit thermal effects from these emissions are restricted to humans. However, tissue heating can occur in all living organisms that are exposed. In addition, exposure at millimetric frequencies used by 5G may impact surface tissues and organs of plants and small-size species. It is also expected that the addition of 5G to existing networks will intensify radiofrequency absorption by living organisms.

A European Parliament report proposed policy options on the effects of RF-EMF exposure of plants, animals, and other living organisms in the context of 5G: funding more research, implementing monitoring networks, accessing more information from operators on antennas and EMF emissions, and developing compliance studies when antennas are installed. However, there is no evidence on the preferences of relevant stakeholders regarding these policy options. This paper reports the findings of a survey of key European stakeholders' policy option preferences based on the European Parliament's report. It reveals a broad consensus on funding more research on the effects of exposure of plants, animals, and other living organisms to EMFs. It also highlights the need for deliberation concerning the

other policy options that could provide solutions for regulatory authorities, central administrations, the private sector, nongovernmental associations and advocates, and academics. Such deliberation would pave the way for effective solutions, focusing on long-term output from funding research, and enabling short-term socially and economically acceptable actions for all parties concerned.

Excerpts

From a regulatory perspective, current guidelines on exposure thresholds to limit thermal energy from mobile communications emissions developed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and by the Institute of Electrical and Electronics Engineers (IEEE) only concern human health (ICNIRP, 1998, 2020; IEEE, 1991, 2019).3 It is worth noting that ICNIRP and IEEE thresholds, developed under the assumptions that biological effects are due to excessive tissue heating and that no effects occur below the threshold, remain controversial (ICBE-EMF, 2022). According to the International Commission on the Biological Effects of Electromagnetic Fields (ICBE-EMF), adverse effects have been observed below the threshold, such as nonthermal induction of reactive oxygen species, DNA damage, cardiomyopathy, carcinogenicity, sperm damage, and neurological effects (e.g., electromagnetic hypersensitivity)....

According to the International Commission on Radiological Protection (ICRP), steps taken to protect the environment from ionizing radiation should fall within the concept of optimization, the latter understood as the process of determining the level of protection and safety that makes exposures, and the probability and magnitude of potential exposures, as low as reasonably achievable, economic and societal factors being taken into account. Reference levels were derived by the ICRP to relate the effects of ionizing radiation to doses to nonhuman organisms, but the institution states that these values are not limited and are not intended to be used in that manner. Potential synergies between ICNIRP and ICRP approaches were already subject to discussion in the past for human health, in particular, whether ALARA approaches developed by the ICRP could be meaningfully applied to nonionizing radiation (ICNIRP/WHO/ICRP/IRPA/ILO, 2014).

To conclude, humans have so far chosen not to address the effects of RF-EMF on nonhuman organisms even if there is evidence of thermal effects on all living organisms. The controversial debates on RF-EMF effects on human health have probably hampered early attempts to address the effects on nonhuman organisms. Our results show that, for the consulted stakeholders, this topic calls for some action. It is not a matter of hindering progress, but understanding the optimal conditions for technological proliferation, given the current state of knowledge.

https://onlinelibrary.wiley.com/doi/10.1111/risa.14322

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RF-EMF Exposure Assessment of Fetus During The First Trimester of Pregnancy

Sandeep S, Vard A, Guxens M, Bloch I, Wiart J. RF-EMF Exposure Assessment of Fetus During The First Trimester of Pregnancy. *IEEE Access*, doi: 10.1109/ACCESS.2024.3404369.

Abstract

This article describes the computational analysis of Radio Frequency - Electromagnetic Field (RF-EMF) exposure of Uterus-Fetus Units (UFUs) embedded inside the body of a 26 year old human female. Realistic UFU models are obtained from ultrasound images acquired for different fetuses and at specific development stages (7 weeks, 9 weeks and 11 weeks old), for which a deep-learning based segmentation method is developed. Each UFU model is then inserted into a computational electromagnetic model of a 26 year old female. The Specific Absorption Rate (SAR) of the fetus at commonly used wireless communication frequencies is estimated using a commercially available numerical electromagnetic solver. The Inverted F antenna (IFA), which is a commonly used mobile phone antenna was used as the excitation source. Fetus SAR values are reported for different combinations of excitation frequencies, phone positions and UFU ages. It was found that the fetus SAR for all the cases is well below the maximum allowable exposure limit of 80 mW/kg, as prescribed by ICNIRP. Furthermore, we replaced the embryo with uterus tissues and calculated the SAR in the uterus tissues (i.e. uterus tissues with same volume and shape, and at the same location as that of UFU). The uterus SAR values were found to be only marginally different from that of fetus SAR.

Open access paper:
https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=10536873&isnumber=6514899

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Regression calibration of self-reported mobile phone use to optimize quantitative risk estimation in the COSMOS study

Reedijk M, Portengen L, Auvinen A, Kojo K, Heinävaara S, Feychting M, Tettamanti G, Hillert L, Elliott P, Toledano MB, Smith RB, Heller J, Schüz J, Deltour I, Poulsen AH, Johansen C, Verheij R, Peeters P, Rookus M, Traini E, Huss A, Kromhout H, Vermeulen R, Study Group TC. Regression calibration of self-reported mobile phone use to optimize quantitative risk estimation in the COSMOS study. Am J Epidemiol. 2024 May 13:kwae039. doi: 10.1093/aje/kwae039.

Abstract

The Cohort Study of Mobile Phone Use and Health (COSMOS) has repeatedly collected self-reported and operator-recorded data on mobile phone use. Assessing health effects using self-reported information is prone to measurement error, but operator data were available prospectively for only part of the study population and did not cover past mobile phone use. To optimize the available data and reduce bias, we evaluated different statistical approaches for constructing mobile phone exposure histories within COSMOS. We evaluated and compared the performance of four regression calibration (RC) methods (simple, direct, inverse, and generalized additive model for location, shape, and scale), complete-case (CC) analysis and multiple imputation (MI) in a simulation study with a binary health outcome. We used self-reported and operator-recorded mobile phone call data collected at baseline (2007-2012) from participants in Denmark, Finland, the Netherlands, Sweden, and the UK. Parameter estimates obtained using simple, direct, and inverse RC methods were associated with less bias and lower mean squared error than those obtained with CC analysis or MI. We showed that RC methods resulted in more accurate estimation of the relation between mobile phone use and health outcomes, by combining self-reported data with objective operator-recorded data available for a subset of participants.

Excerpts

Self-reported duration of mobile phone use (REPORT) at baseline [21] was based on answers to the question: “Over the last three months, on average, how much time per week did you spend talking on a mobile phone?”. The following response options were provided: “< 5 min/week”, “5-29 min/week”, “30-59 min/week”, “1-3 hours/week”, “4-6 hours/week”, and “>6 hours/week”. In the Netherlands and the UK two further categories of call duration were included, “7-9 hours/week” and “10 or more hours/week”, but these were combined into “>6 hours/week” for the present analyses....

Operator-recorded duration of mobile phone use (RECORD) was collected for all participants who provided consent and had a subscription under their own name. Operator-recorded data were used only when available for all mobile phones that were reported (up to two phones in Denmark, the Netherlands, Sweden, Finland, and up to three in the UK) and for at least three full months at the time the baseline questionnaire was administered. Participants with mobile phones that were also used by others were excluded. Operator-recorded data were available for 21% of participants in Denmark, 76% in Finland, 40% in the Netherlands, 63% in Sweden, and 76% in the UK....

A major issue is how well mobile phone use predicts the exposure of interest, namely radiofrequency electromagnetic fields. While past validation studies have been carried out for the 2nd mobile phone generation, showing fair agreement between amount of use and cumulated emission from the handset [4], fewer data are available on the predictive power of mobile phones of the 3rd, 4th and 5th generations that have and are being used by COSMOS participants....

Table 1 (excerpt)

Complete data by country: Denmark (11%: 2993/25912), Finland (70%: 9162/13062), Netherlands (3%: 3039/88466), Sweden (49%: 24881/50678), United Kingdom (58%: 56862/98685)

Recorded call duration in minutes/week by country (geometric mean): Denmark (60.6), Finland (81.5), Netherlands (23.4), Sweden (78.3), United Kingdom (46.5)

Conclusion

This study addressed an important concern in mobile phone research and more generally in environmental epidemiology: how to leverage self-reported exposure estimates that are often available but error-prone, with more objective measurements that may be obtained in only a subset of participants. Our simulation study indicated RC approaches may improve estimation of exposure-outcome relations between mobile phone use and health outcomes within COSMOS. The prospective design and improved exposure assessment within COSMOS compared to that in previous case-control studies are expected to lead to more robust conclusions about possible health effects from use of mobile phones.

Conflict of Interest: MF was vice chairman (2012-2020) of the International Commission on Non-Ionizing Radiation Protection, an independent body setting guidelines for non-ionizing radiation protection. She has served as advisor to a number of national and international public advisory and research steering groups concerning the potential health effects of exposure to non-ionizing radiation, currently for the World Health Organization (WHO). HK was the chair of the Committee on Electromagnetic Fields of the Health Council of The Netherlands till 2022. He currently is a member of the WHO Task Group for the Environmental Health Criteria Monograph on RF-EMF. AH is a member of the International Commission on Non-Ionizing Radiation Protection since 2020, and of the Committee on Electromagnetic Fields of the

Health Council of The Netherlands, and chairs the Swedish Radiation Safety Authority's (SSM) Scientific Council on Electromagnetic Fields since 2020. AA currently is a member of the WHO Task Group for the Environmental Health Criteria Monograph on RF-EMF. MBT is currently member of the WHO groups tasked with systematic review of evidence on non-ionizing radiation and health, that is feeding into the Environmental Health Criteria Monograph on RF-EMF. All other authors declare they have no competing financial interests.

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https://academic.oup.com/aje/advance-article/doi/10.1093/aje/kwae039/7671112?login=false

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Monitoring of the exposure to electromagnetic fields with autonomous probes installed outdoors in France

Jawad O, Conil E, Agnani J-B, Wang S, Wiart J. Monitoring of the exposure to electromagnetic fields with autonomous probes installed outdoors in France. Comptes Rendus. Physique, Online first (2024), pp. 1-21. doi : 10.5802/crphys.182.

Abstract

The study is based on a new temporal analysis of exposure based on the deployment of autonomous broadband E-field monitoring probes in many French cities. The combination of the probe's data with frequency-selective in situ measurements performed by ANFR and the knowledge of the nearby base station antennas, allows to draw statistical conclusions on the exposure of the population. Indeed, the data collected by the probes reveal that different periodicities exist (seasonality, day/night). This paper shows that the monitoring probes are able to detect the seasonality of the exposure and provide analysis of correlation between monitoring probes and radio environment.

Excerpt

The analysis indicates that the monitoring probes have varying exposure levels. Probes measuring significant levels show a difference in exposure between day and night, a phenomenon observed for the first time in France. An empirical time interval from 8 AM to 11 PM enables to calculate the ratio of averaged E-field levels between day and night. This ratio is between 1.28 and 1.42 for the three probes with the highest RMS level. Several papers, such as [8–10], have characterized the day and night fluctuation, but this has never been demonstrated using French data.

For the first time, the variability of daily working hours has been quantified for all the probes installed in France. The data shows that most of the probes exhibit a 30% variation percentage based on the data gathered from 8 AM to 5 PM. Based on our knowledge, this is the first time that the assessment of the daily variation contributor based on more than 150 probes installed in different environments is achieved. It confirms the level of daily variation contributor to the in situ measurement uncertainty budget, as communicated in the accredited in situ measurement reports [3, 16, 17]....

For the first time, the seasonality of the level of exposure has been analyzed at the French national level. The PCA on dataset No. 2 emphasizes the observation that the positioning of the probe is crucial to

observe a remarkable variation of the exposure level. The probe must not only be installed in an area with many base stations, but also in close proximity to them and in a line-of-sight position for the exposure. A large number of probes measuring low exposure levels can be explained by the fact that the probes are not in a line-of-sight situation. In some cities, probes were installed in low-density areas rather than in front of base stations due to public concern over electromagnetic waves. Upon analysis, we find that some probes measure a lower level of exposure in summer time. This interpretation was confirmed with the Principal Component Analysis, which showed that the second component of the PCA characterizes the difference between probes with higher exposure in summer or winter. This phenomenon can be explained by the fact that some of the cities are very touristic during the summer, leading to increased use of the telecommunication infrastructure. In general, the exposure levels measured by the autonomous probe are very low compared to the limits. The increase of the exposure level is relatively slow, as it has been shown in several ANFR studies [4, 18–20].

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https://comptes-rendus.academie-sciences.fr/physique/articles/10.5802/crphys.182/

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Statistical Analysis of RF-EMF Exposure Induced by Cellular Wireless Networks in Public Transportation Facilities of the Paris Regionx

Y. Zhang *et al*. Statistical Analysis of RF-EMF Exposure Induced by Cellular Wireless Networks in Public Transportation Facilities of the Paris Regionx. *IEEE Access*, vol. 12, pp. 79741-79753, 2024, doi: 10.1109/ACCESS.2024.3410090.

Abstract

Wireless communications are increasingly used today. Despite such use, there is a significant perception of risk which makes exposure monitoring a significant concern today. The work described in this article was carried out within the framework of the European SEAWave project and the French Beyond5G project. The exposure assessment was evaluated using a personal exposimeter (MVG EMF Spy) whose compactness and ease of use make it more suitable and portable than a system combining measuring probes and spectrum analyzers. Measurements were carried out on the cellular frequency bands used by 2G, 3G, 4G, and 5G, as well as that of Wi-Fi, in different modes of public transportation (RER, metro, tramway, bus, and train) circulating in the Paris region. The measurements have been analyzed by frequency band, type of public transportation, and type of environment encountered. For each set of measurements (e.g., metro lines, tramways), the mean, standard deviation, skewness, and kurtosis were evaluated and analyzed. For all exposure measurements taken in the 700, 800, 900, 1800, 2100, 2600, and 3500 MHz frequency bands, the overall average values are 0.39, 0.43, 0.30, 0.21, 0.18, 0.24 and 0.18 V/m, respectively. These measurements have, in all cases, a significant dispersion as shown by the ratios of standard deviations to mean values. The well-known K-means clustering technique was applied to these four parameters for different subsets of data. The number of clusters k = 3 has been chosen based on the analysis of the optimal value of k for the current dataset. Our analysis indicates that the first group's members display the highest mean values with moderate variance and the lowest values for the third and fourth moments. The second cluster is distinguished by points with large mean and variance,

accompanied by moderate skewness and kurtosis. Conversely, the third group comprises points with the smallest mean and variance values, yet the largest measurements for the third and fourth moments.

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=10549999&isnumber=10380310

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Expression levels of tam receptors and ligands in the testes of rats exposed to short and middle-term 2100 MHz radiofrequency radiation

Katirci E, Kirimlioglu E, Oflamaz AO, Hidisoglu E, Cernomorcenco A, Yargıcoğlu P, Ozen S, Demir N. Expression levels of tam receptors and ligands in the testes of rats exposed to short and middle-term 2100 MHz radiofrequency radiation. Bioelectromagnetics. 2024 May 9. doi: 10.1002/bem.22504.

Abstract

With advances in technology, the emission of radiofrequency radiation (RFR) into the environment, particularly from mobile devices, has become a growing concern. Tyro 3, Axl, and Mer (TAM) receptors and their ligands are essential for spermatogenesis and testosterone production. RFR has been shown to induce testicular cell apoptosis by causing inflammation and disrupting homeostasis. This study aimed to investigate the role of TAM receptors and ligands in the maintenance of homeostasis and elimination of apoptotic cells in the testes (weeks), short-term sham exposure (sham/1 week), and middle-term sham exposure (sham/10 weeks). Testicular morphology was assessed using hematoxylin-eosin staining, while immunohistochemical staining was performed to assess expression levels of TAM receptors and ligands in the testes of all groups. The results showed that testicular morphology was normal in the control, sham/1 week, and sham/10 weeks groups. However, abnormal processes of spermatogenesis and seminiferous tubule morphology were observed in RFR exposure groups. Cleaved Caspase 3 immunoreactivity showed statistically significant difference in 1 and 10 weeks exposure groups compared to control group. Moreover, there was no significant difference in the immunoreactivity of Tyro 3, Axl, Mer, Gas 6, and Pros 1 between groups. Moreover, Tyro 3 expression in Sertoli cells was statistically significantly increased in RFR exposure groups compared to the control. Taken together, the results suggest that RFR exposure negatively affects TAM signalling, preventing the clearance of apoptotic cells, and this process may lead to infection and inflammation. As a result, rat testicular morphology and function may be impaired.

https://pubmed.ncbi.nlm.nih.gov/38725116/

Highlights

Exposure to radiofrequency radiation (RFR) disrupts normal seminiferous tubule morphology.
RFR exposure in round spermatids may induce apoptosis independent of Tyro 3, Axl, and Mer (TAM) receptors.
TAM receptors and ligands are expressed in rat testis.

Conclusions

TAM receptors and ligands may play an important role in the spermatogenesis processes and may affect the functions of Leydig cells and Sertoli cells. In the present study, we have reported that RFR exposure

impair the morphology of rat testis. However, the impact on testicular function remains uncertain and requires further investigation. RFR exposure may negatively affect TAM signaling and enhances the accumulation of apoptotic cells.

Humans are exposed to RFR at a variable rate on a daily basis. Cell phones are the main source of RFR exposure, further complicating personal exposure times. In this study, cleaved caspase 3, TAM receptors and ligands were evaluated in rat testicular tissue exposed to 2100 MHz RFR. This study highlights the importance of radiofrequency exposure in male infertility. It provides a model for RFR reproductive toxicity studies. In order to better study the toxicity potential of RFR in the male reproductive system, it is necessary to study the intrauterine development and possibly live/healthy birth rates of the fetuses produced by mating RFR-exposed male mice with healthy female mice. In addition, long-term animal studies are urgently needed to investigate the potential health effects of frequencies used by upcoming 5G on the male reproductive system.

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Effects of non-ionizing radio frequency electromagnetic radiation on the development and behavior of early embryos of *Danio rerio* (zebrafish)

Khira R, Uggini GK. Effects of non-ionizing radio frequency electromagnetic radiation on the development and behavior of early embryos of *Danio rerio*. Electromagn Biol Med. 2024 May 12:1-8. doi: 10.1080/15368378.2024.2352429.

Abstract

Biological effects of radio frequency electromagnetic radiation (RF-EMR) in the range of 900-1800 MHz emerging from the mobile phone were investigated and were found to influence the locomotor pattern when exposure was initiated from 1 hour post fertilization (hpf) in zebrafish embryos (ZE), *Danio rerio*. Mobile phones and other wireless devices offer tremendous advantages. However, on the flipside they are leading to an increased electromagnetic energy in the environment, an excess of which could be termed as electromagnetic pollution. Herein, we tried to understand the effects of RF-EMR emerging from the mobile phone, on the development and behavior of ZE, exposed to RF-EMR (specific absorption rate of 1.13 W/kg and 1800 MHz frequency) 1 hr daily, for 5 days. To understand if there could be any developmental stage-specific vulnerability to RF-EMR, the exposure was initiated at three different time points: 1hpf, 6hpf and 24hpf of ZE development. Observations revealed no significant changes in the survival rate, morphology, oxidative stress or cortisol levels. However, statistically significant variations were observed in the batch where exposure started at 1 hpf, with respect to locomotion patterns (distance travelled: 659.1 ± 173.1 mm Vs 963.5 ± 200.4 mm), which could be correlated to anxiety-like behavior; along with a corresponding increase in yolk consumption (yolk sac area: 0.251 ± 0.019 mm^2 Vs 0.225 ± 0.018 mm^2). Therefore, we conclude that RF-EMR exposure influences the organism maximally during the earliest stage of development, and we also believe that an increase in the time of exposure (corresponding to the patterns of current usage of mobile phones) might reveal added afflictions.

Plain Language Summary

Mobile phones and other wireless devices are on a rampant usage worldwide. They work by radiating low energy radiofrequency electromagnetic radiations. An excessive usage of wireless devices is leading

to increased presence of these radiations in our surroundings. Since these radiations are not physically sensed by the organisms, its impact stays elusive. Nevertheless, the interaction of these radiations with biological systems may produce some unwarranted effects. When we exposed the ZE to the mobile phone radiation daily 1 hr for 5 days, our observations revealed that the youngest of the experimental group showed susceptibility. The effect was evident through haphazard movements and stressed behavior. So, it is important to be aware of the potential effects and take necessary precautions by following safety guidelines, especially when the organism is in its early life stage.

https://pubmed.ncbi.nlm.nih.gov/38734994

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Multi-frequency electromagnetic radiation induces anxiety in mice via inflammation in the cerebral cortex

Jing X, Menghua L, Lihui Z, Qian W, Xueli W, Xuelong Z, Zhihui L, Guofu D, Changzhen W. Multi-frequency electromagnetic radiation induces anxiety in mice via inflammation in the cerebral cortex. Environ Sci Pollut Res Int. 2024 May 9. doi: 10.1007/s11356-024-33447-y.

Abstract

Modern life is filled with radiofrequency electromagnetic radiation (RF-EMR) in various frequency bands, while the health risks are not clear. In this study, mice were whole-body exposed to 0.9/1.5/2.65 GHz radiofrequency radiation at 4 W/kg for 2 h per day for 4 weeks to investigate the emotional effects. It was found that the mice showed anxiety but no severe depression. The ELISA results showed a significant decrease in amino acid neurotransmitters (GABA, DA, 5-HT), although acetylcholine (ACH) levels were not significantly altered. Furthermore, Western blot results showed that BDNF, TrkB, and CREB levels were increased in the cerebral cortex, while NF-κB levels were decreased. In addition, pro-inflammatory factors (IL-6, IL-1β, TNF-α) were significantly elevated, and anti-inflammatory factors (IL-4, IL-10) tended to decrease. In conclusion, multi-frequency electromagnetic radiation induces an inflammatory response through the CREB-BDNF-TrkB and NF-κB pathways in the cerebral cortex and causes a decrease in excitatory neurotransmitters, which ultimately causes anxiety in mice.

Excerpt

In conclusion, these findings suggest that multi-frequency RF-EMR may induce anxiety by decreasing brain neurotransmitter levels and triggering inflammatory responses via the CREB-BDNF-TrkB pathway (Fig. 5). Currently, there are few studies on the relationship between multi-frequency electromagnetic radiation and mood changes, and this study provides some data support and a direction for future research. However, further in-depth investigations are needed to elucidate the specific mechanism of whether multi-frequency RF-EMR can induce negative emotions.

https://pubmed.ncbi.nlm.nih.gov/38724846/

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The endocannabinoid system is involved in the anxiety-like behavior induced by dual-frequency 2.65/0.8 GHz electromagnetic radiation in mice

Xue T, Ma RH, Xu C, Sun B, Yan DF, Liu XM, Gao D, Li ZH, Gao Y, Wang CZ. The endocannabinoid system is involved in the anxiety-like behavior induced by dual-frequency 2.65/0.8 GHz electromagnetic radiation in mice. Front Mol Neurosci. 2024 Apr 15;17:1366855. doi: 10.3389/fnmol.2024.1366855.

Abstract

As wireless communication devices gain popularity, concerns about the potential risks of environmental exposure to complex frequency electromagnetic radiation (EMR) on mental health have become a public health issue. Historically, EMR research has predominantly focused on single- frequency electromagnetic waves, neglecting the study of multi-frequency electromagnetic waves, which more accurately represent everyday life. To address these concerns, our study compared the emotional effects of single-frequency and dual-frequency EMR while exploring potential molecular mechanisms and intervention targets. Our results revealed that single-frequency EMR at 2.65 or 0.8 GHz did not induce anxiety-like behavior in mice. However, exposure to dual-frequency EMR at 2.65/0.8 GHz significantly led to anxiety-like behavior in mice. Further analysis of mouse sera revealed substantial increases in corticosterone and corticotrophin releasing hormone levels following exposure to 2.65/0.8 GHz EMR. Transcriptome sequencing indicated a significant decrease in the expression of *Cnr1*, encoding cannabinoid receptor 1 Type (CB1R), in the cerebral. This finding was consistently verified through western blot analysis, revealing a substantial reduction in CB1R content. Additionally, a significant decrease in the endocannabinoid 2-arachidonoylglycerol was observed in the cerebral cortex. Remarkably, administering the cannabinoid receptor agonist Win55-212-2 significantly alleviated the anxiety-like behavior, and the cannabinoid receptor antagonist AM251 effectively counteracted the anti-anxiety effects of Win55-212-2. In summary, our research confirmed that dual-frequency EMR is more likely to induce anxiety-like behavior in mice than single-frequency EMR, with implications for the hypothalamic–pituitary–adrenal axis and the endocannabinoid system. Furthermore, our findings suggest that Win55-212-2 may represent a novel avenue for researching and developing anti-EMR drugs.

Open access paper: https://www.frontiersin.org/articles/10.3389/fnmol.2024.1366855/full

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Assessment of the potential threats to brain health posed by the radiation from 5G sub-6 GHz base stations in China using dosimetric methods

Lin J, Ding G, Liu X, Li J. Assessment of the potential threats to brain health posed by the radiation from 5G sub-6 GHz base stations in China using dosimetric methods. Environ Sci Pollut Res Int. 2024 May;31(21):31015-31027. doi: 10.1007/s11356-024-33172-6.

Abstract

The 5G sub-6 GHz radio frequency (RF) electromagnetic fields (EMF) are the most widely used in China's communications. The public has expressed concerns about possible brain health effects of the higher frequency bands in 5G compared to 2G, 3G, and 4G bands. It is imperative to empirically investigate the potential health hazards of these novel frequency bands in 5G communication technology. This study evaluates the assessment of brain tissue dose coupling from sub-6 GHz band EMF emitted by base stations in China. Based on the 3D virtual human body model, the simulation environment was established. Dose including specific absorption rate (SAR) and internal electric field (IEF) between 2G, 3G, and 4G bands and 5G sub-6 GHz was investigated using normalized exposure values and exposure

limits. The results indicate that the sub-6 GHz high-frequency band of 5G has the lowest dose value. It can be concluded that high-frequency electromagnetic radiation in 5G sub-6 GHz reduces the dose and health threats to the brain. This provides strong support for the promotion of 5G commutation in China and other regions.

Conclusion

The research employed dosimetric methodology to comparatively evaluate the potential threat of communication EMF emitted by base stations to the human brain in China. Normalized evaluation showed that the dose value of brain tissue decreased with the increase of frequency. Moreover, the study explored the brain dose and health threats in accordance with both international mainstream ICNIRP guidelines and Chinese national standards. The findings indicate that the sub-6 GHz high-frequency band of 5G has the lowest dose value, thus ensuring a low risk of use. However, it should be noted that the choice of industry standards and physical evaluation quantities can slightly influence the evaluation results and trends. The research supplements the inadequacy of laboratory animal experiments and comparatively elaborates on the potential harm of EMF exposure from 5G sub-6 GHz to the brain's health. From a perspective of normalized assessment and the guideline comparison assessment, it can be concluded that high-frequency electromagnetic radiation in 5G sub-6 GHz reduces the harm of dose and risk values. This provides strong support for the promotion of 5G commutation in China and other regions. However, the limitation of this study is that the actual public exposure value does not take into account the measured value as the massive geographic information and statistical data. In the subsequent stage, the investigation of exposure measurement and dose evaluation can be merged with epidemiological research to probe deeper into the repercussions of novel frequency bands on the brain and its affiliated organ system.

Open access paper: https://link.springer.com/article/10.1007/s11356-024-33172-6

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Whole-body SAR measurements of millimeter-wave base station in reverberation chambers

Eilers Bischoff J, Joshi P, Colombi D, Xu B, Törnevik C. Whole-body SAR measurements of millimeter-wave base station in reverberation chambers. International Journal of Microwave and Wireless Technologies. Published online 2024:1-6. doi:10.1017/S1759078724000515

Abstract

This paper presents a method for measuring whole-body specific absorption rate (WBSAR) of millimeter-wave base stations (BSs) in a reverberation chamber (RC). The absorbed power in the phantom from the equipment under test (EUT) and hence WBSAR is determined as the difference between the total radiated power with and without the phantom. A chamber transfer function is determined and used to include only the absorption in the phantom due to direct illumination from the EUT, i.e., excluding absorption due to the RC multipath reflections. The measurement method was evaluated at 28 GHz using a horn antenna and a commercial massive multi-input–multi-output BS. The experimental results are in good agreement with simulations. The proposed method allows for measurements of WBSAR within 3 minutes, which is much shorter than traditional approaches. The method is suitable for compliance assessments of BS products with the International Commission on Non-Ionizing Radiation

Protection 2020 electromagnetic field exposure guidelines, which extend the applicability of WBSAR as basic restrictions up to 300 GHz.

https://doi.org/10.1017/S1759078724000515

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Retraction notice to "Exercise ameliorates hippocampal damage induced by Wi-Fi radiation; A biochemical, histological, and immunohistochemical study"

Mohamed AO, Abdel Hafez SMN, Ibrahim RA, Rifaai RA. Retraction notice to "Exercise ameliorates hippocampal damage induced by Wi-Fi radiation; A biochemical, histological, and immunohistochemical study" [J. Chem. Neuroanat. 129 (2023) 102252]. J Chem Neuroanat. 2024 Jun 8:102433. doi: 10.1016/j.jchemneu.2024.102433. Epub ahead of print. PMID: 38851999.

https://pubmed.ncbi.nlm.nih.gov/38851999/

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Review on the impact of cell phone radiation effects on green plants

Panda DK, Das DP, Behera SK, Dhal NK. Review on the impact of cell phone radiation effects on green plants. Environ Monit Assess. 2024 May 21;196(6):565. doi: 10.1007/s10661-024-12623-0.

Abstract

The aim of this review is to assess the impact of cell phone radiation effects on green plants. Rapid progress in networking and communication systems has introduced frequency- and amplitude-modulated technologies to the world with higher allowed bands and greater speed by using high-powered radio generators, which facilitate high definition connectivity, rapid transfer of larger data files, and quick multiple accesses. These cause frequent exposure of cellular radiation to the biological world from a number of sources. Key factors like a range of frequencies, time durations, power densities, and electric fields were found to have differential impacts on the growth and development of green plants. As far as the effects on green plants are concerned in this review, alterations in their morphological characteristics like overall growth, canopy density, and pigmentation to physiological variations like chlorophyll fluorescence and change in membrane potential etc. have been found to be affected by cellular radiation. On the other hand, elevated oxidative status of the cell, macromolecular damage, and lipid peroxidation have been found frequently. On the chromosomal level, micronuclei formation, spindle detachments, and increased mitotic indexes etc. have been noticed. Transcription factors were found to be overexpressed in many cases due to the cellular radiation impact, which shows effects at the molecular level.

https://pubmed.ncbi.nlm.nih.gov/38773047/

Conclusion

Cellular radiation affects plant seed germination, physiological, biochemical, cytogenetic, and molecular characters. In some cases, the effect has been shown to be positive. There is definitely some impact of these radiations; still there are controversies. Negative impacts can be described as heating stress or

charged effect of electric fields, but how the changes are positive nobody explains. Where the positive changes happen or on what frequency, and if power and SAR value is required have not been described. Not much research was found on wild plants, despite having more height and highly exposed in field conditions. Molecular changes in level of mRNA transcriptions have been seen with very less numbers of publications. Changes in the level of ion transports and electron transport chains have been done in very less numbers. Physical absorption and behavior of plant tissues have to be done more widely. The importance of these studies is most crucial because of the increased demand of technology with more number of users and requirement of high-end communication. Vast research in this field is required in order to avoid further hazards.

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Effect of moisture content variation on dielectric properties of various plant leaves at microwave frequencies

Chauhan PD, Gadani DH, Rana VA. Effect of moisture content variation on dielectric properties of various plant leaves at microwave frequencies. Sci Rep. 2024 Jun 8;14(1):13204. doi: 10.1038/s41598-024-64266-3.

Abstract

Complex permittivity of Corn, Jowar, Ashoka and Banana plant leaves was measured using a Vector Network Analyzer (Anritsu Shockline Model-MS46322A) over 500 MHz to 15 GHz frequency range, at different moisture contents. The dielectric constant (ε ') and dielectric loss (ε ”) of the leaves decrease with decrease in moisture content over this frequency range. For the leaves having moisture content less than certain critical moisture level (CML), the values of ε ' and ε " remain almost constant with frequency variation. ε ” does not increase appreciably with the increase in moisture content up to CML. CML is found to vary for different types of leaves. At higher moisture level, ε ' and ε ” exhibit frequency dependence. Above certain moisture level in the leaves, ε ” starts to increase slowly with the increase in frequency above 3 GHz approaching towards the dielectric relaxation of water. The values of ε ' and ε ” were also measured for the extract of leaves and compared with the values calculated using Stogryn equations for the same salinity, and the results agree with the calculated values. The measured values of ε ' and ε ” for the leaves were compared with the values calculated using Debye-Cole dual dispersion dielectric model and are found to match very well.

Open access paper: https://www.nature.com/articles/s41598-024-64266-3

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How the Impact of Electromagnetic Fields on Plants Can Greatly Increase Severity of and Even Occurrence of “Wildfires”: A Four-Part Structure

Pall ML. How the Impact of Electromagnetic Fields on Plants Can Greatly Increase Severity of and Even Occurrence of “Wildfires”: A Four-Part Structure.Ecology & Conservation Science: Open Access. 2024. doi: 10.19080/ECOA.2023.04.555631

Abstract

Low growing plants near buildings and electric powerlines often burn explosively at extreme temperatures, leaving a light gray powder whereas plants away from such sources of electromagnetic fields (EMFs) burn more normally, leaving slightly burned and/or charred materials. It is argued here that EMFs trigger a four-part mechanism producing this unusual pattern. Electronically generated EMFs impact plants via activation of voltage-controlled calcium channels, causing increases in plant terpenes and three other classes of volatiles (polyamines, lipid peroxidation volatiles and methyl jasmonate) and large increases in peroxynitrite and reactive free radicals. Four processes ensue: 1. The volatile terpenes make plants much more flammable. 2. Each of the four classes of volatiles accumulate in the air under very low wind conditions, and the heavy volatile-containing air spreads over the ground, selectively producing plasma membrane depolarization in low growing plants and parts of plants. Depolarization activates the same calcium channels activated by EMFs, selectively spreading and amplifying EMF-like effects to these low growing plants. 3. The terpenes react with free radicals and O2 to produce three classes of explosive terpene-derived chemicals, hydroperoxides, nitrate esters and nitro compounds. Accordingly, the explosive burning of these three classes of terpene derived chemicals in low growing plants produces very rapidly advancing low level firestorms which when they hit adjacent buildings also causes the buildings to burn at extremely high temperatures, leaving a light gray powder. 4. Terpene hydroperoxides because of their low thermostability may cause spontaneous combustion. Appropriate conditions for spontaneous combustion may be limited to plant materials in depressions in the ground. Sixteen fire observations are inconsistent with climate change being the sole cause of fire severity but are consistent with the proposed mechanism. Wind records from four large explosive US fires were examined and were found to be consistent with prediction. High voltage powerline roles in fires may be caused by powerline dirty electricity produced EMFs rather than poor maintenance as has previously been claimed.

Open access paper: https://juniperpublishers.com/ecoa/pdf/ECOA.MS.ID.555631.pdf

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Oxidative Stress Response of Honey Bee Colonies during Long-Term Exposure at a Frequency of 900 MHz under Field Conditions

Vilić M, Žura Žaja I, Tkalec M, Tucak P, Malarić K, Popara N, Žura N, Pašić S, Gajger IT. Oxidative Stress Response of Honey Bee Colonies (*Apis mellifera* L.) during Long-Term Exposure at a Frequency of 900 MHz under Field Conditions. Insects. 2024 May 20;15(5):372. doi: 10.3390/insects15050372.

Abstract

In this study, oxidative stress and lipid peroxidation in honey bee larvae, pupae and the midguts of adult bees were investigated during a one-year exposure to radiofrequency electromagnetic fields (RF-EMFs) at a frequency of 900 MHz under field conditions. The experiment was carried out on honey bee colonies at three locations with electric field levels of 30 mV m^{-1}, 70 mV m^{-1} and 1000 mV m^{-1}. Antioxidant enzymes, glutathione-S-transferase (GST), catalase (CAT) and superoxide dismutase (SOD) and thiobarbituric acid reactive substances (TBARS) as indicators of lipid peroxidation were measured spectrophotometrically. The GST activity within the same developmental stage showed no significant differences regardless of electric field level or sampling time. The highest GST activity was found in the pupae, followed by activity in the larvae and midguts. Both CAT activity and TBARS concentration were the highest in the midguts, regardless of field level and sampling time. The larvae showed a significantly

higher TBARS concentration at the location with an electric field level of 1000 mV m^{-1} compared to the locations with lower levels. Our results show that RF-EMFs at a frequency of 900 MHz can cause oxidative stress in honey bees, with the larval stage being more sensitive than the pupal stage, but there was no linear relationship between electric field level and effect in any of the developmental stages.

Open access paper: https://www.mdpi.com/2075-4450/15/5/372

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The Cellular Response Is Determined by a Combination of Different ELF-EMF Exposure Parameters: A Scope Review

López de Mingo I, Rivera González M-X, Maestú Unturbe C. The Cellular Response Is Determined by a Combination of Different ELF-EMF Exposure Parameters: A Scope Review. *International Journal of Molecular Sciences*. 2024; 25(10):5074. doi: 10.3390/ijms25105074.

Abstract

Since the establishment of regulations for exposure to extremely low-frequency (0–300) Hz electromagnetic fields, scientific opinion has prioritised the hypothesis that the most important parameter determining cellular behaviour has been intensity, ignoring the other exposure parameters (frequency, time, mode, waveform). This has been reflected in the methodologies of the in vitro articles published and the reviews in which they are included. A scope review was carried out, grouping a total of 79 articles that met the proposed inclusion criteria and studying the effects of the different experiments on viability, proliferation, apoptosis, oxidative stress and the cell cycle. These results have been divided and classified by frequency, intensity, exposure time and exposure mode (continuous/intermittent). The results obtained for each of the processes according to the exposure parameter used are shown graphically to highlight the importance of a good methodology in experimental development and the search for mechanisms of action that explain the experimental results, considering not only the criterion of intensity. The consequence of this is a more than necessary revision of current exposure protection regulations for the general population based on the reductionist criterion of intensity.

Conclusions

This review arises from the need to consider each of the parameters of exposure to magnetic fields as an entity capable of producing a determined response in the cell. The importance that has been given to the intensity parameter since the establishment of regulations for the exposure of the general public to low-frequency electromagnetic fields has led to it also being the main parameter in in vitro experiments, considering intensity as the determining parameter for the occurrence of the main cellular effects and placing the “dose effect” as one of the main theories explaining the effects found. We must begin to think of combinations of exposure parameters that act at the cellular level as specific codes that give rise to specific responses. Biology, and more specifically cell biology, entails a set of rules that must be protected as a fundamental right. There must be a commitment on the part of scientific researchers in bioelectromagnetism to develop quality experiments based on rigorous working methodologies and the search for experimental conclusions that contribute to existing knowledge in this field in order to establish models of interaction between magnetic fields and biological systems that allow us to think of

magnetic fields not only as a tool for modulating cell behaviour but also as a possible therapeutic application for various fields of medicine such as oncology, neurodegeneration or the healing of wounds and lesions.

Open access paper: https://www.mdpi.com/1422-0067/25/10/5074

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Modulation of Zebrafish Heart Rate by Alternating Magnetic Fields with Frequencies Close to Heart Rhythm

Krylov VV, Sizov DA, Machikhin AS, Guryleva AV, Tchougounov V, Burlakov AB. Modulation of Zebrafish Heart Rate by Alternating Magnetic Fields With Frequencies Close to Heart Rhythm. *IEEE Journal of Electromagnetics, RF and Microwaves in Medicine and Biology*. 2024. doi: 10.1109/JERM.2024.3397557.

Abstract

Extremely low-frequency magnetic fields (ELF-MF) up to 100 μT exhibit impacts on physiological processes, including heart function. The mechanisms underlying the influence of these fields on fish heart rates remain insufficiently explored. We assumed that the direct impact of ELF-MF with a frequency close to the heart rate could entrain oscillatory processes responsible for autonomously maintaining heart rhythm in zebrafish embryos. Embryos' heart rates ranged from 1.44 to 3 Hz depending on age, and ELF-MF with frequencies precisely matched, 10% higher, or lower than the heart rate were applied. Additionally, embryos experienced ELF-MF with amplitudes varying by an order of magnitude. Almost all tested ELF-MF induced an increased heart rate effect. This effect was the most pronounced when the exposure occurred earlier during ontogenesis. Fields with frequencies close to the heart rate did not entrain cardiac contractions in zebrafish embryos. A significant negative correlation between heart rate increase and ELF-MF frequency was observed for ELF-MF with amplitudes of 1.98–3.2 μT and 46.8 μT but not 30 μT. Probable molecular mechanisms underlying these effects are discussed in terms of magnetic influence on radical pairs within biochemical oscillating processes.

https://ieeexplore.ieee.org/document/10529610

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Prey can detect predators via electroreception in air

England SJ, Robert D. Prey can detect predators via electroreception in air. Proc Natl Acad Sci U S A. 024 Jun 4;121(23):e2322674121. doi: 10.1073/pnas.2322674121.

Abstract

Predators and prey benefit from detecting sensory cues of each other's presence. As they move through their environment, terrestrial animals accumulate electrostatic charge. Because electric charges exert forces at a distance, a prey animal could conceivably sense electrical forces to detect an approaching predator. Here, we report such a case of a terrestrial animal detecting its predators by electroreception. We show that predatory wasps are charged, thus emit electric fields, and that caterpillars respond to such fields with defensive behaviors. Furthermore, the mechanosensory setae of caterpillars are deflected by these electrostatic forces and are tuned to the wingbeat frequency of their insect

predators. This ability unveils a dimension of the sensory interactions between prey and predators and is likely widespread among terrestrial animals.

Open access paper: https://www.pnas.org/doi/10.1073/pnas.2322674121

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Associations between solar and geomagnetic activity and cognitive function in the Normative Aging study

Liddie JM, Vieira CLZ, Coull BA, Sparrow D, Koutrakis P, Weisskopf MG. Associations between solar and geomagnetic activity and cognitive function in the Normative Aging study. Environ Int. 2024 Apr 16;187:108666. doi: 10.1016/j.envint.2024.108666.

Abstract

Background: Studies show that changes in solar and geomagnetic activity (SGA) influence melatonin secretion and the autonomic nervous system. We evaluated associations between solar and geomagnetic activity and cognitive function in the Normative Aging Study from 1992 to 2013.

Methods: We used logistic and linear generalized estimating equations and regressions to evaluate the associations between moving averages of sunspot number (SSN) and Kp index (a measure of geomagnetic activity) and a binary measure for Mini-Mental State Examination (MMSE) scores (≤25 or > 25) and six other cognitive tests as continuous measures, combined into one global composite score and considered separately.

Results: A one-IQR increase in same-day SSN and Kp index were associated with 17% (95% CI: 3%, 34%) and 19% (95% CI: 4%, 36%) increases in the odds of low MMSE score. We observed small increases in the global cognitive score with increasing SSN, although we observed decreases specifically in relation to the backwards digit span test.

Conclusions: Periods of high SGA were associated with cognitive function. SGA may not equally impact all aspects of cognitive function, as evidenced by differences in associations observed for the MMSE, global cognitive score, and individual cognitive tests. Given that much of the pathology of cognitive decline in the elderly remains unexplained, studies specifically targeting decline and with longer follow-up periods are warranted.

Open access paper:
https://www.sciencedirect.com/science/article/pii/S0160412024002526?via%3Dihub

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ICNIRP Statement on Short Wavelength Light Exposure from Indoor Artificial Sources and Human Health

Miller S, Cajochen C, Green A, Hanifin J, Huss A, Karipidis K, Loughran S, Oftedal G, O'Hagan J, Sliney DH, Croft R, van Rongen E, Cridland N, d'Inzeo G, Hirata A, Marino C, Röösli M, Watanabe S; International Commission on Non-Ionizing Radiation Protection (ICNIRP). ICNIRP Statement on Short Wavelength Light Exposure from Indoor Artificial Sources and Human Health. Health Phys. 2024 Apr 1;126(4):241-248. doi: 10.1097/HP.0000000000001790.

Abstract

Concerns have been raised about the possibility of effects from exposure to short wavelength light (SWL), defined here as 380-550 nm, on human health. The spectral sensitivity of the human circadian timing system peaks at around 480 nm, much shorter than the peak sensitivity of daytime vision (i.e., 555 nm). Some experimental studies have demonstrated effects on the circadian timing system and on sleep from SWL exposure, especially when SWL exposure occurs in the evening or at night. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has identified a lack of consensus among public health officials regarding whether SWL from artificial sources disrupts circadian rhythm, and if so, whether SWL-disrupted circadian rhythm is associated with adverse health outcomes. Systematic reviews of studies designed to examine the effects of SWL on sleep and human health have shown conflicting results. There are many variables that can affect the outcome of these experimental studies. One of the main problems in earlier studies was the use of photometric quantities as a surrogate for SWL exposure. Additionally, the measurement of ambient light may not be an accurate measure of the amount of light impinging on the intrinsically photosensitive retinal ganglion cells, which are now known to play a major role in the human circadian timing system. Furthermore, epidemiological studies of long-term effects of chronic SWL exposure per se on human health are lacking. ICNIRP recommends that an analysis of data gaps be performed to delineate the types of studies needed, the parameters that should be addressed, and the methodology that should be applied in future studies so that a decision about the need for exposure guidelines can be made. In the meantime, ICNIRP supports some recommendations for how the quality of future studies might be improved.

Open access paper: https://journals.lww.com/health-physics/fulltext/2024/04000/icnirp_statement_on_short_wavelength_light.7.aspx

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Mobile telephony radiation exerts genotoxic action and significantly enhances the effects of gamma radiation in human cells

Panagopoulos DJ. Mobile telephony radiation exerts genotoxic action and significantly enhances the effects of gamma radiation in human cells. Gen Physiol Biophys. 2024 Mar;43(2):103-120. doi: 10.4149/gpb_2023036.

Abstract

I previously reported chromosomal damage in human peripheral blood lymphocytes (HPBLs) induced by: a) Mobile telephony (MT) electromagnetic fields (EMFs)/electromagnetic radiation (EMR), b) a high caffeine dose, and c) the combination of the two stressors. HPBLs from the same subjects exposed to gamma radiation at doses 0.1, 0.3, or 0.5 Gy, displayed more aberrations than those exposed to MT EMFs or the high caffeine dose in a dose- dependent manner. When the cells exposed to these gamma radiation doses were pre-exposed to a single 15-min MT EMF exposure, the number of aberrations

increased significantly more than the sum number of aberrations induced by the individual stressors in all subjects. Thus, MT EMF exposure at a power density ~ 136 times below the latest International Commission on Non-Ionizing Radiation Protection-ICNIRP exposure limit, apart from the fact that it is genotoxic by itself, significantly enhanced the genotoxic action of gamma radiation. Since gamma radiation at similar doses is applied for diagnostic and therapeutic purposes, people should be aware of the increased risk during treatment periods. Comparison of the genotoxic action between MT EMF and gamma radiation shows that the ICNIRP limits are, at least, $\sim 4.5\times10^4$ times less stringent than the limits for gamma radiation.

Excerpts

The studies that found real-life UMTS (3G/4G) exposure to be even more genotoxic than real-life GSM (2G) (D'Silva et al. 2017, 2021) are in line with the fact that newer types of MT/WC EMFs (3G, 4G, 5G) transmit increasingly higher amount/density of variable information (speech, text, images, video, Internet) making the signal increasingly complicated, unpredictably varying each moment, and thus, increasingly more bioactive due to the inability of the living organisms to adapt to a highly variable stressor. Thus, **the effects under deployment 5G MT EMF are expected to be even more intense than those of 2G, 3G, 4G**. This should have been seriously considered by the responsible public health authorities....

The disruption of cell electrochemical balance by manmade (polarized and coherent) EMFs through irregular gating of voltage-gated ion channels (VGICs) in cell membranes is described by the **"ion forced-oscillation and VGIC dysfunction" mechanism (IFO-VGIC mechanism)** (Panagopoulos et al. 2000, 2002, 2015b, 2021; Panagopoulos 2022b). According to this mechanism, the mobile ions in the cells are forced to oscillate in parallel and in phase with the applied man-made oscillating EMFs and this coordinated oscillation of electric charge exerts constructive Coulomb forces on the channel sensors of the VGICs similar to those exerted by membrane voltage changes that physiologically gate the VGICs. This causes irregular gating, and thus, dysfunction of the VGICs, which leads to intracellular release of ROS that finally cause genetic/cellular damage (Panagopoulos et al. 2021, 2022b)....

What has been referred to by Pall (2018) as voltage-gated calcium channel activation mechanism ("VGCC activation mechanism") is no other than the IFO-VGIC mechanism specifically on the calcium voltage-gated ion channels, and should not be reported as a different mechanism. Pall claimed he suggested a different mechanism simply because he hypothesized that the VGICs are gated by "direct" forces on their voltage-sensors by "penetrating" RF EMFs instead of ELF forces exerted by the oscillating ions in close proximity to the sensors. The impossibility of Pall's claims is analyzed in commentary papers (Foster and Balzano 2021; Panagopoulos 2021; Arribas et al. 2022).

Conclusions:

(1) MT EMF exposure, apart from the fact that it is genotoxic by itself, significantly enhanced the genotoxic action of gamma radiation in combined exposure;

(2) People/patients who are subjected to diagnostic or therapeutic treatment with ionizing radiation should be prudently advised to avoid using Wireless Communication (WC) devices (mobile/smart phones, wi-fi, cordless domestic phones, etc.) for a few days before, during, and after such treatments;

(3) Medical/radiology practitioners should be specifically educated on the risks of anthropogenic EMF-exposures in addition to those of ionizing radiations;

(4) Comparison with caffeine and gamma radiation suggests that the ICNIRP (2020) limits for WC EMF exposure should be lowered by 40,000 and 45,000 times respectively;

(5) The limit for short-term (acute) exposure should then become 0.1 µW/cm2 and accordingly for long- term exposure 0.001 µW/cm2;

(6) The combined effects of real-life man-made EMFs with a variety of other environmental stressors should be examined as a priority by next studies.

Open access paper:
http://www.elis.sk/download_file.php?product_id=8263&session_id=ef2ijbhbn0hevd1s33q2nvkrp6

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Effect of exposure to RF-EMF from lab simulator of 5G NR base station on physiological parameters & cognitive abilities of male rats of different ages

(My note: Methodological limitations of this study reduce generalizability to real-world 5G exposures.)

Krivova NA, Kudabaeva MS, Zaeva OB *et al.* The effect of exposure to RF-EMF from the laboratory simulator of 5G NR base station on physiological parameters and cognitive abilities of male wistar rats of different ages. *Sci Rep* **14**, 10283 (2024). doi: 10.1038/s41598-024-60862-5.

Abstract

In this article, the impact of radiofrequency electromagnetic field (RF-EMF) exposure from a simulated base station for the 5G New Radio (5G NR) telecommunication on rats was studied. The base station affects all age groups of the population, thus, for the first time, the experiment was conducted on male Wistar rats of three different ages (juvenile, adult, and presenile). The base station exposure parameters were chosen according to ICNIRP recommendations for limiting the exposure to radiofrequency electromagnetic field: frequency 2.4 GHz with an average specific absorption rate of 0.0076 W/kg and 0.0059 W/kg over the whole body of experimental animals. Throughout the experiment, body weight was examined weekly, and the dynamics of body weight gain was monitored. Rectal and skin surface temperature on the right hind limb was monitored weekly. Testing in the Morris water maze was performed during the last, Week 5, of RF-EMF exposure. After euthanasia, organ weights were determined in experimental and control animals. None of the investigated parameters did show any statistically significant differences between exposed and control animals of the same age. The data obtained can be used to assess the possible consequences of chronic exposure to RF-EMF from 5G NR base stations.

Open access paper: https://www.nature.com/articles/s41598-024-60862-5

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Human exposure to EMF from 5G base stations: analysis, evaluation and comparison of different assessment methods

Expósito I, Hakizimali C, Sánchez MG, Cuiñas I, Verhaevert J. Human exposure to EMF from 5G base stations: analysis, evaluation and comparison of different assessment methods. Measurement, Volume 229, 2024. doi: 10.1016/j.measurement.2024.114434.

Highlights

This paper analyzes the feasibility of assessing the 5G base stations compliance using broadband field probes and compares their performance with alternative methodologies and equipment.

Performance of three different methodologies and equipment (broadband probes, spectrum analyzers, and drive test scanners), in the context of human exposure to electromagnetic fields (EMF) from 5G base stations, is compared.

Quantification of the uncertainty that the fluctuation in 5G signal levels induces in the assessment of electromagnetic fields exposure is provided.

The use of broadband field probes for 5G exposure assessment is still possible under certain considerations and correcting the results considering the base station load and beamforming effects.

Abstract

5G networks deployment poses new challenges when evaluating human exposure to electromagnetic fields. Fast variation of the user load and beamforming techniques may cause large fluctuations of 5G base stations field level. They may be underestimated, resulting in compliance of base stations not fitting the requirements. Apparently, broadband field meters would not be adequate for measuring such environments. However, we analyze the feasibility of confidently using broadband field meters and compare their performance with alternative equipment. Measurements based on the synchronization signals power level, using spectrum analyzers or drive test scanners, may be valid, if gain differences between the signaling and data radiation patterns are characterized. These methods lead to good results but require more time and knowledge. Nevertheless, using broadband field meters is still possible if the measurement results are corrected considering the base station load. Under specific conditions, explained here, fast assessment of 5G compliance could be provided.

Conclusions

Assessing human exposure to an electromagnetic field in presence of a 5G base station is not an easy task. The implementation of M−MIMO techniques in 5G base stations results in adaptive beamforming. This makes difficult to guarantee that the field levels are at their maximum at the measurement location during the complete measurement period, which would limit the applicability of broadband instruments as having been done for previous generations. In this research, we have compared different methods for 5G exposure assessment, using a broadband field meter with an isotropic probe, a spectrum analyzer and a drive test scanner.

Along the paper, we first give an overview of the 5G signal structure, describing the frequency domain and time domain specifications. Afterwards, possible assessment methods are described. The SSB level is measured using the Keysight FieldFox N9913A SA and the Rohde & Schwarz TSM6 DTS. The values are extrapolated to the worst-case exposure and compared to the measurements done with the

Wavecontrol WPF8 broadband field probe. Measurements are repeated increasing the base station load by performing a heavy download from a 5G user terminal located near the testers.

The proposed methods were field tested at the University of Vigo, Spain, with a commercial 5G base station located on its campus. The measurements were performed at 7 locations in LOS conditions around the base station, gathering data with the three different equipment at the same locations and at the same time. This data collection allows the comparison of the three methodologies under the same radiating conditions.

All results have been analyzed considering the specific measurement uncertainties, which allows a deeper and more precise comparison among them.

From the measurement results, we can extract that the exposure levels are low at this stage of the 5G deployment. When loading the base station, the results showed that using the broadband field meter can overestimate the field level. Thus, it is still a useful method to check if the field levels comply with the regulation in human exposure; very simple and cost-effective compared with others. In-situ measurements of human exposure to EMF have to be practical and easy to carry, involving only the resources and equipment strictly necessary, but without compromising the validity of the results. When the reference levels are surpassed, more accurate methods based in the assessment and extrapolation of the SSB level could be a solution. The drawback is the required post processing, specially correcting the gain difference between SSB and data signals. If not provided by the network operator, this difference can be determined through measurements, as explained along this document. Measuring with an SA in max-hold mode in the bandwidth of the SSB does not work in 5G as it does in LTE, as we cannot be sure if the measured level corresponds to the SSB or to the user data, no matter if we are forcing the load of the station or not.

The analysis of the results demonstrate that broadband instruments can be used for assessing human exposure to EMF in the vicinity of 5G base stations, which radiating elements provide fields with extreme fluctuations in their intensity as a function of the system load and beamforming configuration. This is accurate when measurements are done by forcing an extra load of the station and the pointing of an antenna beam towards the probe. The validation of this fast method as a first attempt to assess the compliance of 5G stations permits the testing of these base stations in an efficient way. Only when broadband instrument results (including their uncertainties) would overpass the reference levels, a more detailed analysis would be necessary, which procedure and tips are also depicted along this paper.

https://www.sciencedirect.com/science/article/pii/S0263224124003191

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Absorption of 5G sub-6 GHz electromagnetic radiation from base station to male reproduction system

Lin J, Li J, Ding G. Absorption of 5G sub-6 GHz electromagnetic radiation from base station to male reproduction system. Int J Radiat Biol. 2024 May 6:1-8. doi: 10.1080/09553002.2024.2347354.

Abstract

Background: The impact of electromagnetic radiation from communication on the male reproductive system has emerged as a significant concern in public health. A notable distinction of the 5G sub-6 GHz

band, compared to traditional 2G, 3G, and 4G frequency bands, is the inclusion of higher frequency bands. This has raised public concerns regarding the potential effects of these higher frequencies on organisms, particularly their reproductive systems. While it is imperative to investigate the biological effects and potential risks associated with these new frequency bands in laboratory settings, comparing and evaluating differences between various frequency bands remain challenging due to the absence of standardized parameters such as exposure conditions and duration. In contrast, dose assessment offers a simpler and more reliable approach.

Materials and methods: The dose assessment method was employed in this study to investigate the risks associated with sub-6 GHz electromagnetic radiation from 5G base stations on the male reproductive system. A classical human body model (Duke) was utilized, and an electromagnetic simulation environment was established based on the actual polarization direction of the exposed base stations and various body postures. This research explored the effects of field direction, posture, public population, and frequency on the specific absorption rate of the reproductive system.

Results and conclusions: While maintaining the same level of exposure, a higher frequency results in a reduced dosage on reproductive system. Further analysis reveals that, considering the public exposure threshold, the employment of higher frequency bands in 5G sub-6 GHz does not present a greater dosage on reproductive system compared to lower frequency bands. Consequently, with regard to dosage, there is no need for excessive concern among the general public regarding the impact of electromagnetic radiation emitted by 5G base stations operating below 6 GHz on male reproductive health.
https://pubmed.ncbi.nlm.nih.gov/38709715/

Excerpts

The normalized evaluation revealed a strong negative correlation between the RSSAR results and frequency (figures 6 and 8), indicating the reproductive system's response to varying frequencies of electromagnetic waves. It also indicates that high-frequency skin effects are particularly prominent in the reproductive system. In the exposure limit assessment, there was an evident inflection point at 2.2 GHz where the trend of RSSAR values with frequency changes reached its maximum peak (figure 10). Therefore, when considering the exposure threshold, the higher frequency bands in 5G did not show higher dose values on RSSAR, but on the contrary, higher dose values were obtained in the 4G bands (such as 2.2 GHz in this study). These findings suggest that the potential risk of higher frequency electromagnetic waves in 5G sub-6 GHz is lower, as indicated by both normalized and exposure limit assessments.

Restriction and future focus

This research also has certain limitations. The exposure environment has not been considered in the context of the actual 5G exposure environment. With the introduction of 5G base stations, the grid of base stations may become denser and the energy of a single beam of electromagnetic radiation may be higher (Sofri et al. Citation2022). Although reference (Celaya-Echarri et al. Citation2020) simulated and compared the exposure values caused by base stations in the 2G–5G frequency band, the electric field conditions in real communities should also be measured and compared in detail. In future work,

exposure measurements and dose assessing could be combined with epidemiological investigations to further explore the effects of new frequency bands on reproductive and other systems.

Conclusions

The absorbed dose level of electromagnetic radiation emitted by communication base stations on the male reproductive system was analyzed, with a specific focus on the primary frequency points within the sub-6 GHz frequency band. The study revealed that higher frequencies resulted in reduced dose values while maintaining equivalent exposure levels. Further analysis demonstrated that, considering the exposure threshold, the utilization of higher frequencies in 5G sub-6 GHz did not present a greater risk compared to lower frequencies. Therefore, from a dosage assessment perspective, concerns regarding the impact of sub-6 GHz electromagnetic radiation emitted by 5G base stations on male reproductive health are unwarranted.

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Central Causation of Autism/ASDs via Excessive [Ca^{2+}]i Impacting Six Mechanisms Controlling Synaptogenesis during the Perinatal Period: The Role of Electromagnetic Fields and Chemicals and the NO/ONOO(-) Cycle, as Well as Specific Mutations

Pall ML. Central Causation of Autism/ASDs via Excessive [Ca2+]i Impacting Six Mechanisms Controlling Synaptogenesis during the Perinatal Period: The Role of Electromagnetic Fields and Chemicals and the NO/ONOO(-) Cycle, as Well as Specific Mutations. Brain Sciences. 2024; 14(5):454. doi: 10.3390/brainsci14050454. (Published: 30 April 2024)

Abstract

The roles of perinatal development, intracellular calcium [Ca2+]i, and synaptogenesis disruption are not novel in the autism/ASD literature. The focus on six mechanisms controlling synaptogenesis, each regulated by [Ca2+]i, and each aberrant in ASDs is novel. The model presented here predicts that autism epidemic causation involves central roles of both electromagnetic fields (EMFs) and chemicals. EMFs act via voltage-gated calcium channel (VGCC) activation and [Ca2+]i elevation. A total of 15 autism-implicated chemical classes each act to produce [Ca2+]i elevation, 12 acting via NMDA receptor activation, and three acting via other mechanisms. The chronic nature of ASDs is explained via NO/ONOO(-) vicious cycle elevation and MeCP2 epigenetic dysfunction. Genetic causation often also involves [Ca2+]i elevation or other impacts on synaptogenesis. The literature examining each of these steps is systematically examined and found to be consistent with predictions. Approaches that may be used for ASD prevention or treatment are discussed in connection with this special issue: The current situation and prospects for children with ASDs. Such approaches include EMF, chemical avoidance, and using nutrients and other agents to raise the levels of Nrf2. An enriched environment, vitamin D, magnesium, and omega-3s in fish oil may also be helpful.

Excerpts

Figure 1 is an outline of the mechanisms proposed here and, in some cases, elsewhere, to act during the perinatal period of brain development [5], to disrupt synaptogenesis and therefore cause autism spectrum disorders (ASDs). Accordingly, key factors in autism/ASD causation are proposed to be the six

mechanisms in the lower left part of Figure 1 (in red), each of which have been shown to have important roles in synaptogenesis in the developing brain. These six mechanisms are neuronal migration, dendritic outgrowth, synapse formation, synapse maturation, synaptic pruning, and lowered MeCP2 function. It is shown below that these six mechanisms are regulated by intracellular calcium ([Ca2+]i).

VGCC activity acts via [Ca2+]i to produce diverse biological effects via the pathways shown in Figure 2

.... Let us shift now to ASD treatment and prevention. These are presented here not to give medical advice, but rather to enlighten the reader in the central issues of this special issue: The current situation and prospects for children with ASDs. Both treatment and prevention require avoidance of electronically-generated EMFs and diverse chemicals, however difficult that may be. Let us start with EMFs. There are many sources of EMFs in our living spaces, workplaces, educational and recreational environments, and even outdoors. Many of these are discussed in Section 2.1.

There are “safety guidelines” initially proposed by ICNIRP, an organization set up by the industry and these ICNIRP safety guidelines have been adopted, sometimes with minor modifications, over much of the world. The ICNIRP and similar “safety guidelines” are all based on thermal effects produced over either a 6 min or 30 min period. However, as discussed above, biological effects are caused by electric forces or time-varying magnetic forces produced by electronically-generated EMFs, and are unrelated to thermal effect “safety guidelines”. It follows that all assurances of safety based on these “safety guidelines” have no scientific merit.

Pregnant women should not use cell phones, cordless phones, should avoid Wi-Fi fields, and should use wired connections to the internet, avoid Bluetooth, should not spend time near smart meters, cell phone towers, avoid high voltage powerlines, etc. Pregnant women should avoid being in buildings with high dirty electricity in their electric powerlines. Such avoidance is very challenging. A second choice is to use shielding to protect the fetus and the young baby after birth.

You can get large shielded T-shirts to protect the fetus, wearing a regular cloth T-shirt underneath to minimize body contact. Such shielding materials have large numbers of metal (often silver) fibers. I believe that shielding mostly acts by disrupting the coherence of the EMFs, therefore greatly lowering any electric or magnetic forces. Shielding has been extensively studied in the scientific literature [271,272,273,274,275,276,277]. For example, ref. [271] states that “By using wireless technologies, we increase the influence of the electromagnetic field on the human body. The basic measures for the protection against electromagnetic radiation are: (1) shielding of the radiation source, (2) shielding of the workplace, (3) personal protective equipment, (4) reduction of radiation in the immediate vicinity of the radiation source”. [271] goes on to discuss the shielding effects of both fabrics containing tiny metal fibers and also brick walls.

You can buy shielding paint of two different types to protect yourself in your house and, if you live in an apartment, this may be the only way to protect yourself from your neighbors’ EMFs. Shielding paint can be either graphite (black) paint which can be painted over with other colors. Other more pleasant colored shielding paint can be purchased containing tiny metallic particles. You can also buy open shielding cloth to put over windows, making them into lace like curtains to lower EMF exposures coming through the windows. Similar approaches can be used after birth to protect the young baby. It is highly desirable to purchase a good EMF meter to provide information and prevent the worst exposures throughout the perinatal period.

Open access paper: https://www.mdpi.com/2076-3425/14/5/454

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The effects of radiofrequency electromagnetic fields exposure on human self-reported symptoms: A systematic review of human experimental studies (WHO SR8)

(Note: Methodological problems with many studies included in this systematic review undermine the validity of this review paper.)

Bosch-Capblanch X, Esu E, Oringanje CM, Dongus S, Jalilian H, Eyers J, Auer C, Meremikwu M, Röösli M. The effects of radiofrequency electromagnetic fields exposure on human self-reported symptoms: A systematic review of human experimental studies. Environment International. doi: 10.1016/j.envint.2024.108612. Available online 2 April 2024.

Abstract

Background The technological applications of radiofrequency electromagnetic fields (RF-EMF) have been steadily increasing since the 1950s exposing large proportions of the population. The World Health Organization (WHO) is assessing the potential health effects of exposure to RF-EMF.

Objectives To systematically assess the effects of exposure to RF-EMF on self-reported non-specific symptoms in human subjects and to assess the accuracy of perception of presence or absence of RF-EMF exposure.

Methods Eligibility criteria: experimental studies carried out in the general population and in individuals with idiopathic environmental intolerance attributed to EMF (IEI-EMF), in any language.

Information sources: Medline, Web of Science, PsycInfo, Cochrane Library, Epistemonikos and Embase and consulted the EMF portal, searched till April 2022.

Risk of bias: we used the Risk of Bias (RoB) tool developed by OHAT adapted to the topic of this review.

Synthesis of results: we synthesized studies using random effects meta-analysis and sensitivity analyses where appropriate.

Results Included studies: 41 studies were included, mostly cross over trials and from Europe, with a total of 2,874 participants.

Synthesis of results: considering the primary outcomes, we carried out meta-analyses of 10 exposure-outcomes pairs. All evidence suggested no or small non-significant effects of exposure on symptoms with high (three comparisons), moderate (four comparisons), low (one comparison) or very low (two comparisons) certainty of evidence. The effects (standard mean difference, where positive values indicate presence of symptom being exposed) in the general population for head exposure were (95% confidence intervals) 0.08 (−0.07 to 0.22) for headache, −0.01 (−0.22 to 0.20) for sleeping disturbances and 0.13 (−0.51 to 0.76) for composite symptoms; and for whole-body exposure: 0.09 (−0.35 to 0.54), 0.00 (−0.15 to 0.15) for sleeping disturbances and −0.05 (−0.17 to 0.07) for composite symptoms. For IEI-EMF individuals SMD ranged from −0.19 to 0.11, all of them with confidence intervals crossing the value

of zero. Further, the available evidence suggested that study volunteers could not perceive the EMF exposure status better than what is expected by chance and that IEI-EMF individuals could not determine EMF conditions better than the general population.

Discussion Limitations of evidence: experimental conditions are substantially different from real-life situations in the duration, frequency, distance and position of the exposure. Most studies were conducted in young, healthy volunteers, who might be more resilient to RF-EMF than the general population. The outcomes of interest in this systematic review were symptoms, which are self-reported. The available information did not allow to assess the potential effects of exposures beyond acute exposure and in elderly or chronic ill people. It cannot be ruled out that a real EMF effect in IEI-EMF groups is masked by a mix with insensitive subjects. However, studies on symptom reporting and/or field perception did not find any evidence that there are particularly vulnerable individuals in the IEI-EMF group, although in open provocation studies, when volunteers were informed about presence or absence of EMF exposure, such differences have been consistently observed.

Interpretation: available evidence suggests that acute RF-EMF below regulatory limits does not cause symptoms and corresponding claims in everyday life are related to perceived and not real EMF exposure status.

Excerpts

4.4. Implications for practice

We could not find any evidence that would support an association between exposure to RF-EMF below regulatory recommendations and a large variety of short term reported symptoms; neither evidence that could suggest the capacity of individuals to detect the exposure to RF-EMF. This is the case for the general population, for IEI-EMF individuals, in the main meta-analyses as well as in the exposure–response and sensitivity analyses.

While these findings cannot rule out other long term potential harms of RF-EMF, they suggest that the presence or absence of common symptoms may not become good clinical predictors of the occurrence or evolution of IEI-EMF. It may also indicate that notion of acute effects from RF-EMF below regulatory limits in the everyday environment are better explained with the nocebo or the attribution hypothesis (Dieudonné, 2020).

4.5. Implications for research

The body of evidence in this review seems to consistently suggest the lack of association between EMF exposure and symptoms, in a variety of conditions and populations. The most critical aspect challenging the certainty of the evidence was the limited detail in the methodology of included studies, particularly in the issues related to the exposure randomisation and allocation concealment. While we hardly downgrades the evidence on the grounds of ‘indirectness’, most of the studies were focusing on adults, young adults and even adolescents, which may have limited the external validity of findings.

In order to confirm the findings of this systematic review, future research should, thus, consider adhering to best reporting practices and considering a wider scope of participants, including, for example, the elderly.

Future research should also be carried out standardising the design of experiments in terms of exposure ranges, timing and sequence of events, so as to make studies more comparable. It may be worth to increase exposure levels above regulatory limits for the general population to explore potential critical threshold for non-specific symptoms. Self-evident such studies need to follow a prudent approach to ensure that any symptoms are transient and do not result in a long term health impairment.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024001983

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Is the sustainability of exposure to non-ionizing electromagnetic radiation possible?

Calvente I, Núñez MI. Is the sustainability of exposure to non-ionizing electromagnetic radiation possible? Medicina Clínica (English Edition), 162(8):387-393. 2024. doi: 10.1016/j.medcle.2023.11.016.

Abstract

Technological advances imply an increase in artificially generating sources of electromagnetic fields (EMF), therefore, resulting in a permanent exposure of people and the environment (electromagnetic pollution). Inconsistent results have been published considering the evaluated health effects. The purpose of this study was to review scientific literature on EMF to provide a global and retrospective perspective, on the association between human exposure to non-ionizing radiation (NIR, mainly radiofrequency-EMF) and health and environmental effects. Studies on the health effects of 5G radiation exposure have not yet been performed with sufficient statistical power, as the exposure time is still relatively short and also the latency and intensity of exposure to 5G. The safety standards only consider thermal effects, do not contemplate non-thermal effects. We consider relevant to communicate this knowledge to the general public to improve education in this field, and to healthcare professionals to prevent diseases that may result from RF-EMF exposures.

Excerpts

ICNIRP reviews safety guidelines but does not provide solutions, uses SAR, only considers thermal effects, does not consider non-thermal effects. Scientific evidence shows the importance of considering both thermal and non-thermal effects, short and long-term biological effects, and other factors. On the other hand, more frequent periodic reviews of the regulations are needed. According to ICNIRP the last one was in 2020. Even considering the leap in technology use in 2020, should we wait as many years as now (approx. 10) for a new update?

There are countries with stricter regulations than those established by IARC (sic) that are more concerned about the effects of this type of exposure (Italy, Belgium, Austria (Salzburg), Switzerland, Russia, China)....

In the face of such divergent assessments of wireless RF radiation, the practice of ALARA – as low as reasonably achievable – for RF health and safety should be followed.

On the basis of the evidence presented here, is it possible to speak of sustainability in relation to electromagnetic fields?

https://www.sciencedirect.com/science/article/pii/S2387020624001268

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Environmental Factors as the Main Hormonal Disruptors of Male Fertility

Wdowiak N, Wójtowicz K, Wdowiak-Filip A, Pucek W, Wróbel A, Wróbel J, Wdowiak A. Environmental Factors as the Main Hormonal Disruptors of Male Fertility. J Clin Med. 2024 Mar 29;13(7):1986. doi: 10.3390/jcm13071986.

Abstract

Introduction and objective: Many scientific reports confirm a systematic decline in male semen parameters over the last decades. This phenomenon has been observed in all parts of the world, and its occurrence is associated, among others, with the hazardous effects of some environmental factors. The environmental factors for which the adverse effect on male fertility has been proven include water, air, and soil pollution, as well as electromagnetic fields and ionizing radiation. The aim of this article was the evaluation of the effect of selected environmental factors on male reproductive capacity based on an analysis of the current scientific reports.

Review methods: A systematic literature review was carried out using three databases: PubMed, EMBASE, and Scopus. The search was limited to the period from 2015 until the end of December 2023. Brief description of the state of knowledge: Environmental factors, such as heavy metals, tobacco smoke, pesticides, dioxins, furans, phthalates, and bisphenols, are well-tested substances that exert an adverse effect on male fertility. A harmful effect of electromagnetic fields and water and air pollution on reproductive functions may be expected; however, this has not been fully proven.

Summary: Results obtained by many researchers published to date should evoke great concern regarding the quality of the environment in which we live, as well as fears about the effect of environmental factors not only on male fertility, but also on all aspects of human health. The majority of environmental pollutants affect the male body by causing oxidative stress and through their effect on the endocrine system.

Excerpt

12. Electromagnetic Fields

Electromagnetic radiation (EMR) originating from both the natural environment and human activity constantly affects living organisms. The effect of EMR on the reproductive system may occur as a result of the thermal effect, generation of oxidative stress, changes in the structure of proteins, and causing changes in ion transport through cell membranes; however, these pathomechanisms have not yet been

fully explained. Based on studies conducted to date it is known that electromagnetic fields generate oxidative stress, disrupting the function of sperm mitochondria and causing the activation of cell membrane NADH oxidase [43].

Balance in the free radical system, which is affected by the electromagnetic fields, as well as the activity of ion channels, are together responsible for the process of sperm hyperactivation. Human spermatozoa, in order to become ready to fertilize an oocyte, undergo many metabolic changes affecting the cell membrane, which leads to capacitation occurring in the woman's reproductive tract. As a result of these transformations, sperm can interact with the structures of the corona radiata, and subsequently with the zona pellucida of the oocyte. This process is necessary for fertilization. Possible premature capacitation taking place in the seminal plasma causes energy depletion of the sperm and reduces the chance for fertilization. Balance in the free radical system is the factor responsible for the proper moment of capacitation. Ion channels are responsible for the proper course of this process, including CatSper, a pH-regulated, calcium-selective ion channel, KSper (Slo3), and the voltage-gated channel Hv1. To date, it has been considered that many other channels regulate these processes; however, this was not supported by research, and only the implementation of the patch–clamp technique shed new light on the possibilities of opportunities to learn about this process. It is known that mutations and deletions of the genes responsible for the function of these channels are responsible for the existence of certain types of male infertility. The voltage-gated channel Hv1, which is an electrical voltage sensor responsible for processes related to fertilization, seems to be the most sensitive to the effect of EMF. The results of studies concerning the effect of EMF on the immune system cells confirmed that the frequency close to 15 Hz has the greatest impact on the transport of Ca^{2+} ions into the cell. Therefore, it may be expected that similar relationships will also concern sperm [43,44].

It has long been known that welding arcs are a very harmful source of EMF for males. Their radiation consists of intensive thermal radiation of high-temperature welding gases, welded or cut elements, electrode, and flux material, on which the lines and bands of radiation characteristic of these materials overlap. The gas burner flame temperature usually does not exceed 2000 K. Thus, this radiation consists mainly of infrared and light, and only hydrogen and acetylene burners are characterized by a higher combustion temperature and emit near-ultraviolet light. Scientific reports concerning the effect of welding on male fertility confirm that in males performing this profession, deterioration of the main sperm parameters occurs, and their partners are at an increased risk of miscarriage. The type of harmful effect on the male reproductive system depends on the type of materials to be welded and applies primarily to mild steel [43,44].

Exposure to strong EMF also concerns employees operating radar stations. Currently, various types of radars operate on frequencies from 3 MHz (HF band) to 110 GHz (W band). In the lower part of this range operate radars which measure the height of the ionosphere, and those using the phenomenon of reflection of electromagnetic waves from the ionosphere for detecting objects hidden beyond the horizon, often over a distance of thousands of kilometers. Most radars operate at frequencies ranging from several hundred megahertz to 100 GHz, including speed cameras known to drivers, which are used to take photos of cars and are based on the 34.3 ± 0.1 GHz band. The reports concerning their effect on male fertility are contradictory. Some researchers describe an increase in the percentage of abnormal sperm and reduction in sperm motility, with a simultaneous absence of effect on its density in

employees of radar stations. In turn, other researchers describe a decreased sperm density in people exposed to radar waves. There are also reports that do not indicate any differences in the quality of sperm between males exposed to a radar, and those not exposed to its effect.

Due to the development of telecommunication technologies, at present, almost every person is exposed to EMF related to GSM. Our own study conducted at the beginning of the 'era of mobile phones' demonstrated an increase in the percentage of abnormal sperm and a decrease in the percentage of sperm in progressive movement, together with an increase in exposure to GSM. Studies concerning the effect of mobile phone technology on sperm have been continued by many researchers. They demonstrated that the waves emitted by mobile phones cause an increased production of the reactive oxygen species (ROS), leading to oxidative stress in sperm, and intensification of sperm DNA fragmentation. Similar relationships were confirmed on animal models. In a study in which mice were exposed to radiation of 900 mW/kg for 12 h daily for 7 days an adverse effect of EMR was observed on mitochondrial genome integrity. It was also proven that long-lasting telephone calls lead to an increase in temperature in the brain, which may affect the activity of the hypothalamic–pituitary–gonadal axis [43,44].

A significant exposure to electromagnetic fields also concerns males working on high-voltage electrical installations. It was found that among employees exposed for many years to contact with voltage of 400 kV, fewer children were born compared to the control group. Among children exposed to high voltage, the male gender prevailed. It was also observed that among offspring of males exposed to high voltage, congenital defects occurred more frequently.

There are also other scientific reports that confirm a beneficial effect of electromagnetic fields with lower frequency ranges on both sperm parameters and the function of tissues responsible for human reproduction. Some scientific studies confirmed that exposure of sperm to magnetic fields within the range from 10–50 Hz contributes to the improvement of the motility of human sperm, whereas others presented opposite results.

In animal models, while investigating the exposure of fish reproductive cells to magnetic fields, an improvement was observed in sperm motility parameters, and an increase in the percentage of fertilizations. Electromagnetic fields have found application in the treatment of prostate disorders in animals. A group of researchers confirmed that in dogs, the exposure of the prostate to frequencies of 4–12 Hz has a healing effect on prostate enlargement, not causing changes in sperm parameters of the animals. The results of studies confirming a beneficial effect of electromagnetic fields provide hope for their use in the treatment of human infertility; however, a long-term impact of this type of energy will require meticulous research, especially regarding possible epigenetic effects diagnosed only in future generations. Own studies of sperm exposed in vitro to weak EMF, close to that used at security checkpoints, showed an effect on DNA methylation [43,44].
At present, we are unable to specify what amount of energy related to EMF is harmful, neutral, or beneficial for human reproductive capacity. It may be expected that there are amounts of energy with neutral or beneficial effect, and only exceeding them may cause harmful effects.

Open access paper: https://www.mdpi.com/2077-0383/13/7/1986

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Influence of power control in the mobile network on the radiation level

Mitić D, Lebl A, Markov Ž. Influence of power control in the mobile network on the radiation level. Journal of Electrical Engineering, 75(2):161-165. 2024. doi: 10.2478/jee-2024-0019.

Abstract

The paper evaluates how the control of transmitted power affects the intensity of radiation in a mobile network cell. Cell models without power control, with standard power control and a model with power control and channel reallocation are considered. The relative reduction of radiation is evaluated and several examples of calculations are presented. Remarks are given on the dependence of radiation reduction on the number of traffic channels, traffic intensity and signal attenuation coefficient. The assessment procedure and results are based on previously verified traffic process simulation models.

Conclusion

The paper shows that control of emitted power, in addition to saving energy and reducing interference, also contributes to the radiation reduction.

Control of the emission power by matching the power with the user's distance affects the reduction of radiation in proportion to the increase in the number of frequency carriers. The radiation level depends on the distribution of the users' surface density in the cell and on the environmental signal attenuation coefficient.

Additional control of the emission power by channel reallocation can further reduce the radiation level. This reduction is greater when there is a smaller number of frequency carriers (but greater than 1), with less offered traffic and with a higher attenuation coefficient.

Open access paper: https://doi.org/10.2478/jee-2024-0019

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Frequency selective human-centric sub 6 GHz electromagnetic measurements in shopping mall

Berisha D, Rexhëbeqaj-Hamiti V, Dobruna J, Maloku H, Limani Fazliu Z, Ibrani M. (2024). Frequency selective human-centric sub 6 GHz electromagnetic measurements in shopping mall. *Cogent Engineering*, *11*(1). doi: 10.1080/23311916.2024.2340311.

Abstract

Limiting human exposure to radio frequency electromagnetic fields in crowded indoor public spaces such as shopping malls, is identified as one of the key metrics in the process of green and digital environment transformation. To assess the exposure levels in shopping malls, we conducted a human centric extensive measurement campaign using three-axial frequency selective measurement equipment. Our study involved various indoor locations within the mall, capturing electrical field levels at different times and days of the week. A total of 529,340 samples were collected during working days, and 430,020 samples were collected during weekends. We measured E-field strength, power density,

and calculated total exposures for frequency bands ranging from 88 MHz to 5850 MHz. The presented comparative analysis revealed that mobile communications technologies operating at 900 MHz and 1800 MHz were the main contributors to personal exposure levels in different mall environments.

Conclusions

This paper presents the exposure levels in shopping malls during different days of the week, obtained through a rigorous 3-month measurement campaign utilizing frequency selective measurement equipment. The collected data underwent careful processing, including screening of each measured E-field exposure level to ensure accurate sampling and minimize errors.

The average total E-field exposure value during the weekday was 0.39 V/m, while during the weekend 0.33 V/m. The highest contributors to the total exposure levels in various shopping mall environments are mobile communication technologies operating at 900 MHz and 1800 MHz (2G–3G–4G). The Downlink 2G–3G operating at 900 MHz, has an average electric field exposure value of 0.2 V/m during the weekdays and during the weekend, while the Downlink 2G–4G operating at 1800 MHz has an average E-field value of 0.1 V/m during the weekdays and 0.17 V/m during the weekend.

On weekdays, the main factor contributing to total exposure levels was 2G–3G mobile communications operating at 900 MHz (Downlink), accounting for 52.4% of the exposure, followed by mobile communications at 1800 MHz (Uplink and Downlink. Furthermore, the highest E-field values during weekdays were observed in the Downlink 2G–3G band and Wi-Fi 2 G technology, exceeding the upper limit of 6 V/m.

During the weekend, the primary contributor to total exposure levels remained the 2G–3G communications at 900 MHz (Downlink), accounting for 37% of the exposure. However, there was an increase in e-field values for 2G–4G communications at 1800 MHz (Downlink), with its contribution rising to 34% compared to 15% during weekdays. The highest observed value was for Wi-Fi 5G technology, reaching 4.98 V/m, although its contribution to the total exposure levels was only 0.6%.

Based on the cumulative distribution analysis, it can be inferred that during the weekdays, 90% of the measured data have an E-field exposure value of less than 1 V/m. On the other hand, during the weekend, 90% of the measured data have a value smaller than 0.64 V/m. These values are in line with the E-field values recorded in similar studies as referenced in.

In conclusion, based on our extensive measurement campaign, personal exposure levels are higher in shopping malls during the weekdays compared to the weekend. The highest contributors to the total personal exposure at shopping malls are the Mobile communication technologies (Uplink/Downlink) and WI-FI technologies.

Contrary to our initial expectations regarding the indoor environment of the shopping mall, our measurement data reveals that Wi-Fi technologies are not the primary contributors to the total exposure. Instead, mobile communication technologies operating at 900 MHz and 1800 MHz have emerged as the dominant sources due to their high data rates and extensive coverage.

https://www.tandfonline.com/doi/full/10.1080/23311916.2024.2340311

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Progress in microwave absorbing materials: A critical review

Sharma S, Parne SR, Panda SSS, Gandi S. Progress in microwave absorbing materials: A critical review. Adv Colloid Interface Sci. 2024 Apr 4;327:103143. doi: 10.1016/j.cis.2024.103143.

Abstract

Microwave-absorbing materials play a significant role in various applications that involve the attenuation of electromagnetic radiation. This critical review article provides an overview of the progress made in the development and understanding of microwave-absorbing materials. The interaction between electromagnetic radiation and absorbing materials is explained, with a focus on phenomena such as multiple reflections, scattering, and polarizations. Additionally, types of losses that affect the performance of microwave absorbers are also discussed, including dielectric loss, conduction loss, relaxation loss, magnetic loss, and morphological loss. Each of these losses has different implications for the effectiveness of microwave absorbers. Further, a detailed review is presented on various types of microwave absorbing materials, including carbonaceous materials, conducting polymers, magnetic materials, metals and their composites, 2D materials (such as MXenes and 2D-transition metal dichalcogenides), biomass-derived materials, carbides, sulphides, phosphides, high entropy (HE) materials and metamaterials. The characteristics, advantages, and limitations of each material are examined. Overall, this review article highlights the progress achieved in the field of microwave-absorbing materials. It underlines the importance of optimizing different types of losses to enhance the performance of microwave absorbers. The review also recognizes the potential of emerging materials, such as 2D materials and high entropy materials, in further advancing microwave-absorbing properties.

https://pubmed.ncbi.nlm.nih.gov/38598925/

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Rosmarinic Acid Protects the Testes of Rats against Cell Phone and Ultra-high Frequency Waves Induced Toxicity

Fatahi Asl J, Goudarzi M, Mansouri E, Shoghi H. Rosmarinic Acid Protects the Testes of Rats against Cell Phone and Ultra-high Frequency Waves Induced Toxicity. Iran J Med Sci. 2024 Apr 1;49(4):237–46. doi: 10.30476/ijms.2023.97695.2952.

Abstract

Background: Cell phone and Ultra-High Frequency (UHF) waves produce oxidative stress and cause testicular toxicity. This investigation was directed to evaluate the effectiveness of Rosmarinic Acid (RA) against oxidative stress caused by UHF radiation in rats.

Methods: Forty-two male Wistar rats were divided into six groups. The control received 5 mL normal saline (0.9% NaCl) by gavage, the cell phone group received 915 MHz, the UHF waves group just received 2450 MHz, the RA/cell phone group received RA plus 915 MHz, RA/UHF waves group received RA plus 2450 MHz, and RA just received RA (20 mg/kg). After 30 days of consecutive radiation, the biochemical and histopathological parameters of their testes were measured. Statistical comparison was made using one-way ANOVA followed by Tukey's post hoc test.

Results: Cell phone and UHF wave radiation significantly diminished the activity of antioxidant enzymes such as superoxide dismutase, catalase, and glutathione peroxidase, and glutathione content (P<0.001). On the opposite, UHF significantly increased oxidative stress indices including malondialdehyde level, nitric oxide level, and protein carbonyl content (P<0.001). UHF also significantly reduced the number of Sertoli cells, spermatogonia, primary spermatocyte, epithelial height, and seminiferous tubular and luminal diameters (P<0.001). RA, as an effective antioxidant, reverses the above-mentioned harms and moderates the adverse effects of UHF on the testes of rats by significantly diminishing the oxidative stress indices and antioxidant enzyme rise and improving the histological parameters (P<0.001).

Conclusion: RA can protect the testes of rats from UHF-induced toxicity by reducing oxidative stress. RA as a food supplement might be useful for protecting humans exposed to UHF environmental contamination.

Open access paper: https://ijms.sums.ac.ir/article_49676.html

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Panax ginseng Ameliorates Pituitary-Ovarian Dysfunction Induced by RF EMR from Cell Phones via Upregulation of the CREM Signaling Pathway

Oyewopo OA, Badejogbin OC, Ajadi IO, Enye LA, Ajadi MB, Ebuwa IV, Owolabi OV, Areloegbe SE, Olaniyi KS. Panax ginseng Ameliorates Pituitary-Ovarian Dysfunction Induced by Radiofrequency Electromagnetic Radiation from Cell Phones via Upregulation of the CREM Signaling Pathway. Curr Drug Discov Technol. 2024 Apr 30. doi: 10.2174/0115701638279386240425050818.

Abstract

Background: Panax ginseng (PG) is a plant that contains ginsenosides, which are considered adaptogens that confer cellular protection. However, the impact of PG on pituitary-ovarian dysfunction and subsequent infertility is unknown. This study investigated the hypothesis that PG would attenuate pituitary-ovarian dysfunction associated with mobile phone's Radiofrequency Electromagnetic Radiation (RF-EMR) in experimental rat models and the possible involvement of a cAMP Response Element Modulator (CREM)-dependent pathway.

Methods: Twenty adult female Wistar rats were divided randomly into four groups, each consisting of five rats. The control group was administered a vehicle (distilled water) orally, while the P. ginseng group received 200 mg/kg of P. ginseng extract orally. The RF-EMR group was exposed to 900MHz radiation, and the RF-EMR + PG group was exposed to the same radiation while also being treated with 200 mg/kg of P. ginseng orally. These treatments were administered daily for a period of 56 days.

Results: The RF-EMR group exhibited significant reductions in serum levels of LH, FSH, estradiol, and progesterone compared to the control group. Moreover, levels of superoxide dismutase (SOD) and glutathione peroxidase (GPx) were significantly lower in the RF-EMR group compared to the control. Additionally, there was a notable decrease in the expression of the CREM gene, accompanied by disrupted pituitary/ovarian morphology in the RF-EMR group compared to the control. However, the administration of PG mitigated these changes.

Conclusion: The findings of this study indicate that P. ginseng extract shields against pituitary-ovarian impairment linked to RF-EMR exposure from cell phones by boosting antioxidant capacity and promoting the CREM-dependent pathway.

https://pubmed.ncbi.nlm.nih.gov/38693729/

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Electric and magnetic field pollution in near substations and investigation of anxiety and depressive effects on adult individuals living in this area

Sert C, Başak N, Koruk İ. Electric and magnetic field pollution in near substations and investigation of anxiety and depressive effects on adult individuals living in this area. Electromagn Biol Med. 2024 May 3:1-11. doi: 10.1080/15368378.2024.2348574.

Abstract

Exposure to electromagnetic fields causes a variety of health problems in living systems. We investigated EMF pollution in Şanlıurfa city center and also investigated anxiety-depression symptoms in individuals (18-40 years old) exposed to this pollution. For this purpose, electric field and magnetic field measurements were taken at Electricity Distribution Center and 44 substations (for each transformer), at 0 points, 1 meter away, 2 meters away and the house/office closest to the transformer. The experimental group was individuals living in electricity distribution center residences and individuals living near transformers (n = 55). The control group was selected from individuals who lived outside the city center of Şanlıurfa, did not have transformers or high transmission lines near their homes, and did not have any chronic diseases that could cause stress (n = 50). Anxiety and depression symptoms of the groups were measured using the Beck Anxiety Inventory Scale (BAI) and Beck Depression Inventory Scale (BDI). The relationship between EMF pollution and anxiety-depression was evaluated statistically. Maximum MF and EF values were recorded as 0.22 mT and 65.9 kV/m, respectively. All measured MF values were below standards, but EF values were above standards at some points. In conclusion, there is no statistically convincing evidence of a relationship between EMF exposure and anxiety-depression (p > 0.05). This result shows that there may be more meaningful results in places with higher EMF levels. We interpreted the fact that exposure to electromagnetic fields does not cause anxiety and depression in individuals, as the measured values are below the limit values.

Plain language summary

Electromagnetic field pollution causes various health problems in living systems. Research on this subject continues. We investigated electromagnetic field pollution in Şanlıurfa city center and investigated the psychological effects on individuals exposed to this pollution. For this purpose, electric and magnetic field measurements were made at 0 points, 1 meter, 2 meters away and at the closest places to the transformer in 44 substations. The experimental group was individuals living near a transformer, the control group was individuals living outside the city center and without a transformer/high transmission line near their home. Anxiety and depression symptoms of the groups were measured using the Beck Anxiety and Depression test. The relationship between EMF pollution and anxiety-depression was evaluated statistically. As a result, no statistical change was observed regarding a relationship between electromagnetic pollution and anxiety-depression.

https://pubmed.ncbi.nlm.nih.gov/38699873/

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The effect of a rotating magnetic field on the antioxidant system in healthy volunteers - preliminary study

Cecerska-Heryć E, Gliźniewicz M, Grygorcewicz B, Serwin N, Stodolak P, Słodzińska W, Birger R, Goszka M, Polikowska A, Budkowska M, Rakoczy R, Dołęgowska B. The effect of a rotating magnetic field on the antioxidant system in healthy volunteers - preliminary study. Sci Rep. 2024 Apr 15;14(1):8677. doi: 10.1038/s41598-024-59391-y.

Abstract

Oxidative stress is characterized by an excessive concentration of reactive oxygen species (ROS) resulting from a disturbance in the balance between ROS production and their removal by antioxidant systems (SOD, CAT, GPx). Prolonged and intense oxidative stress can cause various forms of damage to cells, which markers are total antioxidant capacity (TAC), reactive oxygen species modulator (ROMO1), and malondialdehyde (MDA). It has been demonstrated that magnetic fields can positively affect human health, for example, by reducing oxidative stress. Determination of the effect of a rotating magnetic field (RMF) on the activity/concentration of selected oxidative stress markers. A group of 30 healthy volunteers (15 women and 15 men) (mean age 24.8 ± 5.1) in the study classified into the following groups: internal control group (CG);1 h 25 Hz (samples placed in the field for one hour at 25 Hz); 3 h 25 Hz (samples placed in the field for 3 h at 25 Hz), the 1 h 50 Hz group (placed in RMF for an hour at 50 Hz), and a group of 3 h 50 Hz (samples placed in the field for 3 h at 50 Hz). Serum samples were collected in K_2EDTA tubes.. The magnetic induction value obtained for RMF is 37.06 mT and 42.64 mT. Activity/concentration of selected oxidative stress markers was analyzed by ELISA. The influence of an RMF on the activity/concentration of SOD, MDA, TAC, and ROMO1 was demonstrated ($p < 0.001$; $p = 0.0013$; $p < 0.001$; $p = 0.003$). The RFM can reduce oxidative stress, as evidenced by higher SOD and CAT activities in the CG than in samples placed in the RFM. Prolonged exposure to the RFM at 50 Hz increased the TAC level, indicating an intensification of oxidative stress in these samples. The optimal conditions for staying in the RFM (reducing oxidative stress) are 1 h 50 Hz for SOD and MDA; 3 h 25 Hz for CAT and TAC. In the case of ROMO1, it is stated that 1 h 25 Hz are the optimal conditions for no increased production of ROS.

Open access paper: https://www.nature.com/articles/s41598-024-59391-y

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Pulsating Extremely Low-Frequency Electromagnetic Fields Influence Differentiation of Mouse Neural Stem Cells towards Astrocyte-like Phenotypes: In Vitro Pilot Study

Isaković J, Slatković F, Jagečić D, Petrović DJ, Mitrečić D. Pulsating Extremely Low-Frequency Electromagnetic Fields Influence Differentiation of Mouse Neural Stem Cells towards Astrocyte-like Phenotypes: In Vitro Pilot Study. Int J Mol Sci. 2024 Apr 4;25(7):4038. doi: 10.3390/ijms25074038.

Abstract

Even though electromagnetic fields have been reported to assist endogenous neurogenesis, little is known about the exact mechanisms of their action. In this pilot study, we investigated the effects of pulsating extremely low-frequency electromagnetic fields on neural stem cell differentiation towards specific phenotypes, such as neurons and astrocytes. Neural stem cells isolated from the telencephalic wall of B6(Cg)-Tyrc-2J/J mouse embryos (E14.5) were randomly divided into three experimental groups and three controls. Electromagnetic field application setup included a solenoid placed within an incubator. Each of the experimental groups was exposed to 50Hz ELF-EMFs of varied strengths for 1 h. The expression of each marker (NES, GFAP, β-3 tubulin) was then assessed by immunocytochemistry. The application of high-strength ELF-EMF significantly increased and low-strength ELF-EMF decreased the expression of GFAP. A similar pattern was observed for β-3 tubulin, with high-strength ELF-EMFs significantly increasing the immunoreactivity of β-3 tubulin and medium- and low-strength ELF-EMFs decreasing it. Changes in NES expression were observed for medium-strength ELF-EMFs, with a demonstrated significant upregulation. This suggests that, even though ELF-EMFs appear to inhibit or promote the differentiation of neural stem cells into neurons or astrocytes, this effect highly depends on the strength and frequency of the fields as well as the duration of their application. While numerous studies have demonstrated the capacity of EMFs to guide the differentiation of NSCs into neuron-like cells or β-3 tubulin+ neurons, this is the first study to suggest that ELF-EMFs may also steer NSC differentiation towards astrocyte-like phenotypes.

Open access paper: https://www.mdpi.com/1422-0067/25/7/4038

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Invited Perspective: Why Systematic Reviews, Scoping Reviews, and Evidence-to-Decision Frameworks Are Critical for Transparent, Consistent, Equitable, and Science-Based Decision-Making in Environmental Health

My note: Systematic reviews require a multitude of macro- and micro-decisions. When conducted by biased investigative teams, systematic reviews generate erroneous conclusions and policy implications. This applies to EMF as well as chemical exposures.

Chartres N, Joglekar R. Invited Perspective: Why Systematic Reviews, Scoping Reviews, and Evidence-to-Decision Frameworks Are Critical for Transparent, Consistent, Equitable, and Science-Based Decision-Making in Environmental Health. Environ Health Perspect. 2024 Mar;132(3):31304. doi: 10.1289/EHP14346.

No abstract

Excerpt

"... systematic review is simultaneously being corrupted as agencies, including the Texas Commission on Environmental Quality (TCEQ) and the US Environmental Protection Agency (EPA), as part of implementing the amended the Toxic Substances Control Act, are appropriating the term in regulatory decision-making without meeting many of the standards of an empirically based systematic review. 4,9–12 This could result in rulemakings that underestimate the true risk of harm posed by toxic chemical exposures, which could have devastating implications for vulnerable populations, including low-wealth communities of color. 11"

Open access paper: https://ehp.niehs.nih.gov/doi/10.1289/EHP14346

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Mobile phone use and brain tumour risk – COSMOS, a prospective cohort study

(My note: Numerous methodological problems undermine the validity of the results and conclusions of this study.)

Feychting M, Schüz J, Toledano MB, Vermeulen R, Auvinen A, Poulsen AH, Deltour I, Smith RB, Heller J, Kromhout H, Huss A, Johansen C, Tettamanti G, Elliott P. Mobile phone use and brain tumour risk – COSMOS, a prospective cohort study. Environment International. 2024, doi: 10.1016/j.envint.2024.108552.

Abstract

Background: Each new generation of mobile phone technology has triggered discussions about potential carcinogenicity from exposure to radiofrequency electromagnetic fields (RF-EMF). Available evidence has been insufficient to conclude about long-term and heavy mobile phone use, limited by differential recall and selection bias, or crude exposure assessment. The Cohort Study on Mobile Phones and Health (COSMOS) was specifically designed to overcome these shortcomings.

Methods: We recruited participants in Denmark, Finland, the Netherlands, Sweden, and the UK 2007-2012. The baseline questionnaire assessed lifetime history of mobile phone use. Participants were followed through population-based cancer registers to identify glioma, meningioma, and acoustic neuroma cases during follow-up. Non-differential exposure misclassification was reduced by adjusting estimates of mobile phone call-time through regression calibration methods based on self-reported data and objective operator-recorded information at baseline. Hazard ratios (HR) and 95% confidence intervals (CI) for glioma, meningioma, and acoustic neuroma in relation to lifetime history of mobile phone use were estimated with Cox regression models with attained age as the underlying time-scale, adjusted for country, sex, educational level, and marital status.

Results: 264,574 participants accrued 1,836,479 person-years. During a median follow-up of 7.12 years, 149 glioma, 89 meningioma, and 29 incident cases of acoustic neuroma were diagnosed. The adjusted HR per 100 regression-calibrated cumulative hours of mobile phone call-time was 1.00 (95 % CI 0.98-1.02) for glioma, 1.01 (95 % CI 0.96-1.06) for meningioma, and 1.02 (95 % CI 0.99-1.06) for acoustic neuroma. For glioma, the HR for ≥ 1908 regression-calibrated cumulative hours (90th percentile cut-point) was 1.07 (95 % CI 0.62-1.86). Over 15 years of mobile phone use was not associated with an increased tumour risk; for glioma the HR was 0.97 (95 % CI 0.62-1.52).

Conclusions: Our findings suggest that the cumulative amount of mobile phone use is not associated with the risk of developing glioma, meningioma, or acoustic neuroma.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024001387
Supplementary material:
https://www.sciencedirect.com/science/article/pii/S0160412024001387#s0065

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Dominance of Smartphone Exposure in 5G Mobile Networks

Chiaraviglio L, Lodovisi C, Bartoletti S, Elzanaty A, M. Slim-Alouini M. Dominance of Smartphone Exposure in 5G Mobile Networks. IEEE Transactions on Mobile Computing, 23(3):2284-2302, 2024. doi: 10.1109/TMC.2023.3252662.

Abstract

The deployment of 5G networks is sometimes questioned due to the impact of ElectroMagnetic Field (EMF) generated by Radio Base Station (RBS) on users. The goal of this work is to analyze such issue from a novel perspective, by comparing RBS EMF against exposure generated by 5G smartphones in commercial deployments. The measurement of exposure from 5G is hampered by several implementation aspects, such as dual connectivity between 4G and 5G, spectrum fragmentation, and carrier aggregation. To face such issues, we deploy a novel framework, called 5G-EA, tailored to the assessment of smartphone and RBS exposure through an innovative measurement algorithm, able to remotely control a programmable spectrum analyzer. Results, obtained in both outdoor and indoor locations, reveal that smartphone exposure (upon generation of uplink traffic) dominates over the RBS one. Moreover, Line-of-Sight locations experience a reduction of around one order of magnitude on the overall exposure compared to Non-Line-of-Sight ones. In addition, 5G exposure always represents a small share (up to 38%) compared to the total one radiated by the smartphone.

Excerpt

Our results demonstrate that the smartphone exposure dominates over the RBS one upon generation of UL traffic, especially when the UE is in Non-Line-of-Sight (NLOS) with respect to the RBS. On the contrary, both smartphone exposure and total EMF are reduced up to one order of magnitude when the smartphone UL traffic traverses a radio link in Line-of-Sight (LOS) with respect to the serving RBS. Interestingly, the exploitation of dual connectivity feature between 4G and 5G reveals that only a small smartphone exposure share (at most equal to 38%) is due to 5G, while the largest exposure levels are derived from the carrier aggregation over 4G bands. Moreover, both total and smartphone exposure-per-bit metrics are inversely proportional to the maximum amount of UL traffic generated by the smartphone in the measurement location, thus suggesting that innovative exposure estimators, based on the reporting of maximum UL traffic from the smartphone, can be designed.

Open access paper: https://doi.ieeecomputersociety.org/10.1109/TMC.2023.3252662

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Human exposure to EMF from 5G base stations: analysis, evaluation and comparison of different assessment methods

Expósito I, Hakizimali C, García Sánchez M, Cuiñas I, Verhaevert J. Human exposure to EMF from 5G base stations: analysis, evaluation and comparison of different assessment methods. Measurement. 2024. doi: 10.1016/j.measurement.2024.114434.

Highlights

- This paper analyzes the feasibility of assessing the 5G base stations compliance using broadband field probes and compares their performance with alternative methodologies and equipment.
- Performance of three different methodologies and equipment (broadband probes, spectrum analyzers, and drive test scanners), in the context of human exposure to electromagnetic fields (EMF) from 5G base stations, is compared.
- Quantification of the uncertainty that the fluctuation in 5G signal levels induces in the assessment of electromagnetic fields exposure is provided.
- The use of broadband field probes for 5G exposure assessment is still possible under certain considerations and correcting the results considering the base station load and beamforming effects.

Abstract

5G networks deployment poses new challenges when evaluating human exposure to electromagnetic fields. Fast variation of the user load and beamforming techniques may cause large fluctuations of 5G base stations field level. They may be underestimated, resulting in compliance of base stations not fitting the requirements. Apparently, broadband field meters would not be adequate for measuring such environments. However, we analyze the feasibility of confidently using broadband field meters and compare their performance with alternative equipment. Measurements based on the synchronization signals power level, using spectrum analyzers or drive test scanners, may be valid, if gain differences between the signaling and data radiation patterns are characterized. These methods lead to good results but require more time and knowledge. Nevertheless, using broadband field meters is still possible if the measurement results are corrected considering the base station load. Under specific conditions, explained here, fast assessment of 5G compliance could be provided.

Conclusions

Assessing human exposure to an electromagnetic field in presence of a 5G base station is not an easy task. The implementation of M−MIMO techniques in 5G base stations results in adaptive beamforming. This makes difficult to guarantee that the field levels are at their maximum at the measurement location during the complete measurement period, which would limit the applicability of broadband instruments as having been done for previous generations. In this research, we have compared different methods for 5G exposure assessment, using a broadband field meter with an isotropic probe, a spectrum analyzer and a drive test scanner.

Along the paper, we first give an overview of the 5G signal structure, describing the frequency domain and time domain specifications. Afterwards, possible assessment methods are described. The SSB level is measured using the Keysight FieldFox N9913A SA and the Rohde & Schwarz TSM6 DTS. The values are extrapolated to the worst-case exposure and compared to the measurements done with the Wavecontrol WPF8 broadband field probe. Measurements are repeated increasing the base station load by performing a heavy download from a 5G user terminal located near the testers.

The proposed methods were field tested at the University of Vigo, Spain, with a commercial 5G base station located on its campus. The measurements were performed at 7 locations in LOS conditions around the base station, gathering data with the three different equipment at the same locations and at

the same time. This data collection allows the comparison of the three methodologies under the same radiating conditions.

All results have been analyzed considering the specific measurement uncertainties, which allows a deeper and more precise comparison among them.

From the measurement results, we can extract that the exposure levels are low at this stage of the 5G deployment. When loading the base station, the results showed that using the broadband field meter can overestimate the field level. Thus, it is still a useful method to check if the field levels comply with the regulation in human exposure; very simple and cost-effective compared with others. In-situ measurements of human exposure to EMF have to be practical and easy to carry, involving only the resources and equipment strictly necessary, but without compromising the validity of the results. When the reference levels are surpassed, more accurate methods based in the assessment and extrapolation of the SSB level could be a solution. The drawback is the required post processing, specially correcting the gain difference between SSB and data signals. If not provided by the network operator, this difference can be determined through measurements, as explained along this document. Measuring with an SA in max-hold mode in the bandwidth of the SSB does not work in 5G as it does in LTE, as we cannot be sure if the measured level corresponds to the SSB or to the user data, no matter if we are forcing the load of the station or not.

The analysis of the results demonstrate that broadband instruments can be used for assessing human exposure to EMF in the vicinity of 5G base stations, which radiating elements provide fields with extreme fluctuations in their intensity as a function of the system load and beamforming configuration. This is accurate when measurements are done by forcing an extra load of the station and the pointing of an antenna beam towards the probe. The validation of this fast method as a first attempt to assess the compliance of 5G stations permits the testing of these base stations in an efficient way. Only when broadband instrument results (including their uncertainties) would overpass the reference levels, a more detailed analysis would be necessary, which procedure and tips are also depicted along this paper.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0263224124003191

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5G NR launching in Greece: Preliminary in situ and monitoring network measurements of electromagnetic fields exposure levels at rooftops

Christopoulou MI, Kyritsi T, Yalofas A, Koutounidis D, Karabetsos E. 5G NR launching in Greece: Preliminary in situ and monitoring network measurements of electromagnetic fields exposure levels at rooftops. Bioelectromagnetics. 2024 Mar 5. doi: 10.1002/bem.22502.

Highlights

- In situ measurements of electromagnetic field (EMF) exposure levels at rooftops, close to 117 base stations operating at 5G FR1 in Greece in order to evaluate the contribution of 5G to the total exposure.
- Statistical analysis of the follow-up for inspections of the same base stations, before and after the 5G FR1 launching in Greece.
- Case study of a 5G FR1 base station during its pilot and regular operation based on in situ and broadband & frequency selective 24/7 monitoring sensors measurements data.

Abstract

In Greece, 5G New Radio (NR) has started launching in the end of 2020, at the 3400-3800 MHz (FR1) frequency band. Focusing on 117 Base Stations (BSs) which were already equipped with 5G NR antennas, in situ broadband and frequency selective measurements have been conducted at minimum three points of interest, at adjacent rooftops (when accessible). The points have been selected according to the sweeping method and the electric field strength (E) value has been stored on the selected worst-case scenario point. Spectrum analysis was conducted in the FR1, for the allocated spectrum that corresponds to each mobile communication provider, in order to get preliminary results concerning the contribution of the 5G NR emissions in the general public exposure levels. The vast majority of the in situ measurements has been conducted in urban environments from the beginning of 2021 until the mid of 2022, since in Greece 5G NR services launching started from the big cities. Additionally, a 5G NR BS, installed in a suburban environment (in the city of Kalamata) is thoroughly investigated during its pilot and regular operation, based on broadband and frequency selective measurements data derived by the National Observatory of Electromagnetic Fields (NOEF) monitoring sensor network. In situ measurement data within the 5G NR frequency range are verified via the NOEF's output. The 5G NR contribution to the total E-field levels is assessed in time, from pilot to regular operation of the BS. In all cases, compliance with the reference levels for general public exposure is affirmed.

https://pubmed.ncbi.nlm.nih.gov/38444067/

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The determinants of legislation for radiofrequency electromagnetic fields (RF-EMFs) with the onset of 5G: An empirical analysis

Recuero Virto L, Czerwiński M, Froidevaux J. The determinants of legislation for radiofrequency electromagnetic fields (RF-EMFs) with the onset of 5G: An empirical analysis with a worldwide cross-sectional dataset. Risk Anal. 2024 Mar 31. doi: 10.1111/risa.14298.

Abstract

The unprecedented exposure of radiofrequency electromagnetic field (RF-EMF) to humans from mobile communications raises serious public concern about the possibility of unexpected adverse health effects and has stimulated authorities to adopt precautionary exposure limits. These limits are distinctly different across countries, and the causes of these differences are unclear from the literature. This article is the first empirical analysis on the determinants of RF-EMF exposure legislation, using a novel cross-sectional database of 164 countries worldwide. The analysis shows that decentralization and mobile competition in countries with low mobile network deployment tend to promote more stringent RF-EMF exposure limits across the dataset with 164 countries. In more decentralized countries, the regions had a greater influence on national legislation and could accommodate local demands with the advent of mobile technology in the 2000s. In contrast, decentralization and mobile competition in countries with high levels of mobile network deployment tend to relax RF-EMF exposure limits in the sample of 61 countries with fifth-generation (5G) technology. Indeed, restrictive RF-EMF exposure limits are constraining 5G deployment in a context of the widespread adoption of mobile-broadband technologies. These results should be useful for policymakers and mobile operators alike to anticipate the outcome of legislation in countries that have yet to introduce 5G technology. The results should also

be useful when reviewing policies and strategies for the implementation of the upcoming 6G technology in frequency bands that will be increasingly higher (above 6 GHz up to THz for very local usage), and hence where the health effects on humans are less well studied.

https://pubmed.ncbi.nlm.nih.gov/38556257/

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Editorial: Neurological Illness and National Security: Lessons to Be Learned

Relman DA. Neurological Illness and National Security: Lessons to Be Learned. JAMA. Published online March 18, 2024. doi:10.1001/jama.2023.26818

No abstract

Excerpt

In 2016, a set of troubling neurological symptoms was reported through confidential channels by US government personnel based at the US Embassy in Havana, Cuba. As the number of cases in Havana escalated and then similar cases occurred over the next 5 years in other locations around the globe, efforts to understand this syndrome, now known as anomalous health incidents (AHIs), were hampered by their unusual features, incomplete information, nonstandardized clinical testing, delayed reporting, and the sensitive nature of the circumstances, individuals, and their work. A subset of individuals described the abrupt onset, sometimes in the middle of the night, of a loud, grinding, clicking, buzzing, or high-pitched piercing sound inside the head, occasionally likened to a slide whistle, and a sensation of pressure, sometimes in one ear, on one side of the head, or in the face or chest. Most strikingly, these phenomena often displayed strong location dependence, in that they quickly dissipated when the individuals vacated their initial location, and then returned when the location was revisited. In some cases, this location dependence was reported to occur repeatedly by the same individual or by multiple individuals as they moved away from and then returned within minutes to a specific location, such as part of a room. These abrupt-onset sensory phenomena were followed by a mix of vertigo, dizziness, imbalance, blurry vision, tinnitus, headache, nausea, and cognitive dysfunction, sometimes leading to chronic disability.

In this issue of JAMA, Chan et al1 and Pierpaoli et al2 at the National Institutes of Health (NIH) report on an extensive clinical assessment of 86 participants with AHIs and 30 control participants, and on magnetic resonance imaging (MRI) findings of 81 of these participants with AHIs and 48 control participants, respectively. Overall, the authors found few significant differences between participants with AHIs and control participants, and no consistent evidence of brain injury. These findings differ from previous clinical and imaging studies of smaller numbers of cases from Havana and China that found evidence of vestibular, oculomotor, and pupillary abnormalities3,4 and a variety of MRI findings.5

With few differences between cases and controls in the 2 current studies, one might suspect that nothing or nothing serious happened with these cases. This would be ill-advised. Two detailed investigations of AHIs (in which I played a role) found the cases with abrupt-onset, location-dependent sensory phenomena to be unlike any disorder reported in the neurological or general medical literature, and potentially caused by an external mechanism.6-9 The first of these investigations was undertaken

by the US National Academy of Sciences in 2019-2020 and the second by a panel of experts on behalf of the US Intelligence Community in 2021-2022. The latter is described in more detail below. Both of these investigations involved experienced clinicians, detailed interviews with many affected individuals, careful reviews of the literature, and informal reviews of some medical records, but not physical examinations or directed testing. After considering a wide variety of possible mechanisms, both studies concluded that some of the cases with abrupt-onset, location-dependent sensory phenomena could be plausibly explained by exposure to directed, pulsed radiofrequency energy, despite important uncertainties. Others have also pointed to pulsed radiofrequency energy as a plausible mechanism.10,11 The US Intelligence Community has discounted this possibility and concluded that reported symptoms were probably the result of "preexisting conditions, conventional illnesses, and environmental factors," influenced by their assessment that no foreign adversary played a role in these cases.12 While many cases may be explained in this fashion, the evidence that might favor known conditions, illnesses, and factors in some of the cases with abrupt-onset, location-dependent auditory-vestibular phenomena is weak at best....

Open access paper: https://jamanetwork.com/journals/jama/fullarticle/2816534

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Clinical, biomarker, and research tests among US government personnel and their family members involved in anomalous health incidents

Chan L, Hallett M, Zalewski CK, et al; NIH AHI Intramural Research Program Team. Clinical, biomarker, and research tests among US government personnel and their family members involved in anomalous health incidents. JAMA. Published March 18, 2024. doi:10.1001/jama.2024.2413

Key Points

Questions Do US government officials and their family members involved in anomalous health incidents (AHIs) differ from control participants with respect to clinical, biomarker, and research assessments?

Findings In this exploratory study that included 86 participants reporting AHIs and 30 vocationally matched control participants, there were no significant differences in most tests of auditory, vestibular, cognitive, visual function, or blood biomarkers between the groups. Participants with AHIs performed significantly worse on self-reported and objective measures of balance, and had significantly increased symptoms of fatigue, posttraumatic stress disorder, and depression compared with the control participants; 24 participants (28%) with AHIs presented with functional neurological disorders.

Meaning In this exploratory study, there were no significant differences between individuals reporting AHIs and matched control participants with respect to most clinical, research, and biomarker measures, except for self-reported and objective measures of imbalance; symptoms of fatigue, posttraumatic stress, and depression; and the development of functional neurological disorders in some.

Abstract

Importance Since 2015, US government and related personnel have reported dizziness, pain, visual problems, and cognitive dysfunction after experiencing intrusive sounds and head pressure. The US government has labeled these anomalous health incidents (AHIs).

Objective To assess whether participants with AHIs differ significantly from US government control participants with respect to clinical, research, and biomarker assessments.

Design, Setting, and Participants Exploratory study conducted between June 2018 and July 2022 at the National Institutes of Health Clinical Center, involving 86 US government staff and family members with AHIs from Cuba, Austria, China, and other locations as well as 30 US government control participants.

Exposures AHIs.

Main Outcomes and Measures Participants were assessed with extensive clinical, auditory, vestibular, balance, visual, neuropsychological, and blood biomarkers (glial fibrillary acidic protein and neurofilament light) testing. The patients were analyzed based on the risk characteristics of the AHI identifying concerning cases as well as geographic location.

Results Eighty-six participants with AHIs (42 women and 44 men; mean [SD] age, 42.1 [9.1] years) and 30 vocationally matched government control participants (11 women and 19 men; mean [SD] age, 43.8 [10.1] years) were included in the analyses. Participants with AHIs were evaluated a median of 76 days (IQR, 30-537) from the most recent incident. In general, there were no significant differences between participants with AHIs and control participants in most tests of auditory, vestibular, cognitive, or visual function as well as levels of the blood biomarkers. Participants with AHIs had significantly increased fatigue, depression, posttraumatic stress, imbalance, and neurobehavioral symptoms compared with the control participants. There were no differences in these findings based on the risk characteristics of the incident or geographic location of the AHIs. Twenty-four patients (28%) with AHI presented with functional neurological disorders.

Conclusions and Relevance In this exploratory study, there were no significant differences between individuals reporting AHIs and matched control participants with respect to most clinical, research, and biomarker measures, except for objective and self-reported measures of imbalance and symptoms of fatigue, posttraumatic stress, and depression. This study did not replicate the findings of previous studies, although differences in the populations included and the timing of assessments limit direct comparisons.

Open access paper: https://jamanetwork.com/journals/jama/fullarticle/2816533

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Neuroimaging findings in US government personnel and their family members involved in anomalous health incidents

Pierpaoli C, Nayak A, Hafiz R, et al; NIH AHI Intramural Research Program Team. Neuroimaging findings in US government personnel and their family members involved in anomalous health incidents. JAMA. Published March 18, 2024. doi:10.1001/jama.2024.2424

Key Points

Question Can a systematic evaluation using quantitative magnetic resonance imaging (MRI) metrics identify potential brain lesions in patients who have experienced anomalous health incidents (AHIs) compared with a well-matched control group?

Findings In this exploratory study that involved brain imaging of 81 participants who experienced AHIs and 48 matched control participants, there were no significant between-group differences in MRI measures of volume, diffusion MRI–derived metrics, or functional connectivity using functional MRI after adjustments for multiple comparisons. The MRI results were highly reproducible and stable at longitudinal follow-ups. No clear relationships between imaging and clinical variables emerged.

Meaning In this exploratory neuroimaging study, there was no significant MRI-detectable evidence of brain injury among the group of participants who experienced AHIs compared with a group of matched control participants. This finding has implications for future research efforts as well as for interventions aimed at improving clinical care for the participants who experienced AHIs.

Abstract

Importance US government personnel stationed internationally have reported anomalous health incidents (AHIs), with some individuals experiencing persistent debilitating symptoms.

Objective To assess the potential presence of magnetic resonance imaging (MRI)–detectable brain lesions in participants with AHIs, with respect to a well-matched control group.

Design, Setting, and Participants This exploratory study was conducted at the National Institutes of Health (NIH) Clinical Center and the NIH MRI Research Facility between June 2018 and November 2022. Eighty-one participants with AHIs and 48 age- and sex-matched control participants, 29 of whom had similar employment as the AHI group, were assessed with clinical, volumetric, and functional MRI. A high-quality diffusion MRI scan and a second volumetric scan were also acquired during a different session. The structural MRI acquisition protocol was optimized to achieve high reproducibility. Forty-nine participants with AHIs had at least 1 additional imaging session approximately 6 to 12 months from the first visit.

Exposure AHIs.

Main Outcomes and Measures Group-level quantitative metrics obtained from multiple modalities: (1) volumetric measurement, voxel-wise and region of interest (ROI)–wise; (2) diffusion MRI–derived metrics, voxel-wise and ROI-wise; and (3) ROI-wise within-network resting-state functional connectivity using functional MRI. Exploratory data analyses used both standard, nonparametric tests and bayesian multilevel modeling.

Results Among the 81 participants with AHIs, the mean (SD) age was 42 (9) years and 49% were female;

among the 48 control participants, the mean (SD) age was 43 (11) years and 42% were female. Imaging scans were performed as early as 14 days after experiencing AHIs with a median delay period of 80 (IQR, 36-544) days. After adjustment for multiple comparisons, no significant differences between participants with AHIs and control participants were found for any MRI modality. At an unadjusted threshold ($P < .05$), compared with control participants, participants with AHIs had lower intranetwork connectivity in the salience networks, a larger corpus callosum, and diffusion MRI differences in the corpus callosum, superior longitudinal fasciculus, cingulum, inferior cerebellar peduncle, and amygdala. The structural MRI measurements were highly reproducible (median coefficient of variation <1% across all global volumetric ROIs and <1.5% for all white matter ROIs for diffusion metrics). Even individuals with large differences from control participants exhibited stable longitudinal results (typically, <±1% across visits), suggesting the absence of evolving lesions. The relationships between the imaging and clinical variables were weak (median Spearman $\rho = 0.10$). The study did not replicate the results of a previously published investigation of AHIs.

Conclusions and Relevance In this exploratory neuroimaging study, there were no significant differences in imaging measures of brain structure or function between individuals reporting AHIs and matched control participants after adjustment for multiple comparisons.

Open access paper: https://jamanetwork.com/journals/jama/fullarticle/2816532

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Do blue light filter applications improve sleep outcomes? A study of smartphone users' sleep quality in an observational setting

Rabiei M, Masoumi SJ, Haghani M, Nematolahi S, Rabiei R, Mortazavi SMJ (2024). Do blue light filter applications improve sleep outcomes? A study of smartphone users' sleep quality in an observational setting. Electromagnetic Biology and Medicine, DOI: 10.1080/15368378.2024.2327432.

Abstract

Exposure to blue light at bedtime, suppresses melatonin secretion, postponing the sleep onset and interrupting the sleep process. Some smartphone manufacturers have introduced night-mode functions, which have been claimed to aid in improving sleep quality. In this study, we evaluate the impact of blue light filter application on decreasing blue light emissions and improving sleep quality. Participants in this study recorded the pattern of using their mobile phones through a questionnaire. In order to evaluate sleep quality, we used a PSQI questionnaire. Blue light filters were used by 9.7% of respondents, 9.7% occasionally, and 80% never. The mean score of PSQI was more than 5 in 54.10% of the participants and less than 5 in 45.90%. ANOVA test was performed to assess the relationship between using blue light filter applications and sleep quality (p-value = 0.925). The findings of this study indicate a connection between the use of blue light filter apps and habitual sleep efficiency in the 31–40 age group. However, our results align only to some extent with prior research, as we did not observe sustained positive effects on all parameters of sleep quality from the long-term use of blue light filtering apps. Several studies have found that blue light exposure can suppress melatonin secretion, exacerbating sleep problems. Some studies have reported that physical blue light filters, such as lenses, can affect melatonin secretion and improve sleep quality. However, the impact of blue light filtering applications remains unclear and debatable.

Plain Language Summary

Using smartphones before bedtime and being exposed to its blue light can make it harder to fall asleep and disrupt your sleep. Some smartphone makers have introduced a night mode feature claiming it can help improve your sleep. In this study, we wanted to find out if using these blue light filters on smartphones really makes a difference. We asked people how often they used blue light filters on their phones and also had them fill out a questionnaire about their sleep quality. Only about 10% of people said they used blue light filters regularly, another 10% used them occasionally, and the majority, around 80%, never used them. When we looked at the results, more than half of the participants had sleep scores higher than 5, indicating they might have sleep problems. Less than half had sleep scores lower than 5, suggesting better sleep quality. We used some statistical tests to see if using blue light filters had any link to sleep quality, and the results showed that there was only a connection between the use of blue light filter apps and habitual sleep efficiency in the 31–40 age group. Our findings matched what other studies have found before, that using blue light filters on smartphones may not significantly help improve sleep. So, while it might be a good idea to limit smartphone use before bed, using a blue light filter app may not be the magic solution for better sleep.

https://www.tandfonline.com/doi/full/10.1080/15368378.2024.2327432

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Mobile phone radiation disturbs cytokinesis and causes cell death in buccal cells: Results of controlled human intervention study

Kundi M, Nersesyan A, Schmid G, Hutter HP, Eibensteiner F, Mišík M, Knasmüller S. Mobile phone specific radiation disturbs cytokinesis and causes cell death but not acute chromosomal damage in buccal cells: Results of a controlled human intervention study. Environ Res. 2024 Mar 5:118634. doi: 10.1016/j.envres.2024.118634.

Abstract

Several human studies indicate that mobile phone specific electromagnetic fields may cause cancer in humans but the underlying molecular mechanisms are currently not known. Studies concerning chromosomal damage (which is causally related to cancer induction) are controversial and are based on the use of questionnaires to assess the exposure. We realized the first human intervention trial in which chromosomal damage and acute toxic effects were studied under controlled conditions. The participants were exposed via headsets at one randomly assigned side of the head to low and high doses of a UMTS signal (n = 20, to 0.1 W/kg and n = 21 to 1.6 W/kg Specific Absorption Rate) for 2h on 5 consecutive days. Before and three weeks after the exposure buccal cells were collected from both cheeks and micronuclei (MN, which are formed as a consequence of structural and numerical chromosomal aberrations) and other nuclear anomalies reflecting mitotic disturbance and acute cytotoxic effects were scored. We found no evidence for induction of MN and of nuclear buds which are caused by gene amplifications, but a significant increase of binucleated cells which are formed as a consequence of disturbed cell divisions, and of karyolitic cells, which are indicative for cell death. No such effects were seen in cells from the less exposed side. Our findings indicate that mobile phone specific high frequency electromagnetic fields do not cause acute chromosomal damage in oral mucosa cells under the present experimental conditions. However, we found clear evidence for disturbance of the cell cycle and cytotoxicity. These effects may play a causal role in the induction of adverse long term health effects in humans.

Final paragraph of paper:

As mentioned in the introduction, evidence is accumulating that exposure to HF-EMF is associated with specific brain tumors (Brabant et al., 2023; Carlberg et al., 2017; Coureau et al., 2014; Hardell and Carlberg, 2015; Hardell et al., 2013; IARC, 2013; INTERPHONE Study Group, 2010). The results of the present investigation indicate that molecular mechanisms other than chromosomal damage may cause neoplastic transformation of the cells as a consequence of exposure to mobile phone specific HF-EMF. As described in the result section, we found in the present study clear evidence for induction of acute toxicity and disturbance of the cell cycle (cytokinesis) as a consequence of exposure to a high radiation dose (1.6 W/kg). It is possible that these effects cause inflammatory responses and/or release of ROS, which were seen in a number of laboratory studies (e.g. Alipour et al., 2022; Benavides et al., 2023; IARC, 2013; Yakymenko et al., 2016). These processes may possibly lead to formation of neoplastic cells.

Open access paper:
https://www.sciencedirect.com/science/article/pii/S0013935124005383?via%3Dihub

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Evaluation of neonatal outcomes according to the specific absorption rate values of phones used during pregnancy

Büyükeren M, Karanfil Yaman F. Evaluation of neonatal outcomes according to the specific absorption rate values of phones used during pregnancy. J Turk Ger Gynecol Assoc. 2024 Mar 6;25(1):7-12. doi: 10.4274/jtgga.galenos.2023.2022-10-1.

Abstract

Objective: The aim was to compare neonatal outcomes according to cell phone specific absorption rate (SAR) levels and daily time spent on cell phones by pregnant women.

Material and methods: Women who gave birth at Konya City Hospital between September 2020 and February 2021 were included in this retrospective study. Gestational ages, birth weight, birth length, head circumference, sex, 5-minute APGAR scores, neonate postpartum resuscitation requirement, delivery type, the model of phone used by the pregnant women, and the average time spent on the phone during a day were recorded. To determine the relation between the SAR values of the phones used and delivering a small for gestational age (SGA) baby, receiver operating characteristic curve analysis was performed.

Results: In total 1495 pregnant women were included. The rate of delivering a SGA fetus was significantly higher in women who used phones with higher SAR values (p=0.001). The cut-off value for the SAR level was 1.23 W/kg with 69.3% sensitivity and 73.0% specificity (area under the curve: 0.685; 95% confidence interval: 0.643-0.726). No correlation was found between time spent on the phone and SGA birth rate. Although both phone SAR values and time spent on the phone were higher in the symmetrical SGA group compared to the asymmetrical SGA group, the difference was not significant (p>0.05). Although the women who had preterm delivery had higher phone SAR values and had spent more time on the phone compared to those who had term deliveries, the difference was again not significant (p>0.05).

Conclusion: As the SAR values of cell phones used during pregnancy increased, there was a trend towards delivering a SGA baby.

Open access paper: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10921072/

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Do somatic symptom distress and attribution predict symptoms associated with environmental factors?

Köteles F, Nordin S. Do somatic symptom distress and attribution predict symptoms associated with environmental factors? J Psychosom Res. 2024 Mar 1;179:111637. doi: 10.1016/j.jpsychores.2024.111637.

Abstract

Objective: Not much is known on the development of symptoms associated with environmental factors (SAEF), also known as (idiopathic) environmental intolerances. Findings from qualitative studies suggest that appearance of symptoms might be the first step, followed by the acquisition of a specific attribution. The current study investigated cross-sectional and longitudinal (three years) associations between attribution and symptoms with respect to symptoms associated with chemical substances, certain indoor environments (buildings), sounds, and electromagnetic fields (EMFs).

Methods: We used data from the first two waves of the population-based Västerbotten Environmental Health Study (n = 2336). Participants completed the Patient Health Questionnaire Somatic Symptom Scale (PHQ-15), the Environmental Symptom-Attribution Scale, and answered single questions on the four aforementioned SAEFs.

Results: Using binary logistic regression analyses, all four SAEFs showed significant cross-sectional associations with somatic symptom distress and the respective attribution. In the longitudinal analysis, development of SAEF-Sound and SAEF-Chemicals were predicted by both somatic symptom distress and attribution. SAEF-EMFs was predicted only by attribution, whereas neither somatic symptom distress nor attribution forecasted SAEF-Buildings.

Conclusion: Overall, these findings suggest that attribution (i.e., a specific expectation) plays a substantial role in the development and maintenance of many SAEFs.

Open access paper:
https://www.sciencedirect.com/science/article/pii/S0022399924000497?via%3Dihub

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Micro-environmental personal radio-frequency electromagnetic field exposures in Melbourne: A longitudinal trend analysis

Bhatt CR, Henderson S, Sanagou M, Brzozek C, Thielens A, Benke G, Loughran S. Micro-environmental personal radio-frequency electromagnetic field exposures in Melbourne: A longitudinal trend analysis. Environ Res. 2024 Mar 13:118629. doi: 10.1016/j.envres.2024.118629.

Abstract

Background: A knowledge gap exists regarding longitudinal assessment of personal radio-frequency electromagnetic field (RF-EMF) exposures globally. It is unclear how the change in telecommunication technology over the years translates to change in RF-EMF exposure. This study aims to evaluate longitudinal trends of micro-environmental personal RF-EMF exposures in Australia.

Methods: The study utilised baseline (2015-16) and follow-up (2022) data on personal RF-EMF exposure (88 MHz-6 GHz) measured across 18 micro-environments in Melbourne. Simultaneous quantile regression analysis was conducted to compare exposure data distribution percentiles, particularly median (P50), upper extreme value (P99) and overall exposure trends. RF-EMF exposures were compared across six exposure source types: mobile downlink, mobile uplink, broadcast, 5G-New Radio, Others and Total (of the aforementioned sources). Frequency-specific exposures measured at baseline and follow-up were also compared. Total exposure across different groups of micro-environment types were also compared.

Results: For all micro-environmental data, total (median and P99) exposure levels did not significantly change at follow-up. Overall exposure trend of total exposure increased at follow-up. Mobile downlink contributed the highest exposure among all sources showing an increase in median exposure and overall exposure trend. Of seven micro-environment types, five of them showed total exposure levels (median and P99) and overall exposure trend increased at follow-up.

Excerpt

The assessment of change in total personal RF-EMF exposure distribution at follow-up across all micro-environments and those for different micro-environment types showed inconsistent changes in the exposure levels and overall exposure trend. The median and upper extreme total RF-EMF exposure levels across the micro-environments showed no significant change; whilst overall trend of total exposure at follow-up increased during the study period. Mobile downlink, the largest exposure source, median exposure and overall exposure trend increased (26.7%, up to 34.3%, respectively) at follow-up. The observed increase in median and upper extreme exposure levels as well as overall total exposure trend at follow-up remained consistent for the majority of micro-environment types.

Open access paper:
https://www.sciencedirect.com/science/article/pii/S0013935124005334?via%3Dihub

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New-generation electronic appliances and cardiac implantable electronic devices: a systematic literature review of mechanisms and in vivo studies

Kewcharoen J, Shah K, Bhardwaj R, Contractor T, Turagam MK, Mandapati R, Lakkireddy D, Garg J. New-generation electronic appliances and cardiac implantable electronic devices: a systematic literature

review of mechanisms and in vivo studies. J Interv Card Electrophysiol. 2024 Mar 5. doi: 10.1007/s10840-024-01777-z.

Abstract

Introduction: Cardiac implantable electronic device (CIED) functions are susceptible to electromagnetic interference (EMI) from electromagnetic fields (EMF). Data on EMI risks from new-generation electronic appliances (EA) are limited.

Objective: We performed a systematic literature review on the mechanisms of EMI, current evidence, and recently published trials evaluating the effect of EMF on CIEDs from electric vehicles (EV), smartphone, and smartwatch technology and summarize its safety data.

Methods: Electronic databases, including PubMed and EMBASE, were searched for in vivo studies evaluating EMF strength and incidence between CIEDs and commercial EVs, new-generation smartphones, and new-generation smartwatches.

Results: A total of ten studies (three on EVs, five on smartphones, one on smartphones, one on smartphones and smartwatches) were included in our systematic review. There was no report of EMI incidence associated with EVs or smartwatches. Magnet-containing smartphones (iPhone 12) can cause EMI when placed directly over CIEDs - thereby triggering the magnet mode; otherwise, no report of EMI was observed with other positions or smartphone models.

Conclusion: Current evidence suggests CIED recipients are safe from general interaction with EVs/HEVs, smartphones, and smartwatches. Strictly, results may only be applied to commercial brands or models tested in the published studies. There is limited data on EMI risk from EVs wireless charging and smartphones with MagSafe technology.

https://pubmed.ncbi.nlm.nih.gov/38443707/

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Electric vehicles and health: A scoping review

Pennington AF, Cornwell CR, Sircar KD, Mirabelli MC. Electric vehicles and health: A scoping review. Environ Res. 2024 Mar 16:118697. doi: 10.1016/j.envres.2024.118697.

Abstract

Background: The health impacts of the rapid transition to the use of electric vehicles are largely unexplored. We completed a scoping review to assess the state of the evidence on use of battery electric and hybrid electric vehicles and health.

Methods: We conducted a literature search of MEDLINE, Embase, Global Health, CINAHL, Scopus, and Environmental Science Collection databases for articles published January 1990 to January 2024. We included articles if they presented observed or modeled data on the association between battery electric or hybrid electric cars, trucks, or buses and health-related outcomes. We abstracted data and

summarized results.

Results: Out of 897 reviewed articles, 52 met our inclusion criteria. The majority of included articles examined transitions to the use of electric vehicles (n = 49, 94%), with fewer studies examining hybrid electric vehicles (n = 11, 21%) or plug-in hybrid electric vehicles (n = 8, 15%). The most common outcomes examined were premature death (n = 41, 79%) and monetized health outcomes such as medical expenditures (n = 33, 63%). We identified only one observational study on the impact of electric vehicles on health; all other studies reported modeled data. Almost every study (n = 51, 98%) reported some evidence of a positive health impact of transitioning to electric or hybrid electric vehicles, although magnitudes of association varied. There was a paucity of information on the environmental justice implications of vehicle transitions.

Conclusions: The results of the current literature on electric vehicles and health suggest an overall positive health impact of transitioning to electric vehicles. Additional observational studies would help expand our understanding of the real-world health effects of electric vehicles. Future research focused on the environmental justice implications of vehicle fleet transitions could provide additional information about the extent to which the health benefits occur equitably across populations.

https://pubmed.ncbi.nlm.nih.gov/38499224/

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Electromagnetic exposure analysis of the subway passenger under the civil communication system radiation

Zhou WY, Zhang XY, Lu M. Electromagnetic exposure analysis of the subway passenger under the civil communication system radiation. PLoS One. 2024 Mar 11;19(3):e0300049. doi: 10.1371/journal.pone.0300049.

Abstract

In order to assess the electromagnetic exposure safety of passengers under the civil communication system of the subway, the radio-frequency (RF) electromagnetic environment of subway carriage is established by using COMSOL Multiphysics software, it includes a 1-1/4 " leaky coaxial cable (LCX1) and a 1-5/8" leaky coaxial cable (LCX2), which are designed to be the exposure sources, and twelve passengers at different position. The electromagnetic environment model has been verified through field measurement. The exposure dose distribution of twelve passengers is compared and analyzed, when LCX1 and LCX2 works respectively. The simulated results show that, to compare with LCX2, the electromagnetic dose absorbed by the passengers is reduced by 9.19% and 22.50% at 2100 MHz and 2600 MHz respectively. The specific absorption rate (SAR) of passengers obtains the maximum value of 1.91×10^{-4} W/Kg and the temperature rise to 0.214 K when the LCX1 works at 3400 MHz. By comparing with the public exposure limitation of the International Commission of Non-Ionizing Radiation Protection (ICNIRP), it demonstrates the electromagnetic exposure safety of the passengers under the civil communication system. More importantly, the proposed LCX1 not only could add the 5G signal cover but also lower the SAR absorbed by the passengers, which indicates that the public electromagnetic exposure dose could be reduced by adjusting the radiation performances of exposure source, which provide a new way for electromagnetic protecting.

Open access paper: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0300049

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Impact of specific electromagnetic radiation on wakefulness in mice

Deng H, Liu L, Tang X, Lu Y, Wang X, Zhao Y, Shi Y. Impact of specific electromagnetic radiation on wakefulness in mice. Proc Natl Acad Sci U S A. 2024 Apr 9;121(15):e2313903121. doi: 10.1073/pnas.2313903121.

Abstract

Electromagnetic radiation (EMR) in the environment, particularly in the microwave range, may constitute a public health concern. Exposure to 2.4 GHz EMR modulated by 100 Hz square pulses was recently reported to markedly increase wakefulness in mice. Here, we demonstrate that a similar wakefulness increase can be induced by the modulation frequency of 1,000 Hz, but not 10 Hz. In contrast to the carrier frequency of 2.4 GHz, 935 MHz EMR of the same power density has little impact on wakefulness irrespective of modulation frequency. Notably, the replacement of the 100 Hz square-pulsed modulation by sinusoidal-pulsed modulation of 2.4 GHz EMR still allows a marked increase of wakefulness. In contrast, continuous sinusoidal amplitude modulation of 100 Hz with the same time-averaged power output fails to trigger any detectable change of wakefulness. Therefore, alteration of sleep behavior by EMR depends upon not just carrier frequency but also frequency and mode of the modulation. These results implicate biological sensing mechanisms for specific EMR in animals.

Significance

Increased wakefulness in mice was previously found to be a direct result of prolonged exposure to 2.4 GHz electromagnetic radiation (EMR) with 100 Hz square-pulsed modulation at 1/8 duty cycle. Several key issues remain unaddressed. Does the frequency of the square-pulsed modulation matter? Are the sharp edges of the square pulses a major contributor to sleep/wakefulness alteration? Can carrier frequencies other than 2.4 GHz induce sleep/wakefulness alteration? Does the duty cycle matter? In this study, we answer these questions by demonstrating the dependency of sleep/wakefulness alteration on EMR modulation frequency, carrier frequency, and modulation mode.

Excerpts

Modeling and experimental assessment of human exposure to 935 MHz or 2.14 GHz EMR at a dose level of 3.6 W/kg local SAR revealed a maximal skin temperature increase of 0.31 °C and a brain temperature elevation of <0.1 °C (21). In our case, the maximum local SAR value measured with the cSAR3D testing system is 3.6 W/kg and the averaged SAR is 2.81 ± 0.15 W/kg. Hence, the observed EMR impact on sleep in our study is most likely nonthermal....

In conclusion, our study reveals distinct specificity of EMR. Prolonged exposure to the carrier frequency 2.4 GHz EMR with square pulse modulation of different frequencies induces varying changes of wakefulness in mice. In contrast to 2.4 GHz, the carrier frequency 935 MHz has little impact on wakefulness or NREM sleep. Then, 2.4 GHz EMR with sinusoidal pulse modulation, but not continuous sinusoidal modulation of 100 Hz, results in an increase in wakefulness. These findings link specific biological responses to specific parameters of EMR, namely carrier frequency, modulation frequency, and modulation mode. The underlying mechanisms for these observations remain to be unveiled.

https://pubmed.ncbi.nlm.nih.gov/38557178/

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Effect of 2.45 GHz Microwave Radiation on the Inner Ear: A Histopathological Study on 2.45 GHz Microwave Radiation and Cochlea

Tahir E, Akar Karadayı A, Gülşen Gürgen S, Korunur Engiz B, Turgut A. Effect of 2.45 GHz Microwave Radiation on the Inner Ear: A Histopathological Study on 2.45 GHz Microwave Radiation and Cochlea. J Int Adv Otol. 2024 Jan;20(1):35-43. doi: 10.5152/iao.2024.231142.

Abstract

Background: The present study aims to determine the possible low dose-dependent adverse effects of 2.45 GHz microwave exposure and Wi-Fi frequency on the cochlea.

Methods: Twelve pregnant female rats (n=12) and their male newborns were exposed to Wi-Fi frequencies with varying electric field values of 0.6, 1.9, 5, 10 V/m, and 15 V/m during the 21-day gestation period and 45 days after birth, except for the control group. Auditory brainstem response testing was performed before exposure and sacrification. After removal of the cochlea, histopathological examination was conducted by immunohistochemistry methods using caspase (cysteine-aspartic proteases, cysteine aspartates, or cysteine-dependent aspartate-directed proteases)-3, -9, and terminal deoxynucleotidyl transferase dUTP nick end labeling (TUNEL). Kruskal-Wallis and Wilcoxon tests and multivariate analysis of variance were used.

Results: Auditory brainstem response thresholds in postexposure tests increased statistically significantly at 5 V/m and above doses. When the number of apoptotic cells was compared in immunohistochemistry examination, significant differences were found at 10 V/m and 15 V/m doses ($F(5,15)=23.203$, $P=.001$; Pillai's trace=1.912, $\eta 2=0.637$). As the magnitude of the electric field increased, all histopathological indicators of apoptosis increased. The most significant effect was noted on caspase-9 staining ($\eta 2$ c9=0.996), followed by caspase-3 ($\eta 2$ c3=0.991), and TUNEL staining ($\eta 2$ t=0.801). Caspase-3, caspase-9, and TUNEL-stained cell densities increased directly by increasing the electric field and power values.

Conclusion: Apoptosis and immune activity in the cochlea depend on the electric field and power value. Even at low doses, the electromagnetic field in Wi-Fi frequency damages the inner ear and causes apoptosis.

Open access paper: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10895889/

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Ashwagandha Diminishes Hippocampal Apoptosis Induced by Wi-Fi Radiation in Male Quails

Gupta V, Srivastava R. Ashwagandha Diminishes Hippocampal Apoptosis Induced by Microwave Radiation by Acetylcholinesterase Dependent Neuro-Inflammatory Pathway in Male Coturnix coturnix Japonica. Neurochem Res. 2024 Mar 20. doi: 10.1007/s11064-024-04127-7.

Abstract

Microwave radiation (MWR) has been linked to neurodegeneration by inducing oxidative stress in the hippocampus of brain responsible for learning and memory. Ashwagandha (ASW), a medicinal plant is known to prevent neurodegeneration and promote neuronal health. This study investigated the effects of MWR and ASW on oxidative stress and cholinergic imbalance in the hippocampus of adult male Japanese quail. One control group received no treatment, the second group quails were exposed to MWR at 2 h/day for 30 days, third was administered with ASW root extract orally 100 mg/day/kg body weight and the fourth was exposed to MWR and also treated with ASW. The results showed that MWR increased serum corticosterone levels, disrupted cholinergic balance and induced neuro-inflammation. This neuro-inflammation further led to oxidative stress, as evidenced by decreased activity of antioxidant enzymes SOD, CAT and GSH. MWR also caused a significant decline in the nissil substances in the hippocampus region of brain indicating neurodegeneration through oxidative stress mediated hippocampal apoptosis. ASW, on the other hand, was able to effectively enhance the cholinergic balance and subsequently lower inflammation in hippocampus neurons. This suggests that ASW can protect against the neurodegenerative effects of MWR. ASW also reduced excessive ROS production by increasing the activity of ROS-scavenging enzymes. Additionally, ASW prevented neurodegeneration through decreased expression of caspase-3 and caspase-7 in hippocampus, thus promoting neuronal health. In conclusion, this study showed that MWR induces apoptosis and oxidative stress in the brain, while ASW reduces excessive ROS production, prevents neurodegeneration and promotes neuronal health.

Excerpt

Birds were exposed to 2.45 GHz of MW irradiation using Ruckus R310 Wi-fi router with maximum transmission strength of 25dbm at the middle of the cage. Average power density obtained within each partition of cage was found to be 0.1264 mw/cm^2 and overall specific absorption rate (SAR) obtained per bird was determined to be 0.9978 W/Kg.

https://pubmed.ncbi.nlm.nih.gov/38506951/

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Does Microwave Exposure at Different Doses in the Pre/Postnatal Period Affect Growing Rat Bone Development?

Karadayi A, Sarsmaz H, Çigel A, Engiz B, Ünal N, Ürkmez S, Gürgen S. Does Microwave Exposure at Different Doses in the Pre/Postnatal Period Affect Growing Rat Bone Development? Physiol Res. 2024 Mar 11;73(1):157-172.

Abstract

Effects of pre/postnatal 2.45 GHz continuous wave (CW), Wireless-Fidelity (Wi-Fi) Microwave (MW) irradiation on bone have yet to be well defined. The present study used biochemical and histological methods to investigate effects on bone formation and resorption in the serum and the tibia bone tissues

of growing rats exposed to MW irradiation during the pre/postnatal period. Six groups were created: one control group and five experimental groups subjected to low-level different electromagnetic fields (EMF) of growing male rats born from pregnant rats. During the experiment, the bodies of all five groups were exposed to 2.45 GHz CW-MW for one hour/day. EMF exposure started after fertilization in the experimental group. When the growing male rats were 45 days old in the postnatal period, the control and five experimental groups' growing male and maternal rats were sacrificed, and their tibia tissues were removed. Maternal rats were not included in the study. No differences were observed between the control and five experimental groups in Receptor Activator Nuclear factor-kB (RANK) biochemical results. In contrast, there was a statistically significant increase in soluble Receptor Activator of Nuclear factor-kB Ligand (sRANKL) and Osteoprotegerin (OPG) for 10 V/m and 15 V/m EMF values. Histologically, changes in the same groups supported biochemical results. These results indicate that pre/postnatal exposure to 2.45 GHz EMF at 10 and 15 V/m potentially affects bone development.

Excerpt

In the present study, the effects of 2.45 GHz MW radiation on the bone of healthy rat tibia exposed to different doses of EMF during the prenatal and postnatal period were investigated using biochemical methods such as RANK, RANKL, OPG, and histopathological methods such as Tunel and immunohistochemical straining. Our findings showed that 2.45 GHz low-level MW radiation at 10 V/m (the peak SAR 10g value 14.4 mW/kg) and 15 V/m (the peak SAR 10g value 33.8 mW/kg) could cause changes in the bone. To our knowledge, our study seems to be the first investigation in literature focusing on effects on the bone of 2.45 GHz low-level MW radiation at different EMF values. Additionally, this research is the first article to determine the level of thermal and non-thermal effects on bone.

Open access paper: http://www.biomed.cas.cz/physiolres/pdf/73/73_157.pdf

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The neuroprotective effects of baobab and black seed on the rat hippocampus exposed to a 900-MHz electromagnetic field

Mohamed H, Deniz OG, Kaplan S. The neuroprotective effects of baobab and black seed on the rat hippocampus exposed to a 900-MHz electromagnetic field. J Chem Neuroanat. 2024 Mar 4;137:102405. doi: 10.1016/j.jchemneu.2024.102405.

Abstract

This study investigated the potential effects on the hippocampus of electromagnetic fields (EMFs) disseminated by mobile phones and the roles of baobab (Adansonia digitata) (AD) and black seed (Nigella sativa) (BS) in mitigating these. Fifty-six male, 12-week-old Wistar albino rats were divided into eight groups of seven animals each. No EMF exposure was applied to the control, AD or BS groups, while the rats in the Sham group were placed in an EMF system with no exposure. A 900-MHz EMF was applied to the EMF+AD, EMF+BS, EMF+AD+BS and EMF groups for 1 hour a day for 28 days. Pyramidal neurons in the hippocampus were subsequently counted using the optical fractionator technique, one of the unbiased stereological methods. Tissue sections were also evaluated histopathologically under light and electron microscopy. The activities of the enzymes catalase (CAT) and superoxide dismutase (SOD) were also determined in blood serum samples. Analysis of the stereological data revealed no statistically significant differences between the EMF and control or sham groups in terms of pyramidal neuron

numbers ($p>0.05$). However, stereological examination revealed a crucial difference in the entire hippocampus between the control group and the AD ($p<0.01$) and BS ($p<0.05$) groups. Moreover, exposure to 900-MHz EMF produced adverse changes in the structures of neurons at histopathological analysis. Qualitative examinations suggest that a combination of herbal products such as AD and BS exerts a protective effect against such EMF side-effects.

https://pubmed.ncbi.nlm.nih.gov/38447905/

Conclusion

We suggest that using appropriate quantities of natural antioxidants in combination with foodstuffs can inhibit or reduce the harmful effects of EMF radiation on the neurons of the brain. The human population, and especially children, should also be protected against exposure to radiation, especially that emitted from mobile phones. To the best of our knowledge, no prior study has demonstrated the effect of AD and BS in the EMF exposed rat hippocampus. Further studies focusing on the effect mechanism of antioxidants, especially AD and BS, that may represent novel protective substances against the side-effects of EMF radiation in the hippocampus, are now needed. Research involving different methods, durations and doses is therefore required.

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Health and environmental effects to wildlife from radio telemetry and tracking devices—state of the science and best management practices

Manville AM, Levitt BB, Lai HC. Health and environmental effects to wildlife from radio telemetry and tracking devices—state of the science and best management practices. Frontiers in Veterinary Science, 11. 2024. doi: 10.3389/fvets.2024.1283709.

Abstract

This paper discusses the potential health risks and benefits to tagged wildlife from the use of radio tracking, radio telemetry, and related microchip and data-logger technologies used to study, monitor and track mostly wildlife in their native habitats. Domestic pets, especially canids, are briefly discussed as radio-tagging devices are also used on/in them. Radio tracking uses very high frequency (VHF), ultra-high frequency (UHF), and global positioning system (GPS) technologies, including via satellites where platform terminal transmitters (PTTs) are used, as well as geo-locating capabilities using satellites, radio-frequency identification (RFID) chips, and passive integrated responder (PIT) tags, among others. Such tracking technologies have resulted in cutting-edge findings worldwide that have served to protect and better understand the behaviors of myriad wildlife species. As a result, scientists, field researchers, technicians, fish and wildlife biologists and managers, plus wildlife and other veterinarian specialists, frequently opt for its use without fully understanding the ramifications to target species and their behaviors. These include negative physiological effects from electromagnetic fields (EMF) to which many nonhuman species are exquisitely sensitive, as well as direct placement/use-attachment impacts from radio collars, transmitters, and implants themselves. This paper provides pertinent studies, suggests best management practices, and compares technologies currently available to those considering and/or using such technologies. The primary focus is on the health and environmental risk/benefit decisions

that should come into play, including ethical considerations, along with recommendations for more caution in the wildlife and veterinarian communities before such technologies are used in the first place.

Open access paper: https://www.frontiersin.org/articles/10.3389/fvets.2024.1283709

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Electromagnetic fields regulate iron metabolism in living organisms: A review of effects and mechanism

Zhen C, Zhang G, Wang S, Wang J, Shang P. Electromagnetic fields regulate iron metabolism in living organisms: A review of effects and mechanism. Prog Biophys Mol Biol. 2024 Mar 4:S0079-6107(24)00023-3. doi: 10.1016/j.pbiomolbio.2024.03.001.

Abstract

The emergence, evolution, and spread of life on Earth have all occurred in the geomagnetic field, and its extensive biological effects on living organisms have been documented. The charged characteristics of metal ions in biological fluids determine that they are affected by electromagnetic field forces, thus affecting life activities. Iron metabolism, as one of the important metal metabolic pathways, keeps iron absorption and excretion in a relatively balanced state, and this process is precisely and completely controlled. It is worth paying attention to how the iron metabolism process of living organisms is changed when exposed to electromagnetic fields. In this paper, the processes of iron absorption, storage and excretion in animals (mammals, fish, arthropods), plants and microorganisms exposed to electromagnetic field were summarized in detail as far as possible, in order to discover the regulation of iron metabolism by electromagnetic field. Studies and data on the effects of electromagnetic field exposure on iron metabolism in organisms show that exposure profiles vary widely across species and cell lines. This process involves a variety of factors, and the complexity of the results is not only related to the magnetic flux density/operating frequency/exposure time and the heterogeneity of the observed object. A systematic review of the biological regulation of iron metabolism by electromagnetic field exposure will not only contributes to a more comprehensive understanding of its biological effects and mechanism, but also is necessary to improve human awareness of the health related risks of electromagnetic field exposure.

Open access paper:
https://www.sciencedirect.com/science/article/pii/S0079610724000233?via%3Dihub

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0.263 terahertz irradiation induced genes expression changes in *Caenorhabditis elegans (roundworm)*

Shang S, Gao F, Zhang Q, Song T, Wang W, Liu D, Gong Y, Lu X. 0.263 terahertz irradiation induced genes expression changes in *Caenorhabditis elegans*. iScience. 2024 Mar 2;27(4):109391. doi: 10.1016/j.isci.2024.109391.

Abstract

The biosafety of terahertz (THz) waves has emerged as a new area of concern with the gradual application of terahertz radiation. Even though many studies have been conducted to investigate the

influence of THz radiation on living organisms, the biological effects of terahertz waves have not yet been fully revealed. In this study, *Caenorhabditis elegans* (*C. elegans*) was used to evaluate the biological consequences of whole-body exposure to 0.263 THz irradiation. The integration of transcriptome sequencing and behavioral tests of *C. elegans* revealed that high-power THz irradiation damaged the epidermal ultrastructures, inhibited the expression of the cuticle collagen genes, and impaired the movement of *C. elegans*. Moreover, the genes involved in the immune system and the neural system were dramatically down-regulated by high-power THz irradiation. Our findings offer fresh perspectives on the biological impacts of high-power THz radiation that could cause epidermal damage and provoke a systemic response.

Open access paper: https://www.cell.com/iscience/fulltext/S2589-0042(24)00612-6

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Environmental Pollution and Risk of Childhood Cancer: A Scoping Review of Evidence from the Last Decade

Navarrete-Meneses MdP, Salas-Labadía C, Gómez-Chávez F, Pérez-Vera P. Environmental Pollution and Risk of Childhood Cancer: A Scoping Review of Evidence from the Last Decade. *International Journal of Molecular Sciences*. 2024; 25(6):3284. doi: 10.3390/ijms25063284.

Abstract

The long-term effects of environmental pollution have been of concern as several pollutants are carcinogenic, potentially inducing a variety of cancers, including childhood cancer, which is a leading cause of death around the world and, thus, is a public health issue. The present scoping review aimed to update and summarize the available literature to detect specific environmental pollutants and their association with certain types of childhood cancer. Studies published from 2013 to 2023 regarding environmental pollution and childhood cancer were retrieved from the PubMed database. A total of 174 studies were eligible for this review and were analyzed. Our search strategy brought up most of the articles that evaluated air pollution (29%) and pesticides (28%). Indoor exposure to chemicals (11%), alcohol and tobacco use during pregnancy (16%), electromagnetic fields (12%), and radon (4%) were the subjects of less research. We found a particularly high percentage of positive associations between prenatal and postnatal exposure to indoor (84%) and outdoor (79%) air pollution, as well as to pesticides (82%), and childhood cancer. Positive associations were found between leukemia and pesticides and air pollution (33% and 27%); CNS tumors and neuroblastoma and pesticides (53% and 43%); and Wilms tumor and other rare cancers were found in association with air pollution (50%). Indoor air pollution was mostly reported in studies assessing several types of cancer (26%). Further studies are needed to investigate the mechanisms underlying the potential associations between indoor/outdoor air pollution and pesticide exposure with childhood cancer risk as more preventable measures could be taken.

Open access paper: https://www.mdpi.com/1422-0067/25/6/3284

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A broadband multi-frequency microwave combined biological exposure setup

Zhao X, Li Z, Liu X, Wang Y, Dong G, Liu Q, Wang C. A broadband multi-frequency microwave combined biological exposure setup. *Rev. Sci. Instrum.* 1 April 2024; 95 (4): 044702. doi: 10.1063/5.0196908

Abstract

With the rapid popularization of wireless electronic devices, there has been an increasing concern about the impacts of the electromagnetic environment on health. However, most research reports on the biological effects of microwaves have focused on a single frequency point. In reality, people are exposed to complex electromagnetic environments that consist of multiple frequency microwave signals in their daily lives. It is important to investigate whether multi-frequency combined microwave energies have different biological effects compared with single frequency microwave energy. Unfortunately, there are limited reports on this topic due to the lack of suitable platforms for research on multi-frequency microwave energy combined with biological exposure. To address this issue, this study presents a setup that has a very wide working frequency bandwidth and can be compatible with single frequency and multi-frequency microwave combined exposure. Moreover, it can achieve relatively equal exposure to multiple biological samples at any frequency point in the working frequency range, which is crucial for electromagnetic biology research. The experimental results are in good agreement with the simulation results, confirming its capability to facilitate the study of complex electromagnetic environment effects on organisms.

Open access paper: https://pubs.aip.org/aip/rsi/article/95/4/044702/3280194/A-broadband-multi-frequency-microwave-combined

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The effects of radiofrequency electromagnetic fields exposure on tinnitus, migraine and non-specific symptoms in the general and working population: A systematic review and meta-analysis on human observational studies

My note: Numerous problems have been identified with this paper and other systematic reviews commissioned by the WHO for an upcoming monograph on radio frequency effects.

Röösli M, Dongus S, Jalilian H, Eyers J, Esu E, Oringanje CM, Meremikwu M, Bosch-Capblanch X. The effects of radiofrequency electromagnetic fields exposure on tinnitus, migraine and non-specific symptoms in the general and working population: A systematic review and meta-analysis on human observational studies. Environ Int. 2024 Jan;183:108338. doi: 10.1016/j.envint.2023.108338.

Abstract

Background: Applications emitting radiofrequency electromagnetic fields (RF-EMF; 100 kHz to 300 GHz) are widely used for communication (e.g. mobile phones), in medicine (diathermy) and in industry (RF heaters).

Objectives: The objective is to systematically review the effects of longer-term or repeated local and whole human body radiofrequency electromagnetic field (RF-EMF) exposure on the occurrence of symptoms. Primary hypotheses were tinnitus, migraine and headaches in relation to RF-EMF exposure of the brain, sleep disturbances and composite symptom scores in relation to whole-body RF-EMF exposure.

Methods: Eligibility criteria: We included case-control and prospective cohort studies in the general population or workers estimating local or whole-body RF-EMF exposure for at least one week.

Information sources: We conducted a systematic literature search in various databases including Web of Science and Medline. Risk of bias: We used the Risk of Bias (RoB) tool developed by OHAT adapted to the topic of this review.

Synthesis of results: We synthesized studies using random effects meta-analysis.

Results: Included studies: We included 13 papers from eight distinct cohort and one case-control studies with a total of 486,558 participants conducted exclusively in Europe. Tinnitus is addressed in three papers, migraine in one, headaches in six, sleep disturbances in five, and composite symptom scores in five papers. Only one study addressed occupational exposure.

Synthesis of results: For all five priority hypotheses, available research suggests that RF-EMF exposure below guideline values does not cause symptoms, but the evidence is very uncertain. The very low certainty evidence is due the low number of studies, possible risk of bias in some studies, inconsistencies, indirectness, and imprecision. In terms of non-priority hypotheses numerous exposure-outcome combinations were addressed in the 13 eligible papers without indication for an association related to a specific symptom or exposure source.

Discussion: Limitations of evidence: This review topic includes various challenges related to confounding control and exposure assessment. Many of these aspects are inherently present and not easy to be solved in future research. Since near-field exposure from wireless communication devices is related to lifestyle, a particular challenge is to differentiate between potential biophysical effects and other potential effects from extensive use of wireless communication devices that may compete with healthy behaviour such as sleeping or physical activity. Future research needs novel and innovative methods to differentiate between these two hypothetical mechanisms.

Interpretation: This is currently the best available evidence to underpin safety of RF-EMF. There is no indication that RF-EMF below guideline values causes symptoms. However, inherent limitations of the research results in substantial uncertainty.

Other: Funding: This review was partially funded by the WHO radioprotection programme.

Registration: The protocol for this review has been registered in Prospero (reg no CRD42021239432) and published in Environment International (Röösli et al., 2021).

Declaration of competing interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Martin Röösli's research is entirely funded by public or not-for-profit foundations. He has served as advisor to a number of national and international public advisory and research steering groups concerning the potential health effects of exposure to nonionizing radiation, including the World Health Organization, the International Agency for Research on Cancer, the International Commission on Non-Ionizing Radiation Protection, the Swiss Government (member of the working group "mobile phone and radiation" and chair of the expert group BERENIS), the German Radiation Protection Commission

(member of the committee Non-ionizing Radiation (A6) and member of the working group 5G (A630)) and the Independent Expert Group of the Swedish Radiation Safety Authority.

https://www.sciencedirect.com/science/article/pii/S0160412023006116?via%3Dihub

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Effects of radiofrequency electromagnetic field (RF-EMF) exposure on male fertility: A systematic review of experimental studies on non-human mammals and human sperm in vitro (SR 4)

My note: Numerous problems have been identified with this paper and other systematic reviews commissioned by the WHO for an upcoming monograph on radio frequency effects.

Cordelli E, Ardoino L, Benassi B, Consales C, Eleuteri P, Marino C, Sciortino M, Villani P, Brinkworth MH, Chen G, McNamee JP, Wood AW, Belackova L, Verbeek J, Pacchierotti F. Effects of radiofrequency electromagnetic field (RF-EMF) exposure on male fertility: A systematic review of experimental studies on non-human mammals and human sperm in vitro. Environment International. 2024, doi: 10.1016/j.envint.2024.108509. Open access paper:
https://www.sciencedirect.com/science/article/pii/S0160412024000953

Highlights

Risk of bias, inconsistency, publication bias weakened the certainty of results
RF-EMF is unlike to decrease the fecundity of exposed male rodents.
RF-EMF may affect testicular tissue and sperm quality but the evidence is uncertain.
Impact on surrogate markers of fertility may not translate into functional effects.

Abstract

Background The World Health Organization is coordinating an international project aimed at systematically reviewing the evidence regarding the association between radiofrequency electromagnetic field (RF-EMF) exposure and adverse health effects. Reproductive health outcomes have been identified among the priority topics to be addressed.

Objectives To evaluate the effect of RF-EMF exposure on male fertility of experimental mammals and on human sperm exposed in vitro.

Methods Three electronic databases (PubMed, Scopus and EMF Portal) were last searched on September 17, 2022. Two independent reviewers screened the studies, which were considered eligible if met the following criteria: 1) Peer-reviewed publications of sham controlled experimental studies, 2) Non-human male mammals exposed at any stage of development or human sperm exposed in vitro, 3) RF-EMF exposure within the frequency range of 100 kHz-300 GHz, including electromagnetic pulses (EMP), 4) one of the following indicators of reproductive system impairment:•decrease of fertility: rate of infertile males, rate of nonpregnant females, litter size and in vitro fertilization rate;•effects on semen quality: in animal studies sperm count, in both animal and in vitro studies sperm vitality, morphology and DNA/chromatin alterations;•reproductive organ toxicity: testis-epididymis weight, testis or epididymis histology, testis histomorphometry, testicular cell death, estimated testicular cell

production;•hormonal effects: testosterone level.Two reviewers extracted study characteristics and outcome data. We assessed risk of bias (RoB) using the Office of Health Assessment and Translation (OHAT) guidelines. We categorized studies into 3 levels of overall RoB: low, some or high concern. We pooled study results in a random effects meta-analysis comparing average exposure to no-exposure and in a dose–response meta-analysis using all exposure doses. For experimental animal studies, we conducted subgroup analyses for species, Specific Absorption Rate (SAR) and temperature increase. We grouped studies on human sperm exposed in vitro by the fertility status of sample donors and SAR. We assessed the certainty of the evidence using the GRADE approach after excluding studies that were rated as "high concern" for RoB.

Results One-hundred and seventeen papers on animal studies and 10 papers on human sperm exposed in vitro were included in this review. Only few studies were rated as "low concern" because most studies were at RoB for exposure and/or outcome assessment. Subgrouping the experimental animal studies by species, SAR, and temperature increase partly accounted for the heterogeneity of individual studies in about one third of the meta-analyses. In no case was it possible to conduct a subgroup analysis of the few human sperm in vitro studies because there were always 1 or more groups including less than 3 studies. Among all the considered endpoints, the meta-analyses of animal studies provided evidence of adverse effects of RF-EMF exposure in all cases but the rate of infertile males and the size of the sired litters. The assessment of certainty according to the GRADE methodology assigned a moderate certainty to the reduction of pregnancy rate and to the evidence of no-effect on litter size, a low certainty to the reduction of sperm count, and a very low certainty to all the other meta-analysis results. Studies on human sperm exposed in vitro indicated a small detrimental effect of RF-EMF exposure on vitality and no-effect on DNA/chromatin alterations. According to GRADE, a very low certainty was attributed to these results. The few studies that used EMP exposure did not show effects on the outcomes. A low to very low certainty was attributed to these results.

Discussion Many of the studies examined suffered of severe limitations that led to the attribution of uncertainty to the results of the meta-analyses and did not allow to draw firm conclusions on most of the endpoints. Nevertheless, the associations between RF-EMF exposure and decrease of pregnancy rate and sperm count, to which moderate and low certainty were attributed, are not negligible, also in view of the indications that in Western countries human male fertility potential seems to be progressively declining. It was beyond the scope of our systematic review to determine the shape of the dose–response relationship or to identify a minimum effective exposure level. The subgroup and the dose–response fitting analyses did not show a consistent relationship between the exposure levels and the observed effects. Notably, most studies evaluated RF-EMF exposure levels that were higher than the levels to which human populations are typically exposed, and the limits set in international guidelines. For these reasons we cannot provide suggestions to confirm or reconsider current human exposure limits. Considering the outcomes of this systematic review and taking into account the limitations found in several of the studies, we suggest that further investigations with better characterization of exposure and dosimetry including several exposure levels and blinded outcome assessment were conducted. Protocol registration: Protocols for the systematic reviews of animal studies and of human sperm in vitro studies were published in Pacchierotti et al., 2021. The former was also registered in PROSPERO (CRD42021227729 https://www.crd.york.ac.uk/prospero/display_record.php?RecordID = 227729) and the latter in Open Science Framework (OSF Registration DOI https://doi.org/10.17605/OSF.IO/7MUS3).

Excerpts

4.4. Implications for policy and research

In conclusion, our systematic review and *meta*-analyses indicate a possible detrimental effect of RF-EMF exposure on pregnancy rate and sperm count in experimental mammals, whereas the *meta*-analysis of data on litter size was consistent with null.

Although sperm count is not a functional indicator of male fertility, it is a well-standardised analysis routinely applied in clinical andrology. RF-EMF emitting devices are widely applied and epidemiological surveys seem to indicate that, in Western countries, male fertility potential is declining (Auger et al., 2022, Boulicault et al., 2022, Levine et al., 2017). For these reasons the results of our meta-analyses should not be overlooked at a policy level.

It was beyond the scope of our systematic review to determine the shape of the dose–response relationship or to identify a minimum effective exposure level. For these reasons, we cannot provide suggestions to confirm or reconsider current human exposure limits. Nevertheless, it is of note that most studies on male fertility, semen quality and reproductive organ toxicity investigated exposure levels which were rather high with respect to those relevant for human populations: 75–80 % tested exposure levels above 0.4 W/kg (ICNIRP basic restriction for workers) and 46–53 % tested exposure levels above 4 W/kg (ICNIRP health effect level) (ICNIRP, 2020). Thus, it is not known the extent to which the conclusions of the SR meta-analysis can be applied to human exposure levels. Similarly, it is unknown how much our conclusion can be extrapolated to frequencies below 100 MHz and above 10000 MHz, for which only very few studies were retrieved.

During the systematic review, we identified several methodological limitations in the studies that should be overcome to improve the quality of future research. In particular, blinding during experiment performance and outcome assessment should always be applied to minimize bias, an adequate number of cytological or histological preparations should be analysed, automated methods of analysis should be applied whenever possible, a more standardized and complete reporting of technical methods and results should be adopted. Many studies had to be excluded from the systematic review because of insufficient exposure characterization and a large proportion of included studies were rated at either ‘some’ or ‘high concern’ for RoB for similar reasons. We would recommend that future studies bear the reasons for exclusion or RoB concerns in mind in study design and implementation. There are several papers in the research literature with recommendations on how exposure characterisation concerns can be mitigated, for example Kuster and Schonborn (2000). Finally, studies investigating not just a single level but several exposure levels, spanning from low levels comparable to human exposure to higher levels where mild hyperthermic effects could be expected, should be conducted under the same experimental conditions and target tissue temperature monitoring should be employed.

As a final suggestion for future research, we consider it a priority to obtain a scientifically solid database of possible RF-EMF effects on the best predictive surrogate markers of male infertility in experimental rodents. Based on the results of this research, the possibility of testing directly the RF-EMF impact on male reproductive performance could be considered. In view of the limitations of the approach applying *in vitro* exposure of human sperm, we do not recommend further studies of this kind. Conversely, we suggest exploiting semen quality analysis in human biomonitoring investigations of RF-EMF exposed populations....

Other reviews assessing the impact of RF-EMF exposure on male fertility have recently been published, but these only partially assessed the available literature data (Kesari et al., 2018, Sciorio et al., 2022, Sterling et al., 2022, Vornoli et al., 2019). The few recently published systematic reviews on this topic suffered from some methodological limitations such as the lack of a Risk of Bias analysis (Jaffar et al.,

2019, Kim et al., 2021), they limited analysis to only assess effects on semen parameters or were limited to exposure conditions relevant to mobile phone exposures thereby imposing a SAR cut-off (Yu et al., 2021). International committees on human health protection from electromagnetic fields were unable to draw firm conclusions on the possibility of an adverse effect of RF-EMF on male fertility at exposure levels where humans are typically exposed (ICNIRP, 2020, SCENIHR, 2015)....

We considered only original, controlled experimental studies published in peer-reviewed journals. We excluded non-experimental studies (e.g., human epidemiologic or other observational studies), and studies of exposure of both males and females of a mating pair (additional decision and change from protocol, see Section 4.5.2). We excluded papers reporting reviews, opinions, proceedings or meeting abstracts. We did not impose any year-of-publication or language restriction....

For each endpoint, we first conducted a meta-analysis of exposed vs sham control comparisons. When a study had several exposure groups matched to the same comparator, the means and standard deviations of these exposed groups were combined into one exposed group using the formulas provided in the paragraph 6.5.2.10 of the Cochrane Handbook (Higgins and Li, 2022), so that each study was entered only once into the meta-analysis. The exposure level assigned to that combined exposed group was calculated as the average SAR of the exposed groups in that study weighed by the number of animals in each exposed group. In the forest plots this is indicated with an asterisk after the study ID. Studies that compared each exposed group to another separate sham control group were entered as separate studies in the meta-analysis. When multiple studies were reported in the same paper, this is indicated with a number after the study ID in the forest plot....

All data subject to a *meta*-analysis were graphically synthesized by forest plots. A forest plot was drawn in which the studies were divided according to their overall RoB level as “low or some concern” or “high concern”. We decided to exclude from the assessment of the pooled effect sizes the studies rated at “high concern” for RoB in order to draw conclusions based upon the most robust data (see Section 4.5.2)....

After reading the full text, 175 papers on animal studies were excluded. They are listed in Supplementary File 1a with a justification of the exclusion rationale together with those not retrieved or not translated. Over 45 % of the animal studies were excluded because essential information was missing regarding exposure set-up and/or dosimetry, e.g., details on how the exposure system output was established and maintained or exposure frequency. A further 27 % of the studies were excluded because outcome data were deemed out-of-scope or invalid....

Regarding studies on human sperm in vitro, we excluded 33 papers after reading the full text (Supplementary File 1b). Most papers were excluded because they did not report peer-reviewed original results. Other papers could not be included in the systematic review because exposure conditions and/or dosimetry were insufficiently reported or because the exposure conditions did not provide a sufficient exposure contrast between RF-EMF exposed and sham-exposed samples....

4.1. Summary of the evidence and interpretation of the results From experimental animal studies there is moderate certainty of evidence that RF-EMF exposure reduces rate of pregnancy, moderate certainty of evidence that exposure does not reduce litter size, and low certainty of evidence that exposure lowers sperm count. All other results of animal studies and all results on human sperm exposed *in vitro* have very low certainty. We retrieved few independent studies reporting male reproductive effects after experimental animal exposure to EMP. For this source of exposure, results on pregnancy rate, litter size

and sperm count, all consistent with null, have a low certainty. All other results have a very low certainty.

It can be asked whether the results of our *meta*-analyses are consistent with the hypothesis that higher exposure levels, especially those inducing an hyperthermic effect, are more biologically effective than lower exposure levels. The result on the decrease of pregnancy rate is consistent with this hypothesis, as shown by the observation that the pooled effect size is statistically significant only in the subgroup of studies exposed to SAR equal to or higher than 5 W/kg and the statistically significant slope of the linear dose–response relationship. On the other hand, the results on sperm count do not show an increase of the detrimental effect with increasing SAR and all the models of dose–response relationship tested fit the data poorly. Also for other endpoints (the results of which were rated at very low certainty), a direct relationship between the effect and the exposure level is not evident by the subgroup and dose–response analyses and, in some cases, even the possibility of an inverse relationship is suggested by the data. However, this suggestion is not sustained by a solid adverse outcome pathway, and, in some cases, it is based only on few independent studies. We tested if other variables unequally distributed among the subgroups could have a role in increasing the heterogeneity of the observed results and could confound any underlying dose–effect relationship. Indeed, we showed that the absence of blinding during outcome assessment could strongly influence the results for those endpoints that were not measured by automated methods, thus supporting this hypothesis.

4.2. Limitations in the evidence Of all the papers included in the database of animal studies after the title/abstract evaluation, about 60 % had to be excluded for different reasons, with poor exposure characterization accounting for about 45 % of them....

Financial support This project was partially funded by the World Health Organization (contracts 2020/1026306–0, 2022/1275453–1). WHO provided the basis for the protocol and methodological support throughout the review process. Additional in-kind funds were provided by ENEA, Health Canada and Swinburne University of Technology.

Declaration of competing interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments We are grateful to Emilie van Deventer, Maria Rosaria Scarfì and Eric van Rongen for advice regarding the protocols draft and for discussions to ensure consistency in approaches across the multiple ongoing WHO systematic reviews. We wish to thank Flavio Di Marzio for his appreciated graphical help.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024000953

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Mobile phone use and brain tumour risk – COSMOS, a prospective cohort study

My note: This cohort study suffers from numerous methodological problems that undermine the authors' results and conclusions.

Feychting M, Schüz J, Toledano MB, Vermeulen R, Auvinen A, Poulsen AH, Deltour I, Smith RB, Heller J, Kromhout H, Huss A, Johansen C, Tettamanti G, Paul Elliott P. Mobile phone use and brain tumour risk – COSMOS, a prospective cohort study. Environment International. 2024, doi: 10.1016/j.envint.2024.108552.

Abstract

Background Each new generation of mobile phone technology has triggered discussions about potential carcinogenicity from exposure to radiofrequency electromagnetic fields (RF-EMF). Available evidence has been insufficient to conclude about long-term and heavy mobile phone use, limited by differential recall and selection bias, or crude exposure assessment. The Cohort Study on Mobile Phones and Health (COSMOS) was specifically designed to overcome these shortcomings.

Methods We recruited participants in Denmark, Finland, the Netherlands, Sweden, and the UK 2007–2012. The baseline questionnaire assessed lifetime history of mobile phone use. Participants were followed through population-based cancer registers to identify glioma, meningioma, and acoustic neuroma cases during follow-up. Non-differential exposure misclassification was reduced by adjusting estimates of mobile phone call-time through regression calibration methods based on self-reported data and objective operator-recorded information at baseline. Hazard ratios (HR) and 95% confidence intervals (CI) for glioma, meningioma, and acoustic neuroma in relation to lifetime history of mobile phone use were estimated with Cox regression models with attained age as the underlying time-scale, adjusted for country, sex, educational level, and marital status.

Results 264,574 participants accrued 1,836,479 person-years. During a median follow-up of 7.12 years, 149 glioma, 89 meningioma, and 29 incident cases of acoustic neuroma were diagnosed. The adjusted HR per 100 regression-calibrated cumulative hours of mobile phone call-time was 1.00 (95 % CI 0.98–1.02) for glioma, 1.01 (95 % CI 0.96–1.06) for meningioma, and 1.02 (95 % CI 0.99–1.06) for acoustic neuroma. For glioma, the HR for ≥ 1908 regression-calibrated cumulative hours (90th percentile cut-point) was 1.07 (95 % CI 0.62–1.86). Over 15 years of mobile phone use was not associated with an increased tumour risk; for glioma the HR was 0.97 (95 % CI 0.62–1.52).

Conclusions Our findings suggest that the cumulative amount of mobile phone use is not associated with the risk of developing glioma, meningioma, or acoustic neuroma.

Open access paper: https://www.sciencedirect.com/science/article/pii/S0160412024001387

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Headache in the international cohort study of mobile phone use and health (COSMOS) in the Netherlands and the United Kingdom

My note: This cohort study suffers from numerous methodological problems that undermine the authors' results and conclusions.

Traini E, Smith RB, Vermeulen R, Kromhout H, Schüz J, Feychting M, Auvinen A, Poulsen AH, Deltour I, Muller DC, Heller J, Tettamanti G, Elliott P, Huss A, Toledano MB. Headache in the international cohort study of mobile phone use and health (COSMOS) in the Netherlands and the United Kingdom. Environmental Research. 2024. doi: 10.1016/j.envres.2024.118290.

Highlights

- Prospective study exploring the relationship between mobile phone use and headache.
- Associations with call-time were largely explained by texting.
- Associations likely to reflect behavioural aspects of mobile phone use.

Abstract

Headache is a common condition with a substantial burden of disease worldwide. Concerns have been raised over the potential impact of long-term mobile phone use on headache due to radiofrequency electromagnetic fields (RF-EMFs). We explored prospectively the association between mobile phone use at baseline (2009–2012) and headache at follow-up (2015–2018) by analysing pooled data consisting of the Dutch and UK cohorts of the Cohort Study of Mobile Phone Use and Health (COSMOS) (N = 78,437). Frequency of headache, migraine, and information on mobile phone use, including use of hands-free devices and frequency of texting, were self-reported. We collected objective operator data to obtain regression calibrated estimates of voice call duration. In the model mutually adjusted for call-time and text messaging, participants in the high category of call-time showed an adjusted odds ratio (OR) of 1.04 (95 % CI: 0.94–1.15), with no clear trend of reporting headache with increasing call-time. However, we found an increased risk of weekly headache (OR = 1.40, 95 % CI: 1.25–1.56) in the high category of text messaging, with a clear increase in reporting headache with increasing texting. Due to the negligible exposure to RF-EMFs from texting, our results suggest that mechanisms other than RF-EMFs are responsible for the increased risk of headache that we found among mobile phone users.

Excerpts

A study conducted in Sweden and Finland as part of COSMOS found limited evidence for an association between weekly headache and the highest level of mobile phone use and no clear trend with increasing call-time (Auvinen et al., 2019). The association of headache with call-time appeared stronger for calls via the Universal Mobile Telecommunication System (UMTS) (3G) network than via the older Global System for Mobile (GSM) (2G) telecommunications technology, despite the latter involving higher RF-EMF exposure levels to the head (van Wel et al., 2021) ....

Headache has been linked to excessive mobile phone use, but the mechanism by which mobile phone use may cause symptoms is not properly understood (Wang et al., 2017; Cerutti et al., 2016; Frey, 1998; Hocking, 1998; Oftedal et al., 2000; Schoeni et al., 2015). Previous research in adolescents has suggested that other exposures related to mobile phone use, but not exposure to RF-EMFs, should be considered the causal factor for various symptoms, as the strongest associations were found with activities that cause minimal RF-EMF exposure to the head, such as texting or gaming (Schoeni et al., 2017). Other studies have indicated that stress or unfavourable usage, such as late-night use, may be associated with an increase in reported health symptoms, such as headache (Szyjkowska et al., 2014; Röösli, 2008; Thomée et al., 2011). It is therefore crucial to distinguish between using a mobile phone for calling and other activities that expose the brain to RF-EMFs at lower levels, such as Internet browsing (Cabré-Riera et al., 2022a; SSM's Scientific Council on Electromagnetic Fields, 2020).

Our study attempted to disentangle the exposure-outcome gradient by considering call-time as a proxy for RF-EMF exposure and texting as a proxy for usage with negligible RF-EMF exposure to the brain (Wall

et al., 2019). This study's mobile phone usage data was gathered between 2009 and 2012. During those years, texting was the most popular activity unrelated to RF-EMF exposure.....

The Headache Impact Test (HIT-6) score with a cut-off of 56 points defined severe weekly headache. The HIT-6 is a tool used to measure the impact headaches have on one's ability to function in various aspects of daily life, including work, school, home, and social contexts. The score, ranging from 36 to 78 points, provides a measure of the degree to which headaches affect daily life and functioning, with higher scores indicating a more significant impact on the participant's overall life (Kosinski et al., 2003)....

Results from two-exposure models mutually adjusting for both call-time and texting at baseline, showed substantially lower risk estimates for weekly headache in the high call-time (RC-hfa) category (OR = 1.04, 95 % CI: 0.94–1.15), and no evidence of a trend (P trend = 0.292) (Table 2). Associations with texting were robust to adjustment for call-time: we observed an increased risk of weekly headache in the high category of texting (OR = 1.40, 95 % CI: 1.25–1.56) and a trend of increasing risk with increasing texting frequency (P trend<0.001), in line with results from the single-exposure model (Table 3)....

In this large international prospective cohort of mobile phone users in the Netherlands and the UK, mobile phone use for calling and texting at baseline was associated with headaches at follow-up. Mutually adjusting for both call-time and texting considerably attenuated risk estimates for call-time, while associations with texting were still strong and robust to adjustment, with a clear exposure-outcome gradient.

Headache has been linked to excessive mobile phone use, but the mechanism by which mobile phone use may cause symptoms is not properly understood (Wang et al., 2017; Cerutti et al., 2016; Frey, 1998; Hocking, 1998; Oftedal et al., 2000; Schoeni et al., 2015). Previous research in adolescents has suggested that other exposures related to mobile phone use, but not exposure to RF-EMFs, should be considered the causal factor for various symptoms, as the strongest associations were found with activities that cause minimal RF-EMF exposure to the head, such as texting or gaming (Schoeni et al., 2017)....

Our study attempted to disentangle the exposure-outcome gradient by considering call-time as a proxy for RF-EMF exposure and texting as a proxy for usage with negligible RF-EMF exposure to the brain (Wall et al., 2019). This study's mobile phone usage data was gathered between 2009 and 2012. During those years, texting was the most popular activity unrelated to RF-EMF exposure.

In both scenarios, we found an increased risk of headache in the high exposure category of mobile phone use with a positive exposure-outcome gradient confirmed by the test for trend. The attenuated risk estimates for call-time in the mutually adjusted model argue against an effect of exposure to RF-EMFs due to the negligible exposure attributed to texting. This conclusion is also supported by comparing call-time analyses with and without hands-free adjustment, where no risk reduction was found among users for the adjusted exposure metrics....

Regarding secondary health outcomes, we found consistent patterns of results for severe weekly headache and migraine at follow-up in terms of increased risk estimates and significant trends. Increasing risk of daily headache was associated with increasing texting (P trend<0.001) but not with increasing call-time (P trend = 0.448) (Table 2, Table 3).

In both scenarios, we found an increased risk of headache in the high exposure category of mobile phone use with a positive exposure-outcome gradient confirmed by the test for trend. The attenuated risk estimates for call-time in the mutually adjusted model argue against an effect of exposure to RF-EMFs due to the negligible exposure attributed to texting. This conclusion is also supported by comparing call-time analyses with and without hands-free adjustment, where no risk reduction was found among users for the adjusted exposure metrics.

In this study, the distribution of the exposure, specifically regarding call-time, differed between Dutch and UK participants. Mobile phone usage behaviour across countries cannot be assumed to be identical due to various factors such as cultural, economic, technological, and market dynamics (Böhm, 2015). To assess the consistency of our findings, we showed that defining the top exposure category for call-time based on the 80th percentile cut-off, thereby ensuring the inclusion of Dutch participants in the "high" exposure category, yielded results consistent with those obtained using the 90th percentile as a cut-off. These findings suggested that the association we found between call-time and headache was driven not only by UK but also Dutch participants. Of note, all analyses were adjusted for country of residence....

Our study also has limitations. First, we did not have information about "true" RF-EMF exposure. Exposure to RF-EMFs emitted by wireless devices is difficult to quantify, particularly in large populations and over extended periods, as it depends on different factors, such as reception quality or other factors influencing signal strength. In our study, we calculated several exposure metrics as proxies for RF-EMF exposure, which allowed us to estimate the average individual RF-EMF exposure in the population. Additionally, information on other aspects of usage, such as screen time, blue light exposure or unfavourable use at night, may be helpful to include in future studies.

For highly transient and acute symptoms such as headache, using the peak of RF-EMF exposure might be theoretically preferable over the weekly exposure assessed in our study. However, adopting this approach would require substantially different exposure assessment methods that are impractical for large cohort studies, such as asking participants to regularly fill in a detailed usage diary. Given the study design and methodology used to assess RF-EMF exposure in COSMOS, the analysis of the association between RF-EMF peak exposure and reporting of headache symptoms was precluded. In light of the transient nature of headaches, future research may explore the potential effect of peak RF-EMF exposure on symptom onset more thoroughly.

The composition of the Dutch cohort is not representative of the adult population of the Netherlands with respect to sex and age....

Conclusions

In summary, we found that the use of mobile phones, particularly texting, is associated with headaches and migraines, and the associations with call-time were largely explained by texting. As the associations are driven more by text messaging than call-time, they do not appear to be explained by RF-EMF exposure from the mobile device but are likely to reflect lifestyle, other exposures, or behavioural factors associated with mobile phone use.

Declaration of competing interest [Note that text is missing from this paragraph.]

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Maria Feychting reports financial support was provided by Swedish Research Council. Maria Feychting reports financial support was provided by AFA Insurance. Maria Feychting reports financial support was provided by Swedish Research Council for Health, Working Life and Welfare. Maria Feychting reports financial support was provided by Swedish Radiation Safety Authority. Maria Feychting reports financial support was provided by Sweden's Innovation Agency. Paul Elliott reports financial support was provided by Mobile Telecommunications and Health Research. Paul Elliott reports financial support was provided by National Institute for Health and Care Research Health Protection Research Unit. Anssi Auvinen reports financial support was provided by National Technology Agency (TEKES). Anssi Auvinen reports financial support was provided by Pirkanmaa Hospital District. Anssi Auvinen reports financial support was provided by Yrjö Jahnsson Foundation. Anssi Auvinen reports financial support was provided by Mobile Manufacturers Forum. Roel Vermeulen reports financial support was provided by Netherlands Organisation for Health Research and Development. Aslak Harbo Poulsen reports financial support was provided by the Danish Strategic Research Council. Joachim Schuz reports financial support was provided by French Agency for Food, Environmental and Occupational Health & Safety (ANSES). Maria Feychting reports a relationship with World Health Organization that includes:. Maria Feychting reports a relationship with Public Health England Advisory Group on Non-ionizing Radiation that includes:. Maria Feychting reports a relationship with Norwegian Institute of Public Health that includes:. Maria Feychting reports a relationship with Forskningsrådet för hälsa arbetsliv och välfärd that includes:. Maria Feychting reports a relationship with Swedish Radiation Safety Authority that includes:. Maria Feychting reports a relationship with International Commission on Non-Ionizing Radiation Protection that includes:. Aslak Harbo Poulsen reports a relationship with Swedish Radiation Safety Authority that includes:. Anssi Auvinen reports a relationship with International Commission on Non-Ionizing Radiation Protection that includes:. Anssi Auvinen reports a relationship with Scientific Committee on Emerging and Newly Identified Health Risks that includes:. Anssi Auvinen reports a relationship with European Commission, Swedish Radiation Safety Authority that includes:. Anssi Auvinen reports a relationship with World Health Organization that includes:. Anke Huss reports a relationship with Swedish Radiation Safety Authority that includes:. Anke Huss reports a relationship with International Commission on Non-Ionizing Radiation Protection that includes:. Anke Huss reports a relationship with BioEM society that includes:. Anke Huss reports a relationship with Gezondheidsraad that includes:. Anke Huss reports a relationship with Swiss Research Foundation for Electricity and Mobile Communication that includes:. Hans Kromhout reports a relationship with Gezondheidsraad that includes:. Hans Kromhout reports a relationship with World Health Organization that includes:. Mireille B Toledano reports a relationship with UK Committee on Medical Aspects of Radiation in the Environment (COMARE) that includes:.

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Personal exposure to radiofrequency electromagnetic fields: A comparative analysis of international, national, and regional guidelines

My note: This paper suffers from problems that undermine the authors' results and conclusions.

Ramirez-Vazquez R, Escobar I, Vandenbosch GAE, Arribas E. Personal exposure to radiofrequency electromagnetic fields: A comparative analysis of international, national, and regional guidelines. Environmental Research. 2024. doi: 10.1016/j.envres.2024.118124.

Highlights

- International, National and Regional exposure limits for RF-EMF.
- RF-EMF limits are based on the ALARA (As Low As Reasonably Achievable) Principle.
- Maximum exposure limit must be scientific related, not political or in any other way.
- New technologies and new smartphones require less intensity than previous model

Abstract

A worldwide overview and analysis for the existing limits of human exposure to Radiofrequency Electromagnetic Fields (RF-EMF) is given in this paper. These reference levels have been established by different national and even regional governments, which can be based on the guidelines provided by the recommendations of the International Commission on Non-Ionizing Radiation Protection (ICNIRP), the International Committee on Electromagnetic Safety of the Institute of Electrical and Electronics Engineers (IEEE), and even in the United States of the Federal Communications Commission (FCC), as well as, are based on the so-called precautionary principle. Explicit reference is made to the exposure limits adopted in countries or regions, such as Canada, Italy, Poland, Switzerland, China, Russia, France, and regions of Belgium (Brussels, Flanders, Wallonia), where the limits are much lower than the international standards. The limits are compared to a selected set of in-situ measurements. This clearly shows that the measured values are typically very small compared to the international standards but could be somewhat higher compared to the reduced limits. Based on this observation and the reasonable assumption that the sensitivity of people to Electromagnetic Fields (EMF) is the same everywhere (whole-body), we propose the idea to establish a worldwide reference limit for the general public, thus applicable in all countries, if the ICNIRP considers it appropriate. Research must continue to generate measurement data that demonstrate the levels of exposure to which we are really exposed, and with this, provide arguments to the organizations that established the guidelines, especially the ICNIRP, to evaluate whether the current limits are too much. High and can be modified when considered pertinent. To the best of our knowledge, at no time has the reference level for the general public been exceeded.

Conclusion

The duality of limits in the same country does not seem appropriate, because people who live in one area or another have more or less the same interaction with RF-EMF waves. Therefore, the limits should be the same, following the ALARA principle – As Low As Reasonably Achievable. The reasons for setting the maximum exposure limit should only be scientific related, not political or in any other way.

In this paper, we provided an overview, analyze, and discuss existing limits to RF-EMF. The international reference levels established by ICNIRP are also recommended by WHO, IEEE and FCC, and are adopted by most countries. However, some countries such as Canada, Italy, Poland, Switzerland, China, Russia, France, and regions of Belgium establish more restrictive limits than the international ones. The case of Belgium is rather specific because it establishes three very strict and different limits in Brussels, Flanders, and Wallonia.

In addition to the international limits, we have commented on the BioInitiative Limit, based on the Precautionary Principle as a preventive action, an excessively restrictive value that leaves aside more than 60 % of the personal exposure studies to RF-EMF.

There should be a trend towards unifying the limits of exposure to RF-EMF in all countries. This would allow decisions to be made in a scientific and consensual manner. The solutions could follow the ones from the International Union for Pure and Applied Physics (IUPAP), which is an international organization that has sixty member countries and is in charge, among other things, of the correct use of the International System of Units and of reviewing the measurement units of the physical magnitudes.

Based on the observation and analysis of measured levels that in most cases, the measured levels are very small, we propose that a reference limit be established for the general public, reasonable and applied to all countries, if the ICNIRP considers it appropriate. Therefore, research must continue to generate measurement data that demonstrate the levels of exposure to which we are really exposed, and with this, provide arguments to the organizations that established the guidelines, especially the ICNIRP, so that they evaluate whether the current limits are too high and can be modified, when considered pertinent. To the best of our knowledge, at no time has the reference level been exceeded for the general public, and we believe that it will not be exceeded, since the new smartphones require much less intensity than previous models, and the same goes for new technologies, 5G, 6G.

https://www.sciencedirect.com/science/article/pii/S0013935124000288

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How to improve IARC's RF-EMF cancer hazard communication

My note: This paper suffers from problems that undermine the authors' analysis.

Wiedemann PM, Croft RJ. How to improve IARC's RF-EMF cancer hazard communication. Bioelectromagnetics. 2024 Feb 13. doi: 10.1002/bem.22499.

Abstract

A crucial aspect of IARC's evaluation of the relative carcinogenicity of agents is the communication of its conclusions. The present paper addressed the experimental risk perception literature pertaining to IARC's radiofrequency electromagnetic field evaluation communication, and derived specific recommendations for improving it.

Open access paper: https://onlinelibrary.wiley.com/doi/10.1002/bem.22499

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Molecular biomarkers in Electrohypersensitivity and Multiple Chemical Sensitivity: How They Can Help Diagnosis, Follow-Up, and in Etiopathologic Understanding

Irigaray P, Awaida N, Belpomme D. Molecular biomarkers in Electrohypersensitivity and Multiple Chemical Sensitivity: How They Can Help Diagnosis, Follow-Up, and in Etiopathologic Understanding. Medical Research Archives, [S.l.], 12(1), 2024. doi: 10.18103/mra.v12i1.4771.

Abstract

Electrohypersensitivty (EHS) and multiple chemical sensitivity (MCS) are new worldwide emerging neurologic disorders in the framework of sensitivity-related environmental pathology. We have recently extended and confirmed our previous observation showing that EHS and MCS share clinically identical symptoms and may co-exist as a unique, common, sensitivity-related neurologic syndrome in 25% of the cases. There is presently no published biological study of these disorders, except the one we have previously published as preliminary. In the present study, we show that EHS and MCS and the combined syndrome share identical biochemical changes. More precisely, by measuring levels of peripheral blood and urine molecular biomarkers in a cohort of 2,018 consecutive cases, we show that both disorders and the combined syndrome can be objectively characterized, in about 90% of the cases, by a decrease in the production of 6-hydroxymelatonin sulfate in urine, while in 30-50% they are characterized by increased levels of histamine and of heat shock proteins (HSP) 27 and/or 70, and of protein S100B and nitrotyrosine in the peripheral blood. Increased levels of histamine and HSP are indicators of low grade inflammation while increased levels of protein S100B and nitrotyrosine are indicators of blood-brain barrier disruption/opening. In addition, we show that in about 15% of the cases anti-myelin autoantibodies can be detected in the peripheral blood, accounting for the occurrence of an autoimmune response. Sensitivity, specificity and reproducibility of the biochemical tests are discussed, as well as the role of these indicators used as biomarkers for the diagnosis and follow-up of patients. We also discuss cases with undetectable biological change for which they can be nevertheless diagnosed by cerebral neurotransmitters analysis in urine and brain imaging. On the basis of these biological data it is suggested that EHS and/or MCS are new brain disorders, generated via a common etiopathogenic mechanism.

https://esmed.org/MRA/mra/article/view/4771

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Environmental Health Ecosystem Sustainability in The Era of Electromagnetic Radiation Contamination

Matthew UO, Bakare KM, Oyekunle D, Nkeiruka AM, Ebong GN (2024) Environmental Health Ecosystem Sustainability in The Era of Electromagnetic Radiation Contamination. J Comm Med and Pub Health Rep 5(02): doi: 10.38207/JCMPHR/2024/JAN05020418.

Abstract

The primary environmental health sub-disciplines that address the best approaches to environmental health, ecosystem sustainability, and natural habitats are environmental science, toxicology, environmental epidemiology, and occupational and environmental medicine. The intimate connection between environmental toxins and human health gained increased public attention at the beginning of the new millennium. Radiation, chemical, and biological agents are the three primary ecological contaminants. There is contamination in the soil, water, food, and air. The increasing adoption of 5G wireless networks has recently raised interest in its potential to support several digital and critical infrastructures. However, concerns have been raised over the potential health risks associated with fifth-generation wireless networks due to the claims that the electromagnetic radiation in the 5G carrier signal is more potent than in any prior networks. As a subject of public health, environmental health studies the whole range of effects that artificial technology and natural environments have on the general well-being of society-wide space. It establishes the prerequisites for a wholesome atmosphere

as essential in managing factors that may negatively impact the sustainability of ecosystems and the environment's well-being. This study observed that the multistage carcinogenic process, which includes carcinogen activation, oxidative DNA damage, and tumor growth, is aided by hydrogen peroxide formation during the breakdown of water molecules due to 5G electromagnetic frequency radiation as an environmental contaminant.

https://www.acquaintpublications.com/article/environmental_health_ecosystem_sustainability_in_the_era_of_electromagnetic_radiation_contamination

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Assessment of Radio Frequency Electromagnetic Field Exposure Induced by Base Stations in Several Micro-Environments in France

W. B. Chikha et al. Assessment of Radio Frequency Electromagnetic Field Exposure Induced by Base Stations in Several Micro-Environments in France. IEEE Access, vol. 12, pp. 21610-21620, 2024, doi: 10.1109/ACCESS.2024.3363914.

Abstract

Recently, the monitoring of the radiofrequency electromagnetic field (RF-EMF) exposure induced by cellular networks has received a great deal of attention. In this work, a set of 70 microenvironments (MEs) located in urban and rural areas are selected in France under, on the one hand, the French Beyond5G project, and on the other hand, the 5G expOsure, causaL effects and rIsk perception through citizen engagement (GOLIAT) EU project. The purpose of this study is to assess the RF-EMF DL exposure in residential areas, downtowns, business areas, train stations, and public transport rides. For that, we employ the personal ExpoM-RF4 dosimeter placed inside a backpack to perform the measurements in different MEs. To take into consideration the effect of the presence of the human body near the dosimeter, we propose a correction approach that is mainly based on comparing the measurements given by ExpoM-RF4 to the ones provided by a reference system using the Tektronix real-time spectrum analyzer (RTSA) far from the body. Then, we use metrics, such as the quadratic mean, standard deviation, and median of the electric (E) field to carry out a comparative study between different MEs with different RF bands. It was found that the RF-EMF exposure levels for all MEs are well below the maximum allowable exposure limit prescribed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). In addition, we perform clustering analyses using the K-Means technique to group the MEs with comparable exposure levels. The results show that the exposure level is low, but generally higher in MEs located in Paris than in the other considered areas (i.e., Massy and three villages, namely Igny, Bures-sur-Yvette and Gif-Sur-Yvette). For example, we observe that outdoor MEs can be grouped into three clusters, where the average total E fields (ATEFs) are 0.77 V/m, 0.35 V/m, and 0.08 V/m for the MEs belonging to the first, second and third clusters, respectively. Note that the first cluster here mainly contains the MEs located in Paris. This can be explained by the important number of antennas deployed in that area to serve the huge amount of users. We also observe few locations with exceptions confirming the presence of heterogeneous environments in the vicinity of some areas. For instance, three MEs in Paris among fifteen have an exposure level similar to Massy MEs in outdoor

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=10424982&isnumber=10380310

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Electromagnetic Exposure Level of a Pure Electric Vehicle Inverter Based on a Real Human Body

Dong X, Gao Y, Lu M. The Electromagnetic Exposure Level of a Pure Electric Vehicle Inverter Based on a Real Human Body. *Applied Sciences*. 2024; 14(1):32. https://doi.org/10.3390/app14010032.

Abstract

In order to quantitatively analyze the electromagnetic exposure dose of an inverter in a pure electric vehicle to the driver's body and assess the safety of the electromagnetic exposure, based on a real human anatomy model in the virtual home project, a real human model with several organs and tissues, including muscles, bones, a heart, lungs, a liver, kidneys, a bladder, a skull, a scalp, white matter, and a cerebellum, was constructed. The inverter of a pure electric vehicle is considered to be the electromagnetic exposure source; for this study, an equivalent electromagnetic environment model composed of a real human body, an inverter, and a vehicle body was built. The distribution of induced fields in the driver's tissues and organs was calculated and analyzed using the finite element method. The results show that the distribution of the magnetic flux density, induced electric field, and induced current density in the driver's body was affected by the spatial distance of the inverter. The farther the distance was, the weaker the value was. Specifically, due to the different dielectric properties of the different tissues, the induced field in the different tissues was significantly different. However, the maximum magnetic flux density over the space occupied by the driver's body and induced electric field in the driver's trunk and central nervous system satisfied the exposure limits of the International Commission on Non-Ionization Radiation Protection, indicating that the electromagnetic environments generated by the inverter proposed in this paper are safe for the vehicle driver's health. The numerical results of this study could also effectively supplement the study of the electromagnetic environments of pure electric vehicles and provide some references for protecting the drivers of pure electric vehicles from electromagnetic radiation.

Conclusions

Based on the numerical results, we found that although the B-field in the central region of the inverter exceeds the reference level of the ICNIRP for general public exposure, when the distance from the inverter is increased, the B-field values sharply decrease. The maximum B-field over the space occupied by the driver's body and the E-field in the driver's trunk and CNS are all below the exposure limits defined by the ICNIRP for general public exposure. The electromagnetic environment generated by the inverter adopted in this study (12 kW, Semikron, Germany), at its rated state in the paper, is therefore safe and would not affect the PEV driver's health. Additionally, the results of this study could effectively supplement research regarding the electromagnetic environment of PEVs and provide references for the formulation of industry standards for electromagnetic exposure and the design of vehicles that are safe in terms of electromagnetic exposure.

Open access paper: https://www.mdpi.com/2076-3417/14/1/32

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SAR Estimations in a Child Due to RF Exposures from Several Laptops in a Classroom Environment

Soares NE, Bulla G, Fernandez-Rodriguez CE, de Salles AAA. SAR Estimations in a Child Due to RF Exposures from Several Laptops in a Classroom Environment. *2023 IEEE MTT-S Latin America Microwave Conference (LAMC)*, San José, Costa Rica, 2023, pp. 58-60, doi: 10.1109/LAMC59011.2023.10375589.

Abstract

This research provides a detailed examination of the exposure to electromagnetic fields (EMF) in a classroom environment. The study is driven by the escalating integration of electronic devices in educational settings and the subsequent necessity to estimate the implications of this on the overall exposure. The employed methodology simulates a classroom filled with several 7-year-old girls realistic models, each using a laptop, which are the primary sources of electromagnetic radiation. The 1g and 10g peak spatial Specific Absorption Rate (psSAR) are calculated for various parts of the child model, including the head, back, and hands. It is observed that, when several laptops are used, the psSAR can be substantially increased (e.g. up to 40-fold). One objective of this study is to enhance the understanding of potential EMF exposure effects in relation to age and to provide guidelines for the design of safer classrooms in the context of widespread laptop usage.

https://ieeexplore.ieee.org/document/10375589

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Effects of 3.5-GHz radiofrequency radiation on energy-regulatory hormone levels in the blood and adipose tissue

Bektas H, Dasdag S, Altindag F, Akdag MZ, Yegin K, Algul S. Effects of 3.5-GHz radiofrequency radiation on energy-regulatory hormone levels in the blood and adipose tissue. *Bioelectromagnetics* 1–9 (2024). doi: 10.1002/bem.22498.

Highlights

- 3.5 GHz radiofrequency radiation (RFR) may induce alterations in hormones regulating energy metabolism.
- 3.5 GHz RFR may lead to alterations in total antioxidant, total oxidant, and hydrogen peroxide levels.
- Particularly in conjunction with diabetes, 3.5 GHz RFR may result in adverse effects on energy metabolism.
- Although there were changes of the hormone levels in the exposed group, the actual values remained for both sham and exposed groups within the normal range.

Abstract

In recent years exposure of living beings to radiofrequency radiation (RFR) emitted from wireless equipment has increased. In this study, we investigated the effects of 3.5-GHz RFR on hormones that regulate energy metabolism in the body. Twenty-eight rats were divided into four groups: healthy sham (n = 7), healthy RFR (n = 7), diabetic sham (n = 7), and diabetic RFR (n = 7). Over a month, each group spent 2 h/day in a Plexiglas carousel. The rats in the experimental group were exposed to RFR, but the sham groups were not. At the end of the experiment, blood and adipose tissues were collected from euthanized rats. Total antioxidant, total oxidant, hydrogen peroxide, ghrelin, nesfatin-1, and irisin were

determined. Insulin expression in pancreatic tissues was examined by immunohistochemical analysis. Whole body specific absorption rate was 37 mW/kg. For the parameters analyzed in blood and fat, the estimated effect size varied within the ranges of 0.215–0.929 and 0.503–0.839, respectively. The blood and adipose nesfatin-1 ($p = 0.002$), blood and pancreatic insulin are decreased, ($p = 0.001$), gherelin ($p = 0.020$), irisin ($p = 0.020$), and blood glucose ($p = 0.040$) are increased in healthy and diabetic rats exposed to RFR. While nesfatin-1 are negatively correlated with oxidative stress, hyperglycemia and insulin, ghrelin and irisin are positively correlated with oxidative stress and hyperglycemia. Thus, RFR may have deleterious effects on energy metabolism, particularly in the presence of diabetes.

https://onlinelibrary.wiley.com/doi/10.1002/bem.22498

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Genetic profiling of rat gliomas and cardiac schwannomas from life-time radiofrequency radiation exposure study using a targeted next-generation sequencing gene panel

Brooks AM, Vornoli A, Kovi RC, Ton TVT, Xu M, Mashal A, Tibaldi E, Gnudi F, Li JL, Sills RC, Bucher JR, Mandrioli D, Belpoggi F, Pandiri AR. Genetic profiling of rat gliomas and cardiac schwannomas from life-time radiofrequency radiation exposure study using a targeted next-generation sequencing gene panel. PLoS One. 2024 Jan 17;19(1):e0296699. doi: 10.1371/journal.pone.0296699.

Abstract

The cancer hazard associated with lifetime exposure to radiofrequency radiation (RFR) was examined in Sprague Dawley (SD) rats at the Ramazzini Institute (RI), Italy. There were increased incidences of gliomas and cardiac schwannomas. The translational relevance of these rare rat tumors for human disease is poorly understood. We examined the genetic alterations in RFR-derived rat tumors through molecular characterization of important cancer genes relevant for human gliomagenesis. A targeted next-generation sequencing (NGS) panel was designed for rats based on the top 23 orthologous human glioma-related genes. Single-nucleotide variants (SNVs) and small insertion and deletions (indels) were characterized in the rat gliomas and cardiac schwannomas. Translational relevance of these genetic alterations in rat tumors to human disease was determined through comparison with the Catalogue of Somatic Mutations in Cancer (COSMIC) database. These data suggest that rat gliomas resulting from life-time exposure to RFR histologically resemble low grade human gliomas but surprisingly no mutations were detected in rat gliomas that had homology to the human IDH1 p.R132 or IDH2 p.R172 suggesting that rat gliomas are primarily wild-type for IDH hotspot mutations implicated in human gliomas. The rat gliomas appear to share some genetic alterations with IDH1 wildtype human gliomas and rat cardiac schwannomas also harbor mutations in some of the queried cancer genes. These data demonstrate that targeted NGS panels based on tumor specific orthologous human cancer driver genes are an important tool to examine the translational relevance of rodent tumors resulting from chronic/life-time rodent bioassays.

Excerpts

In this study we have demonstrated that the gliomas and cardiac schwannomas in rats resulting from lifetime exposure to low dose far field RFR that are used for cellular telephone communications, are morphologically similar to low grade human gliomas and that about 25% of the mutations seen in these tumors have corresponding alterations in homologs of human cancer genes. Surprisingly, none of the rat

gliomas examined in this study harbored mutations in *Idh1/2* genes that are common in human gliomas....

In summary, our results demonstrate that regardless of their etiology (due to lifetime RFR exposure or arising spontaneously), rat gliomas are primarily *Idh*1/2 wild type unlike most human gliomas. Histologically, most of the rat gliomas resemble diffuse low-grade gliomas in humans and such gliomas that do not harbor *IDH1/2* mutations in humans are known to have poor prognosis. The genetic alterations in other cancer genes evaluated in this panel provide novel insights into tumor progression in rat gliomas and cardiac schwannomas. The relevance of specific mutations to human cancers is variable, with some genes (*Tp53*, *Cdkn2a*, *Erbb2*, *Chek2*, *Kras* and *Pik3r1*) harboring many alterations with COSMIC relevance while the opposite is true for other target genes (*Idh1/2*, *Atrx*, *Notch1*, *Pten*, *Rb1* and *Setd2*). Several of these conserved mutations in rat tumors do not have comparable alterations in the COSMIC database, suggesting that the orthologous mutations could have different functional consequences in rat carcinogenesis and deserve further study. An important consideration is that molecular differences underlying mutational processes contribute to distinct mutational patterns which could be the result of similar etiology, albeit by different mechanisms.

Several of the variants that were detected in gliomas were also observed in non-tumor brain tissues from interim time point providing an insight into the molecular pathogenesis in rodent carcinogenicity studies and these strategies may be utilized to potentially estimate the cancer hazard risk in shorter term animal studies. Finally, this targeted mutation panel may be refined using data from whole genome or exome sequencing of rat tumors and performing error corrected duplex sequencing to increase the sensitivity to detect rare mutations in exposed non-tumor tissues from early time points.

Open access paper: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0296699

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Understanding the public voices and researchers speaking into the 5G narrative

Weller S, McCredden J. Understanding the public voices and researchers speaking into the 5G narrative. Front. Public Health. Vol. 11. 2023 doi: 10.3389/fpubh.2023.1339513.

Abstract

The many different voices speaking into the current narrative surrounding the health effects of 5G technologies necessitate an exploration of the background of the various published author spokespersons and their potential motives. This has been attempted recently by de Vocht and Albers. However, that opinion piece used a narrow investigative lens, resulting in an undermining of both the rationality of the concerned general public and the motives of specific researchers. At the same time, biases, conflicts of interest, and flaws found in "independent" reviews were not considered. To address these oversights, an evidence-based appraisal of public opinion and the scientific caliber of authors involved in the 5G health discussion is warranted. Subsequently, this review article presents an analysis of the available Australian data representing public voices, while also conducting a broader investigation of the level of expertise of the recent author-spokespersons based on their experience as scientists, particularly in the area of health effects of radiofrequency electromagnetic fields. This review thus attempts to more clearly illustrate for the reader the caliber and motives of the voices speaking into the

5G narrative. The article concludes with a set of questions that need to be answered to enable scientists to advise policy makers more effectively on matters of 5G and public health.

Open access paper: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1339513/abstract

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Effects of 700 and 3500 MHz 5G radiofrequency exposure on developing zebrafish embryos

Torres-Ruiz M, Suárez OJ, López V, Marina P, Sanchis A, Liste I, de Alba M, Ramos V. Effects of 700 and 3500 MHz 5G radiofrequency exposure on developing zebrafish embryos. Sci Total Environ. 2024 Jan 8:169475. doi: 10.1016/j.scitotenv.2023.169475.

Abstract

Telecommunications industries are rapidly deploying the fifth generation (5G) spectrum and there is public concern about the safety and health impacts of this type of Radio Frequency Radiation (RFR), in part because of the lack of comparable scientific evidence. In this study we have used a validated commercially available setting producing a uniform field to expose zebrafish embryos (ZFe) to unmodulated 700 and 3500 MHz frequencies. We have combined a battery of toxicity, developmental and behavioral assays to further explore potential RFR effects. Our neurobehavioral profiles include a tail coiling assay, a light/dark activity assay, two thigmotaxis anxiety assays (auditory and visual stimuli), and a startle response - habituation assay in response to auditory stimuli. ZFe were exposed for 1 and 4 h during the blastula period of development and endpoints evaluated up to 120 h post fertilization (hpf). Our results show no effects on mortality, hatching or body length. However, we have demonstrated specific organ morphological effects, and behavioral effects in activity, anxiety-like behavior, and habituation that lasted in larvae exposed during the early embryonic period. A decrease in acetylcholinesterase activity was also observed and could explain some of the observed behavioral alterations. Interestingly, effects were more pronounced in ZFe exposed to the 700 MHz frequency, and especially for the 4 h exposure period. In addition, we have demonstrated that our exposure setup is robust, flexible with regard to frequency and power testing, and highly comparable. Future work will include exposure of ZFe to 5G modulated signals for different time periods to better understand the potential health effects of novel 5G RFR.

https://pubmed.ncbi.nlm.nih.gov/38199355/

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Effects of radiofrequency field from 5G communication on fecal microbiome and metabolome profiles in mice

Wang, X., Zhou, G., Lin, J. *et al.* Effects of radiofrequency field from 5G communication on fecal microbiome and metabolome profiles in mice. *Sci Rep* **14**, 3571 (2024). https://doi.org/10.1038/s41598-024-53842-2

Abstract

With the rapid development of 5G networks, the influence of the radiofrequency field (RF) generated from 5G communication equipment on human health is drawing increasing attention in public. The study aimed at assessing the effects of long-term exposure to 4.9 GHz (one of the working frequencies of 5G communication) RF field on fecal microbiome and metabolome profiles in adult male C57BL/6 mice. The animals were divided into Sham group and radiofrequency group (RF group). For RF group, the mice were whole body exposed to 4.9 GHz RF field for three weeks, 1 h/d, at average power density (PD) of 50 W/m^2. After RF exposure, the mice fecal samples were collected to detect gut microorganisms and metabolites by 16S rRNA gene sequencing and LC–MS method, respectively. The results showed that intestinal microbial compositions were altered in RF group, as evidenced by reduced microbial diversity and changed microbial community distribution. Metabolomics profiling identified 258 significantly differentially abundant metabolites in RF group, 57 of which can be classified to Kyoto Encyclopedia of Genes and Genomes (KEGG) pathways. Besides, functional correlation analysis showed that changes in gut microbiota genera were significantly correlated with changes in fecal metabolites. In summary, the results suggested that altered gut microbiota and metabolic profile are associated with 4.9 GHz radiofrequency exposure.

Open access paper: https://www.nature.com/articles/s41598-024-53842-2

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Estimation of SAR Average in Rats during 5G NR Chronic Exposure

Makhmanazarov R, Tseplyaev I, Shipilov S, Krivova N. Estimation of SAR Average in Rats during 5G NR Chronic Exposure. *Applied Sciences*. 2024; 14(1):208. doi: 10.3390/app14010208.

Abstract

To study physiological reactions in the brain and skin of higher mammals exposed to chronic radiofrequency radiation, specific absorption ratio (SAR) determination is required and time-consuming numerical methods are used. The paper deals with the estimation of the whole-body specific absorption rate (SAR) in rats chronically exposed to external electromagnetic fields, as well as the development of a laboratory setup simulating the operation of a fifth-generation 5G New Radio base station (with a signal bandwidth of 15 MHz and a carrier frequency of 2.4 GHz). The paper presents a modified method for theoretical SAR estimation for one-sided irradiation and distributed absorption. Mean whole-body SAR values were estimated by the proposed method and numerically modeled with the CST Microwave Studio simulation software 2020package using primitive rat models. Dielectric parameters in the numerical simulation were used from the software library. The IEEE/IEC 62704-1 algorithm was used to investigate SAR in numerical simulations. The theoretical estimates and numerical simulations were compared for different SAR distributions and were found to be qualitatively comparable. The differences between approximate theoretical estimates and numerical simulations are 7% and 10% for distributed and non-distributed absorptions, respectively. The proposed method, which takes into account the decreasing power flux density, can be used to estimate the approximate whole-body SAR during chronic electromagnetic field exposure in rats.

Open access paper: https://www.mdpi.com/2076-3417/14/1/208

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The thermal sensation threshold and its reliability induced by the exposure to 28 GHz millimeter-wave

Akiko Y, Shintaro U, Kazuki U, Sachiko K, Norika A, Akimasa H, Yohei O. The thermal sensation threshold and its reliability induced by the exposure to 28 GHz millimeter-wave. Frontiers in Neuroscience. 18. 2024. doi: 10.3389/fnins.2024.1331416.

Abstract

The application of 28 GHz millimeter-wave is prevalent owing to the global spread of fifth-generation wireless communication systems. Its thermal effect is a dominant factor which potentially causes pain and tissue damage to the body parts exposed to the millimeter waves. However, the threshold of this thermal sensation, that is, the degree of change in skin temperature from the baseline at which the first subjective response to the thermal effects of the millimeter waves occurs, remains unclear. Here, we investigated the thermal sensation threshold and assessed its reliability when exposed to millimeter waves. Twenty healthy adults were exposed to 28 GHz millimeter-wave on their left middle fingertip at five levels of antenna input power: 0.2, 1.1, 1.6, 2.1, and 3.4 W (incident power density: 27–399 mW/cm²). This measurement session was repeated twice on the same day to evaluate the threshold reliability. The intraclass correlation coefficient (ICC) and Bland–Altman analysis were used as proxies for the relative and absolute reliability, respectively. The number of participants who perceived a sensation during the two sessions at each exposure level was also counted as the perception rate. Mean thermal sensation thresholds were within 0.9°C–1.0°C for the 126–399 mW/cm² conditions, while that was 0.2°C for the 27 mW/cm² condition. The ICCs for the threshold at 27 and 126 mW/cm² were interpreted as poor and fair, respectively, while those at higher exposure levels were moderate to substantial. Apart from a proportional bias in the 191 mW/cm² condition, there was no fixed bias. All participants perceived a thermal sensation at 399 mW/cm² in both sessions, and the perception rate gradually decreased with lower exposure levels. Importantly, two-thirds of the participants answered that they felt a thermal sensation in both or one of the sessions at 27 mW/cm², despite the low-temperature increase. These results suggest that the thermal sensation threshold is around 1.0°C, consistent across exposure levels, while its reliability increases with higher exposure levels. Furthermore, the perception of thermal sensation may be inherently ambiguous owing to the nature of human perception.

Open access paper:
https://www.frontiersin.org/journals/neuroscience/articles/10.3389/fnins.2024.1331416

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The impact of radiofrequency exposure on Aedes aegypti (Diptera: Culicidae) development [mosquitos]

Nik Abdull Halim NMH, Mohd Jamili AF, Che Dom N, Abd Rahman NH, Jamal Kareem Z, Dapari R. The impact of radiofrequency exposure on Aedes aegypti (Diptera: Culicidae) development. PLoS One. 2024 Feb 27;19(2):e0298738. doi: 10.1371/journal.pone.0298738.

Abstract

Introduction Wireless communication connects billions of people worldwide, relying on radiofrequency electromagnetic fields (RF-EMF). Generally, fifth-generation (5G) networks shift RF carriers to higher frequencies. Although radio, cell phones, and television have benefited humans for decades, higher carrier frequencies can present potential health risks. Insects closely associated with humans (such as mosquitoes) can undergo increased RF absorption and dielectric heating. This process inadvertently impacts the insects' behaviour, morphology, and physiology, which can influence their spread. Therefore, this study examined the impact of RF exposure on Ae. aegypti mosquitoes, which are prevalent in indoor environments with higher RF exposure risk. The morphologies of Ae. aegypti eggs and their developments into Ae. aegypti mosquitoes were investigated.

Methods A total of 30 eggs were exposed to RF radiation at three frequencies: baseline, 900 MHz, and 18 GHz. Each frequency was tested in triplicate. Several parameters were assessed through daily observations in an insectarium, including hatching responses, development times, larval numbers, and pupation periods until the emergence of adult insects.

Results This study revealed that the hatching rate for the 900 MHz group was the highest (79 ± 10.54%) compared to other exposures ($p = 0.87$). The adult emergence rate for the 900 MHz group was also the lowest at 33 ± 2.77%. A significant difference between the groups was demonstrated in the statistical analysis ($p = 0.03$).

Conclusion This work highlighted the morphology sensitivity of Ae. aegypti eggs and their developments in the aquatic phase to RF radiation, potentially altering their life cycle.

This study successfully comprehended the influence of RF exposure on the development of *Aedes* mosquitoes. The 900 MHz RF exposure accelerated the hatching process of *Ae*. *aegypti* mosquitoes and increased the percentage of adult emergence. These findings represented an essential initial stage in understanding the impact of RF radiation on *Aedes* mosquito populations, providing vital insights into the population dynamics. Nevertheless, the potential variability results under distinct study conditions involving RF exposure variation types and the mosquito species studied were necessary. Thus, additional investigation was desirable and crucial to understand the consequences of RF exposure comprehensively on *Ae*. *albopictus* and determine the most efficient approaches for identifying the most effective strategies for dengue vector control. Studies are actively investigating the influence of RF exposure on insects (particularly mosquitoes) due to data suggesting that it can impact hatching and developmental processes. Hence, further studies should be conducted to fully comprehend the scope of these effects and clarify their practical relevance in preventing dengue spread. These ongoing studies are pivotal in learning the potential utility of RF exposure to mitigate the spread of dengue disease and in establishing the most efficacious approaches for translating this knowledge into practical control measures.

Open access paper: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0298738

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Detrimental impact of cell phone radiation on sperm DNA integrity (Review)

Koohestanidehaghi Y, Khalili MA, Dehghanpour F, Seify M. Detrimental impact of cell phone radiation on sperm DNA integrity. Clin Exp Reprod Med. 2024 Jan 24. doi: 10.5653/cerm.2023.06121.

Abstract

Radiofrequency electromagnetic radiation (RF-EMR) from various sources may impact health due to the generation of frequency bands. Broad pulses emitted within frequency bands can be absorbed by cells, influencing their function. Numerous laboratory studies have demonstrated that mobile phones-generally the most widely used devices-can have harmful effects on sex cells, such as sperm and oocytes, by producing RF-EMR. Moreover, some research has indicated that RF-EMR generated by mobile phones can influence sperm parameters, including motility, morphology, viability, and (most critically) DNA structure. Consequently, RF-EMR can disrupt both sperm function and fertilization. However, other studies have reported that exposure of spermatozoa to RF-EMR does not affect the functional parameters or genetic structure of sperm. These conflicting results likely stem from differences among studies in the duration and exposure distance, as well as the species of animal used. This report was undertaken to review the existing research discussing the effects of RF-EMR on the DNA integrity of mammalian spermatozoa.

EMW can induce oxidative stress, which subsequently leads to disorders such as reduced mobility, morphological changes, acrosome disturbances, and ultimately, damage to the nucleus and genetic material. This oxidative damage to DNA can result in the breakdown of both single-stranded and double-stranded DNA structures, culminating in fragmentation. If the DNA is not repaired and the damage accumulates, the sperm may undergo apoptosis. Damage to the sperm genome can ultimately impact fertility, potentially leading to infertility. Therefore, it is advisable to limit daily exposure to these sources to prevent irreversible damage caused by EMWs. Many men carry their cell phones in their trouser pockets or clipped to their belts, and the use of Bluetooth can increase their susceptibility to RF-EMR exposure. This exposure can induce changes in sperm quality through oxidative stress, potentially leading to infertility. Agarwal et al. [11] suggested that carrying a cell phone in a pocket could lead to a decline in sperm quality. However, it is important to note that the phone and male reproductive organs are separated by multiple tissue layers. Therefore, extrapolating these in vitro effects to real-life conditions requires further studies [11].

In July 2021, the European Parliament commissioned a research report titled “Health impact of 5G.” The report concluded that the commonly used RF-EMFs are likely carcinogenic to humans and have a definitive impact on male fertility. It also suggested potential adverse effects on the development of embryos, fetuses, and newborns. To mitigate these adverse effects, the organization proposed several strategies. These include favoring non-wireless connections, increasing distance from the source of RF-EMFs, switching off devices when not in use, and practicing safe phone usage [55].

Open access paper: https://ecerm.org/journal/view.php?doi=10.5653/cerm.2023.06121

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Acute exposure of microwave impairs attention process by activating microglial inflammation

Jiang S, Ma Y, Shi Y, *et al.* Acute exposure of microwave impairs attention process by activating microglial inflammation. *Cell Biosci* **14**, 2 (2024). doi: 10.1186/s13578-023-01162-9.

Abstract

Background Attention provides the foundation for cognitions, which was shown to be affected by microwave (MW) radiation. With the ubiquitous of microwaves, public concerns regarding the impact of MW radiation on attention has hence been increased. Our study aims to investigate the potential effect and mechanism of acute microwave exposure on attention.

Results We identified obvious impairment of attention in mice by the five-choice serial reaction time (5-CSRT) task. Proteomic analysis of the cerebrospinal fluid (CSF) revealed neuroinflammation and microglial activation potentially due to acute MW exposure. Moreover, biochemical analysis further confirmed microglial activation in the prefrontal cortex (PFC) of mice subjected to acute MW exposure. Finally, minocycline, a commercially available anti-inflammatory compound, attenuated neuroinflammation, inhibited the upregulation of N-methyl-D-aspartic acid receptor (NMDAR) including NR2A and NR2B, and also accelerated the attentional recovery after MW exposure.

Conclusions We believe that microglial activation and NMDAR upregulation likely contribute to inattention induced by acute MW exposure, and we found that minocycline may be effective in preventing such process

Open access paper: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10768366/

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Detrimental effects of electromagnetic radiation emitted from cell phone on embryo morphokinetics and blastocyst viability in mice

Seify M, Khalili MA, Anbari F, Koohestanidehaghi Y. Detrimental effects of electromagnetic radiation emitted from cell phone on embryo morphokinetics and blastocyst viability in mice. Zygote. Published online 2024:1-5. doi:10.1017/S0967199424000042

Abstract

Electromagnetic radiation (EMR) has deleterious effects on sperm motility and viability, as well as oocyte membrane and organelle structure. The aim was to assess the effects of cell phone radiation on preimplantation embryo morphokinetics and blastocyst viability in mice. For superovulation, 20 female mice were treated with intraperitoneal (IP) injections of 10 IU pregnant mare's serum gonadotropin (Folligon® PMSG), followed by 10 IU of human chorionic gonadotropin (hCG) after 48 h. The zygotes (n = 150) from the control group were incubated for 4 days. The experimental zygotes (n = 150) were exposed to a cell phone emitting EMR with a frequency range 900–1800 MHz for 30 min on day 1. Then, all embryos were cultured in the time-lapse system and annotated based on time points from the 2-cell stage (t2) to hatched blastocyst (tHDyz), as well as abnormal cleavage patterns. Blastocyst viability was assessed using Hoechst and propidium iodide staining. Significant increases ($P < 0.05$) were observed in the cleavage division time points of t2, t8, t10, and t12 of the experimental group compared with the controls. In terms of blastocyst formation parameters, a delay in embryo development was observed in the experimental group compared with the controls. Data analysis of the time intervals between the two groups showed a significant difference in the s3 time interval ($P < 0.05$). Also, the rates of fragmentation, reverse cleavage, vacuole formation, and embryo arrest were significantly higher in the experimental group ($P < 0.05$). Furthermore, the cell survival rate in the experimental group was lower than the control group ($P < 0.05$). Exposure to EMR has detrimental consequences for preimplantation embryo

development in mice. These effects can manifest as defects in the cleavage stage and impaired blastocyst formation, leading to lower cell viability.

https://www.cambridge.org/core/journals/zygote/article/abs/detrimental-effects-of-electromagnetic-radiation-emitted-from-cell-phone-on-embryo-morphokinetics-and-blastocyst-viability-in-mice/BC3E03A74EC2E5E9C97D6CF6E22253A3

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Radio-tracking systems emit pulsed waves that could affect the health and alter the orientation of animals

Balmori A. Radio-tracking systems emit pulsed waves that could affect the health and alter the orientation of animals. Journal for Nature Conservation. Vol. 77. 2024, doi: 10.1016/j.jnc.2023.126520.

Abstract

Any study carried out with a given technique must avoid causing harmful effects on the experimental subjects, in order to avoid altering the survival rates of the animals or causing bias in the results of the study. Radio tagging is undoubtedly a very useful technique, and in many cases is the only option available to obtain information on the ecology and movements of wild animals, but unfortunately it has been used indiscriminately, without regard to the problems it can cause. The most well-known of these are the effects from the weight of the device and the harness, but there are others that have not yet been taken into account and that have not been sufficiently studied, such as the non-thermal effects of modulated and/or pulsed electromagnetic fields on the health and orientation of radio-tracked animals. This commentary provides a brief overview of the scientific evidence on the effects of electromagnetic fields, and underlines the importance of carrying out relevant studies in order to check for the possible effects of radio transmitters on animals.

https://www.sciencedirect.com/science/article/pii/S1617138123001917

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A study on effects of cell phone tower-emitted non-ionizing radiations in an Allium cepa test system

Sharma A, Sharma S, Bahel S, Katnoria JK. A study on effects of cell phone tower-emitted non-ionizing radiations in an Allium cepa test system. Environ Monit Assess. 2024 Feb 13;196(3):261. doi: 10.1007/s10661-024-12435-2.

Abstract

Considering enormous growth in population, technical advancement, and added reliance on electronic devices leading to adverse health effects, *in situ* simulations were made to evaluate effects of non-ionizing radiations emitted from three cell phone towers (T1, T2, and T3) of frequency bands (800, 1800, 2300 MHz), (900, 1800, 2300 MHz), and (1800 MHz), respectively. Five sites (S1–S5) were selected near cell phone towers exhibiting different power densities. The site with zero power density was considered

as control. Effects of radiations were studied on morphology; protein content; antioxidant enzymes like ascorbate peroxidase (APX), superoxide dismutase (SOD), glutathione-S-transferase (GST), guaiacol peroxidase (POD), and glutathione reductase (GR); and genotoxicity using *Allium cepa*. Mean power density ($\mu W/cm^2$) was recorded as 1.05, 1.18, 1.6, 2.73, and 12.9 for sites 1, 2, 3, 4, and 5, respectively. A significant change in morphology, root length, fresh weight, and dry weight in *Allium cepa* was observed under the exposure at different sites. Protein content of roots showed significant difference for samples at all sites while bulbs at sites S4 and S5 when compared to control. Antioxidant activity for root in terms of APX, GST, and POD showed significant changes at S4 and S5 and GR at site S5 and SOD at S1, S2, S3, S4, and S5. Similarly, bulbs showed significant changes at sites S4 and S5 for APX while at sites S3, S4, and S5 for POD and S2, S3, S4, and S5 for SOD and S5 for GR and GST. Genotoxicity study has shown induction of abnormalities at different stages of the cell cycle in *Allium cepa* root tips. The samples under exposure to radiation with maximum power density have shown maximum induction of oxidative stress and genotoxicity.

https://pubmed.ncbi.nlm.nih.gov/38349609/

Excerpts

Specific locations with cell phone towers were identified using the Tarang Sanchar portal. The power density ($\mu W/cm^2$) at different sites near towers was noted manually using an electromagnetic radiation detector (model: PCE-EM 29; make: PCE instruments, UK). Five sites were selected following the criteria of high-power density exposure and site with convenient experimental setup. Cell phone towers emitting radiations of different frequency bands, viz., 800, 1800, and 2300 MHz, for Reliance Jio 900, 1800 and 2300 MHz for Airtel, and 1800 MHz for Vodafone Idea (VI), were located at the sites of experiment. Depending upon the distance from the cell towers, five sites near towers showed the increasing order of their power density with decreasing distance. Site 1 showed a mean power density of 1.05 $\mu W/cm^2$ at a distance of 20 m from cell towers, with an angle of $\angle 16.67°$. Meanwhile, site 2 recorded a mean power density of 1.18 $\mu W/cm^2$ at a distance of 15 m, with an angle of $\angle 21.77°$. Site 3 exhibited a mean power density of 1.6 $\mu W/cm^2$ at a distance of 10 m and an angle of $\angle 30.94°$. Site 4 showed a mean power density of 2.73 $\mu W/cm^2$ at a distance of 5 m and an angle of $\angle 50.19°$. In contrast, site 5 displayed a higher mean power density of 12.9 $\mu W/cm^2$ at distance of 1 m and an angle of $\angle 80.21°$ with an average temperature recorded to be 20–24 °C and relative humidity of 45–50%. The specifics regarding the selection of the exposure sites are provided in Fig. 1. Keeping all other environmental conditions constant and altering only one parameter that is power density, the site with zero power density is designated as the control at a distance of 50 m and an angle of $\angle 6.818°$.

Conclusion

The present study clearly revealed that plant samples under exposure to electromagnetic radiations generated from cell phone towers at varied frequencies and maximum power densities had altered morphological and biochemical characteristics. The enhanced level of antioxidative enzymes like APX, GST, GR, POD, and SOD during the present study indicate the enhancement of oxidative stress and genotoxicity. The harmful effects of exposure to non-ionizing radiations were also witnessed through reduced protein content in test samples as compared to that of control. The genotoxicity studies revealed that the damage by exposure to radiations was high for root samples as compared to bulb samples indicating that root tip cells of *Allium cepa* were sensitive bioindicators to reveal toxicity of radiation pollution. This study is the first of its kind conducted in the field and reveals that further

advance research is the need of an hour for in-depth understanding and devising the effective protective measures for mitigation of the detrimental effects of radiations.

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A systematic review on cellular responses of Escherichia coli to nonthermal electromagnetic irradiation

Askaripour K, Żak A. A systematic review on cellular responses of Escherichia coli to nonthermal electromagnetic irradiation. Bioelectromagnetics. 2024 Jan;45(1):16-29. doi: 10.1002/bem.22484.

Highlights

- The present review aims to systematically evaluate literature to reach a firm conclusion on the causality between nonthermal electromagnetic radiation of alternating current and biological effects in *Escherichia coli*.
- The systematic review methodology by OHAT and the risk of bias tool evaluating the validity of experimental design and conduct within research works were followed.
- With 25 of the 114 records screened meeting the eligibility criteria, the evidence summation was performed regarding growth rate, morphology, and gene expression under exposure of extremely low frequency, intermediate frequency, or radio frequency.
- With 85% of experiments in the included studies focusing on the extremely low-frequency range, effects on growth rate, morphology, and gene expression were supported in 74%, 80%, and 33% of the experiments, respectively.

Abstract

Investigation of Escherichia coli under electromagnetic fields is of significance in human studies owing to its short doubling time and human-like DNA mechanisms. The present review aims to systematically evaluate the literature to conclude causality between 0 and 300 GHz electromagnetic fields and biological effects in E. coli. To that end, the OHAT methodology and risk of bias tool were employed. Exponentially growing cells exposed for over 30 min at temperatures up to 37◦C with fluctuations below 1◦C were included from the Web-of-Knowledge, PubMed, or EMF-Portal databases. Out of 904 records identified, 25 articles satisfied the selection criteria, with four excluded during internal validation. These articles examined cell growth (11 studies), morphology (three studies), and gene regulation (11 studies). Most experiments (85%) in the included studies focused on the extremely low-frequency (ELF) range, with 60% specifically at 50 Hz. Changes in growth rate were observed in 74% of ELF experiments and 71% of radio frequency (RF) experiments. Additionally, 80% of ELF experiments showed morphology changes, while gene expression changes were seen in 33% (ELF) and 50% (RF) experiments. Due to the limited number of studies, especially in the intermediate frequency and RF ranges, establishing correlations between EMF exposure and biological effects on E. coli is not possible.

https://pubmed.ncbi.nlm.nih.gov/37807247/

Conclusions

The present review systemically evaluates whether the current literature, passing through the risk of bias tool, while fulfilling the selection criteria defined in the PECO statement, supports an association between nonthermal electromagnetic fields and alterations in the biological composition and functioning of *E. coli* strains. The findings from the 21 included studies are dependent on the specific endpoints assessed, which include cell growth, morphology, and gene expression. The conclusions are subject to certain limitations, as the review focuses on exponentially growing strains that were exposed to nonthermal EMFs of frequencies 0–300 GHz for a minimum duration of 30 min.

In each study, it is possible that multiple experiments were conducted. Among these studies, 85% of experiments (16 articles) focused on the extremely low-frequency range, with 60% specifically examining 50 Hz. Additionally, 5% of experiments (one article) addressed the IF range, while 10% of experiments (four articles) addressed the RF range. In the investigation of nonthermal effects of extremely low-frequency electromagnetic fields (ELF-EMF), 74% of the experiments supported the effects on growth rate (investigated in nine articles), 80% supported the effects on morphology (investigated in three articles), and 33% supported the effects on gene expression (investigated in eight articles). Within the IF range, nonthermal effects on growth rate were observed in 100% of experiments (conducted in one article), but no experiments supported such effects on gene expression (investigated in one article). In the RF range, 71% of experiments supported nonthermal effects on growth rate (conducted in two articles), while 50% supported nonthermal effects on gene expression (conducted in two articles). Therefore, due to the limited number of studies available on the IF and RF ranges, the reliability of the results may primarily apply to ELF-EMF, particularly at 50 Hz.

When experiments demonstrated biological effects, the observed pattern varied as either beneficial or detrimental, depending on the exposure conditions and experimental setup. For example, out of 38 experiments on growth rate, 12 showed beneficial effects while 16 showed detrimental effects. This controversy can be explained by the concept of the *biological window*, in which EMF may contribute to positive physiological processes. However, if the accumulated exposure exceeds the cell-specific energy limit, detrimental effects may prevail. Several sources exhibited inconsistencies when observing these effects.

In terms of exposure parameters, continuity, referring to intermittent or continuous status, had a significant effect on the results, with pulsed signals showing a greater impact compared to sinusoidal signals. Extremely low frequencies and radio frequencies had a major impact on the investigated endpoints, while intermediate frequencies have received limited research attention. The intensity and duration of exposure influenced the absorbed energy levels, resulting in varying effects ranging from beneficial to neutral or detrimental. Modulation may introduce significant differences compared to unmodulated signals, depending on the modulation frequency. The optimal measurement time point depends on the specific endpoint and necessitates mechanistic understanding for accurate identification.

Special attention is needed regarding sufficient and clear reports on the amount of electromagnetic irradiation absorbed by the strains, as it can make the quantitative comparison between studies possible, and discriminate between nondetrimental or detrimental effects. Besides, special attention to the background electromagnetic irradiation as a confounder and the measurement time point for allowing the outcome to develop is required. Deficiencies associated with the risk of bias including *research personnel blinded to the study group*, *randomization of exposure*, *allocation concealment*, *attrition/exclusion bias*, and their possible effect on the outcome should be considered. More mechanistic investigations regarding cellular processes and their related genes are demanded.

Based on the limited number of studies encompassing three different frequency ranges and three different endpoints, the systematic review does not establish a conclusive correlation between nonthermal exposure to electromagnetic fields and cellular alterations in *E. coli* strains. However, future research could explore this correlation more specifically, considering the similarity of endpoints and levels of exposure between *E. coli* and humans. This exploration would help shed light on the potential implications of these effects on human health.

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On the Quasistationarity of the Ambient Electromagnetic Field Generated by Wi-Fi Sources

Tuță L, Roșu G, Andone A, Spandole-Dinu S, Fichte LO. On the Quasistationarity of the Ambient Electromagnetic Field Generated by Wi-Fi Sources. *Electronics*. 2024; 13(2):301. doi:10.3390/electronics13020301.

Abstract

In recent decades, the widespread use of mobile phones and wireless technologies has led to a significant increase in radiofrequency electromagnetic fields (RF-EMFs), raising concerns about continuous RF-EMF exposure among the general population. Recent research indicates that real-life RF signals are more biologically active than controlled laboratory signals with a low variability, suggesting that living organisms can adapt to EMF exposure when the pattern has a low variability. However, using real-life sources with unpredictable variation signals in biological experiments contradicts the principle of experiment controllability. This paper aims to investigate the nature of signals generated by current sources of ambient EMFs in terms of stationarity, with the goal of replicating them in biological experiments to study the effects of EMF exposure. Employing a range of statistical methodologies, starting with descriptive statistical analysis and progressing to the advanced APDP and APTF methods, an examination is conducted on a collection of Wi-Fi signal recordings across various operating modes, with particular attention given to video streaming. The chosen datasets are scrutinized with respect to their adherence to a Gaussian distribution and the concept of stationarity. The results indicate that the observed Wi-Fi signals lack stationarity in both the time and frequency domains. However, based on the analytical findings, it is possible to generate signals in frequency that authentically replicate Wi-Fi signals, accounting for nonstationarity considerations.

Conclusions

The stationarity of electromagnetic emission sources, particularly those generating time-varying EMFs, can significantly impact living organisms. Exposure to nonstationary sources with dynamic signals limits an organism's ability to adapt to the changing stimulus. The consideration that real-life source signals may be more biologically active raises concerns about the accuracy and relevance of laboratory sources in experiments studying the effects of RF-EMF exposure. However, using real-life sources with unpredictable variations contradicts the principle of experiment controllability. The investigation into the impact of Wi-Fi routers on living organisms is crucial, as these emission sources exhibit either weak stationarity or nonstationarity, potentially leading to adverse effects on human health.

The paper describes the examination of temporal variations in ambient electromagnetic exposure emanating from Wi-Fi communication devices which involves the application of diverse statistical

methodologies. The objective is to ascertain the stationarity of these signals. The ultimate outcome aims to produce laboratory-controlled signals that faithfully replicate the authentic variability observed in real-life signals generated by Wi-Fi communication devices.

Several datasets were obtained from various frequency-domain measurements with a spectrum analyzer. A stationarity analysis was performed for the measured datasets, in both time and frequency domains, using the ADPD and APTF methods.

The findings derived from the analysis using APTF and APDP indicate that the observed Wi-Fi signals lack stationarity in both the time and frequency domains. This outcome poses a challenge with respect to simulating Wi-Fi signals, suggesting that the incorporation of modulations exclusive to the 802.11 standards (OFDM and DSSS), along with the introduction of Gaussian noise, may prove insufficient for an accurate emulation of authentic Wi-Fi signals.

We suggest, in this case, simulating the spectrum analyzer measurement by generating vectors from the Pearson system of distributions, with statistical parameters that correspond to practical measurements. The quality of these simulated Wi-Fi waveforms will depend on the measurements used to train the algorithm. These waveforms could be used for further EMF investigation by generating them using a portable SDR device, without requiring a Wi-Fi router with Internet access.

Open access paper: https://www.mdpi.com/2079-9292/13/2/301

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Changes in honey bee nutrition after exposure to radiofrequency electromagnetic field

Migdal P, Plotnik M, Bieńkowski P, Murawska A, Berbeć E, Sobkiewicz P, Zarębski K, Latarowski K (2024). Changes in honey bee nutrition after exposure to radiofrequency electromagnetic field. The European Zoological Journal, 91:1, 172-179. doi: 10.1080/24750263.2024.2308550.

Abstract

Urban beekeeping has gained interest in recent years. Bees placed in cities, on the roofs of buildings, are exposed to many different sources of electromagnetic fields of different frequencies and intensities. Knowledge about the impact of electromagnetic fields on the physiology and behavior of insects (including honey bees) is limited. Hence, one of the first steps was to check how radiofrequency electromagnetic fields affect honey bees' nutrition. The level of total proteins, glucose, triglycerides, and TAS activity in bee hemolymph was analyzed. This is because they indicate the honey bee's nutrition level. The experiment involved 2-day-old Carniolan worker honey bees (*Apis mellifera carnica* L.). The bees were exposed to fields of 12 V/m, 28 V/m, and 61 V/m for 0.25, 1 and 3 h. Hemolymph was taken from 40 alive worker honey bees from each group immediately after exposure, by removing the antennae with sterile tweezers. The activity of biochemical markers (total proteins, TAS, and triglycerides) in the bee hemolymph in 12 V/m and 28 V/m groups showed statistically significant differences compared to the control group in most cases. According to our own research, radiofrequency electromagnetic fields disturb honey bee nutrition. The changes in the analyzed indicators may have long-term effects.

Open access paper: https://www.tandfonline.com/doi/full/10.1080/24750263.2024.2308550

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Studies of the Electromagnetic Background at the Antarctic Vostok Station

Shurshakov VA, Belov EV, Ilyin EA, *et al.* Studies of the Electromagnetic Background at the Antarctic Vostok Station. *Hum Physiol* **49**, 906–909 (2023). doi: 10.1134/S0362119723070216.

Abstract

The electromagnetic background was measured in the living quarters of the Vostok Station located on the Antarctic plateau distant from the potential sources of technogenic electromagnetic fields. The level of E-radiation in the range from 0.8 to 8 GHz was determined using a MERA integral dosimeter. Based on the results of long-term continuous (one to 4 months) measurements, the mean flux density was equal to 1.5 ± 0.8 nWt/cm, which is nearly 7000 times lower than the admissible level for population adopted in Russia. The Antarctic Vostok Station can be considered as a plausible location for biomedical investigations into the effects of low-frequency electromagnetic radiation.

Conclusions

(1) The EFD values of technogenic EMR in the living quarters of the Vostok Station are 7 thousand times below the regulatory standards for EMR in the Russian Federation. This fact indicates that the long-term stay of people at the Vostok Station is safe as regards the sanitary standards for EMR. [The Russian regulatory standards for EMR 0.3–300 GHz are 1000 μW/cm^2 for personnel and 10 μW/cm^2 for the population.]

(2) The daily dynamics of the main frequencies in EMR EFD variability and its dependence on solar activity have been revealed.

(3) Since the members of polar expeditions at the Vostok Station perform daily outdoor work (up to 1.5 h), it would be reasonable for future expeditions to measure the EFD of EMR in an open area, which will allow estimating the natural (background) level of EMR EFD in the vicinity of the station.

The Antarctic Vostok Station can be considered as one of the possible places for conducting biomedical research under the conditions of reduced electromagnetic radiation flux.

Open access paper: https://link.springer.com/article/10.1134/S0362119723070216

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Shortwave radiation-induced reproductive organ damage in male rats by enhanced expression of molecules associated with the calpain/Cdk5 pathway and oxidative stress

Yao B, Men J, Liu S, Bai Y, Yu C, Gao Y, Xu X, Zhao L, Zhang J, Wang H, Li Y, Peng R. Shortwave radiation-induced reproductive organ damage in male rats by enhanced expression of molecules associated with the calpain/Cdk5 pathway and oxidative stress. Electromagn Biol Med. 2023 Oct 2;42(4):150-162. doi: 10.1080/15368378.2023.2296896.

Abstract

Shortwave radiation has been reported to have harmful effects on several organs in humans and animals. However, the biological effects of 27 MHz shortwave on the reproductive system are not clear. In this study, we investigated the effects of shortwave whole-body exposure at a frequency of 27 MHz on structural and functional changes in the testis. Male Wistar rats were exposed to **27 MHz continuous shortwaves at average power densities of 0, 5, 10, or 30 mW/cm^2 for 6 min**. The levels of insulin-like factor 3 (INSL3) and anti-sperm antibodies (AsAb) in the peripheral serum, sperm motility, sperm malformation rate, and testicular tissue structure of rats were analyzed. Furthermore, the activity of superoxide dismutase (SOD), catalase (CAT), malondialdehyde (MDA) content, calpain, and Cdk5 expression were analyzed at 1, 7, 14, and 28 days after exposure. We observed that the rats after radiation had decreased serum INSL3 levels ($p < 0.01$), increased AsAb levels ($p < 0.05$), decreased percentage of class A+B sperm ($p < 0.01$ or $p < 0.05$), increased sperm malformation ($p < 0.01$ or $p < 0.05$), injured testicular tissue structure, decreased SOD and CAT activities ($p < 0.01$ or $p < 0.05$), increased MDA content ($p < 0.01$), and testicular tissue expressions of calpain1, calpain2, and Cdk5 were increased ($p < 0.01$ or $p < 0.05$). In conclusion, Shortwave radiation caused functional and structural damage to the reproductive organs of male rats. Furthermore, oxidative stress and key molecules in the calpain/Cdk5 pathway are likely involved in this process.

Plain language summary

Shortwave radiation has been used in communications, medical and military applications, and its damaging effects on several organs of the human body have been reported in the literature. However, the biological effects of shortwave radiation on the male reproductive system are unknown. The present study, by constructing an animal model of short-wave radiation and analyzing the experimental results, revealed that shortwave radiation could cause functional and structural damage to the reproductive organs of male rats, and that oxidative stress and key molecules in the calpain/Cdk5 pathway might be involved in this process. It will provide organizational data for further studies on the mechanisms of male reproductive damage by shortwave radiation.

https://pubmed.ncbi.nlm.nih.gov/38155529/

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Effects of 3.5-GHz radiofrequency radiation on energy-regulatory hormone levels in the blood and adipose tissue

Bektas H, Dasdag S, Altindag F, Akdag MZ, Yegin K, Algul S. Effects of 3.5-GHz radiofrequency radiation on energy-regulatory hormone levels in the blood and adipose tissue. Bioelectromagnetics. 2024 Feb 18. doi: 10.1002/bem.22498.

Abstract

In recent years exposure of living beings to radiofrequency radiation (RFR) emitted from wireless equipment has increased. In this study, we investigated the effects of 3.5-GHz RFR on hormones that regulate energy metabolism in the body. Twenty-eight rats were divided into four groups: healthy sham (n = 7), healthy RFR (n = 7), diabetic sham (n = 7), and diabetic RFR (n = 7). Over a month, each group

spent 2 h/day in a Plexiglas carousel. The rats in the experimental group were exposed to RFR, but the sham groups were not. At the end of the experiment, blood and adipose tissues were collected from euthanized rats. Total antioxidant, total oxidant, hydrogen peroxide, ghrelin, nesfatin-1, and irisin were determined. Insulin expression in pancreatic tissues was examined by immunohistochemical analysis. Whole body specific absorption rate was 37 mW/kg. For the parameters analyzed in blood and fat, the estimated effect size varied within the ranges of 0.215-0.929 and 0.503-0.839, respectively. The blood and adipose nesfatin-1 ($p = 0.002$), blood and pancreatic insulin are decreased, ($p = 0.001$), gherelin ($p = 0.020$), irisin ($p = 0.020$), and blood glucose ($p = 0.040$) are increased in healthy and diabetic rats exposed to RFR. While nesfatin-1 are negatively correlated with oxidative stress, hyperglycemia and insulin, ghrelin and irisin are positively correlated with oxidative stress and hyperglycemia. Thus, RFR may have deleterious effects on energy metabolism, particularly in the presence of diabetes.

https://pubmed.ncbi.nlm.nih.gov/38369591/

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Evidence of spatial clustering of childhood acute lymphoblastic leukemia cases in Greater Mexico City: report from the Mexican Inter-Institutional Group for the identification of the causes of childhood leukemia

Duarte-Rodríguez DA, Flores-Lujano J, McNally RJQ, Pérez-Saldivar ML, Jiménez-Hernández E, Martín-Trejo JA, Espinoza-Hernández LE, Medina-Sanson A, Paredes-Aguilera R, Merino-Pasaye LE, Velázquez-Aviña MM, Torres-Nava JR, Espinosa-Elizondo RM, Amador-Sánchez R, Dosta-Herrera JJ, Mondragón-García JA, González-Ulibarri JE, Martínez-Silva SI, Espinoza-Anrubio G, Paz-Bribiesca MM, Salcedo-Lozada P, Landa-García RÁ, Ramírez-Colorado R, Hernández-Mora L, Santamaría-Ascencio M, López-Loyola A, Godoy-Esquivel AH, García-López LR, Anguiano-Ávalos AI, Mora-Rico K, Castañeda-Echevarría A, Rodríguez-Jiménez R, Cibrian-Cruz JA, Solís-Labastida KA, Cárdenas-Cardos R, López-Santiago N, Flores-Villegas LV, Peñaloza-González JG, González-Ávila AI, Sánchez-Ruiz M, Rivera-Luna R, Rodríguez-Villalobos LR, Hernández-Pérez F, Olvera-Durán JÁ, García-Cortés LR, Mata-Rocha M, Sepúlveda-Robles OA, Bekker-Méndez VC, Jiménez-Morales S, Meléndez-Zajgla J, Rosas-Vargas H, Vega E, Núñez-Enríquez JC, Mejía-Aranguré JM. Evidence of spatial clustering of childhood acute lymphoblastic leukemia cases in Greater Mexico City: report from the Mexican Inter-Institutional Group for the identification of the causes of childhood leukemia. Front Oncol. 2024 Feb 14;14:1304633. doi: 10.3389/fonc.2024.1304633

Abstract

Background: A heterogeneous geographic distribution of childhood acute lymphoblastic leukemia (ALL) cases has been described, possibly, related to the presence of different environmental factors. The aim of the present study was to explore the geographical distribution of childhood ALL cases in Greater Mexico City (GMC).

Methods: A population-based case-control study was conducted. Children <18 years old, newly diagnosed with ALL and residents of GMC were included. Controls were patients without leukemia recruited from second-level public hospitals, frequency-matched by sex, age, and health institution with the cases. The residence address where the patients lived during the last year before diagnosis (cases) or the interview (controls) was used for geolocation. Kulldorff's spatial scan statistic was used to detect spatial clusters (SCs). Relative risks (RR), associated p-value and number of cases included for each cluster were obtained.

Results: A total of 1054 cases with ALL were analyzed. Of these, 408 (38.7%) were distributed across eight SCs detected. A relative risk of 1.61 ($p<0.0001$) was observed for the main cluster. Similar results were noted for the remaining seven ones. Additionally, a proximity between SCs, electrical installations and petrochemical facilities was observed.

Conclusions: The identification of SCs in certain regions of GMC suggest the possible role of environmental factors in the etiology of childhood ALL.

Open access paper:
https://www.frontiersin.org/journals/oncology/articles/10.3389/fonc.2024.1304633/full

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International study of childhood leukemia in residences near electrical transformer rooms

Crespi CM, Sudan M, Juutilainen J, Roivainen P, Hareuveny R, Huss A, Kandel S, Karim-Kos HE, Thuróczy G, Jakab Z, Spycher BD, Flueckiger B, Vermeulen R, Vergara X, Kheifets L. International study of childhood leukemia in residences near electrical transformer rooms. Environ Res. 2024 Feb 10:118459. doi: 10.1016/j.envres.2024.118459.

Abstract

Objectives: New epidemiologic approaches are needed to reduce the scientific uncertainty surrounding the association between extremely low frequency magnetic fields (ELF-MF) and childhood leukemia. While most previous studies focused on power lines, the Transformer Exposure study sought to assess this association using a multi-country study of children who had lived in buildings with built-in electrical transformers. ELF-MF in apartments above built-in transformers can be 5 times higher than in other apartments in the same building. This novel study design aimed to maximize the inclusion of highly exposed children while minimising the potential for selection bias.

Methods: We assessed associations between residential proximity to transformers and risk of childhood leukemia using registry based matched case-control data collected in five countries. Exposure was based on the location of the subject's apartment relative to the transformer, coded as high (above or adjacent to transformer), intermediate (same floor as apartments in high category), or unexposed (other apartments). Relative risk (RR) for childhood leukemia was estimated using conditional logistic and mixed logistic regression with a random effect for case-control set.

Results: Data pooling across countries yielded 16 intermediate and 3 highly exposed cases. RRs were 1.0 (95% CI: 0.5, 1.9) for intermediate and 1.1 (95% CI: 0.3, 3.8) for high exposure in the conditional logistic model. In the mixed logistic model, RRs were 1.4 (95% CI: 0.8, 2.5) for intermediate and 1.3 (95% CI: 0.4, 4.4) for high. Data of the most influential country showed RRs of 1.1 (95% CI: 0.5, 2.4) and 1.7 (95% CI: 0.4, 7.2) for intermediate (8 cases) and high (2 cases) exposure.

Discussion: Overall, evidence for an elevated risk was weak. However, small numbers and wide confidence intervals preclude strong conclusions and a risk of the magnitude observed in power line studies cannot be excluded.

https://pubmed.ncbi.nlm.nih.gov/38346482/

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The role of curcumin during pregnancy on the exposed fetuses' tissues of Wistar rats to electromagnetic field

Kalantar MH, Bayat PD, Ghaffari Khaligh S, Soleimani H. The role of curcumin during pregnancy on the exposed fetuses' tissues of Wistar rats to electromagnetic field. Electromagn Biol Med. 2024 Feb 17:1-10. doi: 10.1080/15368378.2024.2315214.

Abstract

To investigate curcumin (CUR) as the protector against the harmful effects of low-frequency electromagnetic field(LF- EMF, 50 Hz) during pregnancy period, 5 males and 15 females of Wistar rat mated and vaginal plaques were observed. Then, the pregnant rats were divided into six groups. During pregnancy(21 days), the EMF group was exposed to EMF for 30 min/day, the CUR group received a single dose of 50 mg/kg/daily CUR intraperitoneal, the EMF+CUR group was injected CUR and exposed to EMF daily. The DMSO(dimethyl sulfoxide) group was injected solvent of CUR (DMSO) intraperitoneal with the same volume of CUR solvent, the sham group was placed through the solenoid in the same conditions as the first group without exposure and the control group was kept in their cage in normal condition. After four weeks, babies born were divided according to the mother groups and sacrificed. Then, the three tissues injuries were investigated. EMF exposure led to an increase in outstanding necrotic areas in hippocampal tissue, an increase in the amount of hyperemia(p = 0.017) and necrotic(p = 0.005) in kidneys, and degeneration in liver tissue(p = 0.007) in the EMF group compared with EMF+CUR groups. A single dose of CUR daily during pregnancy can protect these tissues from injuries caused by LF-EMF exposure in rat fetuses.

Plain language summary

Electromagnetic fields (EMFs) are able to penetrate and be absorbed by the body. The researchers showed that these radiations might be harmful and lead to cancers, cardiovascular diseases, mental disorders, and fetal abnormalities. Curcumin as an active component in turmeric has anti-inflammatory, antioxidant and anti-hyperlipidemia properties. It can protect the body against diseases such as arthritis, anxiety, and metabolic syndrome. This study examined the effects of curcumin as the protector against the harmful effects of EMF (50Hz) during pregnancy period. So the pregnant rats were divided into six groups. During pregnancy, a group was exposed to EMF for 30 min/day, the second group was injected a dose of curcumin 50mg/kg/daily, the third group was injected curcumin and exposed to EMF daily. The fourth group was injected a curcumin solvent dose, the sham group was placed through the field generator in the same conditions as the first group without exposure and the control group was kept in their cage in normal condition. After four weeks, babies born were divided according to the mother groups and sacrificed. Then, the liver, kidney, and hippocampal tissues were investigated. EMF exposure led to an outstanding increase in necrotic areas in hippocampal tissue, a notable increase in the amount of hyperemia and necrosis in kidneys, and degeneration in liver tissue(p=0.007) in the EMF group compared with the third group that was exposed to EMF and received curcumin. A single dose of curcumin daily during pregnancy can protect these tissues from injuries caused by EMF(50Hz) exposure in rat fetuses.

https://pubmed.ncbi.nlm.nih.gov/38366892/

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Extremely low-frequency EMF facilitate both osteoblast and osteoclast activity through Wnt/β-catenin signaling in the zebrafish scale

Kobayashi-Sun J, Kobayashi I, Kashima M, Hirayama J, Kakikawa M, Yamada S, Suzuki N. Extremely low-frequency electromagnetic fields facilitate both osteoblast and osteoclast activity through Wnt/β-catenin signaling in the zebrafish scale. Front Cell Dev Biol. 2024 Feb 7;12:1340089. doi: 10.3389/fcell.2024.1340089.

Abstract

Electromagnetic fields (EMFs) have received widespread attention as effective, noninvasive, and safe therapies across a range of clinical applications for bone disorders. However, due to the various frequencies of devices, their effects on tissues/cells are vary, which has been a bottleneck in understanding the effects of EMFs on bone tissue. Here, we developed an *in vivo* model system using zebrafish scales to investigate the effects of extremely low-frequency EMFs (ELF-EMFs) on fracture healing. Exposure to 10 millitesla (mT) of ELF-EMFs at 60 Hz increased the number of both osteoblasts and osteoclasts in the fractured scale, whereas 3 or 30 mT did not. Gene expression analysis revealed that exposure to 10 mT ELF-EMFs upregulated *wnt10b* and Wnt target genes in the fractured scale. Moreover, *β*-catenin expression was enhanced by ELF-EMFs predominantly at the fracture site of the zebrafish scale. Inhibition of Wnt/*β*-catenin signaling by IWR-1-endo treatment reduced both osteoblasts and osteoclasts in the fractured scale exposed to ELF-EMFs. These results suggest that ELF-EMFs promote both osteoblast and osteoclast activity through activation of Wnt/*β*-catenin signaling in fracture healing. Our data provide *in vivo* evidence that ELF-EMFs generated with a widely used commercial AC power supply have a facilitative effect on fracture healing.

Open access paper: https://www.frontiersin.org/articles/10.3389/fcell.2024.1340089/full

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Influence of Magnetic Fields, Including the Planetary Magnetic Field, on Complex Life Forms: How Do Biological Systems Function in This Field and in Electromagnetic Fields?

Hart DA. The Influence of Magnetic Fields, Including the Planetary Magnetic Field, on Complex Life Forms: How Do Biological Systems Function in This Field and in Electromagnetic Fields? *Biophysica*. 2024; 4(1):1-21. doi: 10.3390/biophysica4010001.

Abstract
Life on Earth evolved to accommodate the biochemical and biophysical boundary conditions of the planet millions of years ago. The former includes nutrients, water, and the ability to synthesize other needed chemicals. The latter includes the 1 g gravity of the planet, radiation, and the geomagnetic field (GMF) of the planet. How complex life forms have accommodated the GMF is not known in detail, considering that Homo sapiens evolved a neurological system, a neuromuscular system, and a cardiovascular system that developed electromagnetic fields as part of their functioning. Therefore, all

of these could be impacted by magnetic fields. In addition, many proteins and physiologic processes utilize iron ions, which exhibit magnetic properties. Thus, complex organisms, such as humans, generate magnetic fields, contain significant quantities of iron ions, and respond to exogenous static and electromagnetic fields. Given the current body of literature, it remains somewhat unclear if Homo sapiens use exogenous magnetic fields to regulate function and what can happen if the boundary condition of the GMF no longer exerts an effect. Proposed deep space flights to destinations such as Mars will provide some insights, as space flight could not have been anticipated by evolution. The results of such space flight "experiments" will provide new insights into the role of magnetic fields on human functioning. This review will discuss the literature regarding the involvement of magnetic fields in various normal and disturbed processes in humans while on Earth and then further discuss potential outcomes when the GMF is no longer present to impact host systems, as well as the limitations in the current knowledge. The GMF has been present throughout evolution, but many details of its role in human functioning remain to be elucidated, and how humans have adapted to such fields in order to develop and retain function remains to be elucidated. Why this understudied area has not received the attention required to elucidate the critical information remains a conundrum for both health professionals and those embarking on space flight. However, proposed deep space flights to destinations such as Mars may provide the environments to test and assess the potential roles of magnetic fields in human functioning.

Open access paper: https://www.mdpi.com/2673-4125/4/1/1

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Do electromagnetic fields from subsea power cables effect benthic elasmobranch behaviour? A risk-based approach for the Dutch Continental Shelf

Hermans A, Winter HV, Gill AB, Murk AJ. Do electromagnetic fields from subsea power cables effect benthic elasmobranch behaviour? A risk-based approach for the Dutch Continental Shelf. Environ Pollut. 2024 Feb 13:123570. doi: 10.1016/j.envpol.2024.123570.

Abstract

Subsea power cables cause electromagnetic fields (EMFs) into the marine environment. Elasmobranchs (rays, skates, sharks) are particularly sensitive to EMFs as they use electromagnetic-receptive sensory systems for orientation, navigation, and locating conspecifics or buried prey. Cables may intersect with egg laying sites, mating, pupping, and nursery grounds, foraging habitat and migration routes of elasmobranchs and the effects of encountering EMFs on species of elasmobranchs are largely unknown. Demonstrated behavioural effects are attraction, disturbance and indifference, depending on EMF characteristics, exposed life stage, exposure level and duration. We estimated exposure levels of elasmobranchs to subsea power cable EMFs, based on modelled magnetic fields in the Dutch Continental Shelf and compared these to reported elasmobranch sensory sensitivity ranges and experimental effect levels. We conclude that the risk from subsea power cables has a large uncertainty and varies per life stage and species ecology. Based on estimated no-observed effect levels (from 10^{-3} to 10^{-1} μT) we discuss what will probably be the most affected species and life stage for six common benthic elasmobranchs in the Southern North Sea. We then identify critical knowledge gaps for reducing the uncertainty in the risk assessments for EMFs effects on benthic elasmobranchs.

https://pubmed.ncbi.nlm.nih.gov/38360387/

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A Boundary Element Method of Bidomain Modeling for Predicting Cellular Responses to Electromagnetic Fields

Czerwonky DM, Aberra AS, Gomez LJ. A Boundary Element Method of Bidomain Modeling for Predicting Cellular Responses to Electromagnetic Fields. bioRxiv [Preprint]. 2023 Dec 16:2023.12.15.571917. doi: 10.1101/2023.12.15.571917. (preprint, not peer-reviewed)

Abstract
Objective: Commonly used cable equation-based approaches for determining the effects of electromagnetic fields on excitable cells make several simplifying assumptions that could limit their predictive power. Bidomain or "whole" finite element methods have been developed to fully couple cells and electric fields for more realistic neuron modeling. Here, we introduce a novel bidomain integral equation designed for determining the full electromagnetic coupling between stimulation devices and the intracellular, membrane, and extracellular regions of neurons.

Methods: Our proposed boundary element formulation offers a solution to an integral equation that connects the device, tissue inhomogeneity, and cell membrane-induced E-fields. We solve this integral equation using first-order nodal elements and an unconditionally stable Crank-Nicholson time-stepping scheme. To validate and demonstrate our approach, we simulated cylindrical Hodgkin-Huxley axons and spherical cells in multiple brain stimulation scenarios.

Main results: Comparison studies show that a boundary element approach produces accurate results for both electric and magnetic stimulation. Unlike bidomain finite element methods, the bidomain boundary element method does not require volume meshes containing features at multiple scales. As a result, modeling cells, or tightly packed populations of cells, with microscale features embedded in a macroscale head model, is made computationally tractable, and the relative placement of devices and cells can be varied without the need to generate a new mesh.

Significance: Device-induced electromagnetic fields are commonly used to modulate brain activity for research and therapeutic applications. Bidomain solvers allow for the full incorporation of realistic cell geometries, device E-fields, and neuron populations. Thus, multi-cell studies of advanced neuronal mechanisms would greatly benefit from the development of fast-bidomain solvers to ensure scalability and the practical execution of neural network simulations with realistic neuron morphologies.

Open access paper: https://www.biorxiv.org/content/10.1101/2023.12.15.571917v1

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Static magnetic fields as a factor in modification of tissue and cell structure: a review

Saletnik BA, Puchalska-Sarna A, Saletnik A, Lipa T, Dobrzański B, Puchalski C. Static magnetic fields as a factor in modification of tissue and cell structure: a review. *Int. Agrophys.* 2024;38(1):43-75. doi:10.31545/intagr/176998.

Highlights

- The static magnetic field (SMF) is an indispensable factor in the natural environment.
- A moderate SMF in the most commonly used range of 2–80 mT has a potential application in the formation and re-modeling of plants and animals, including human cells.
- SMFs can significantly change the potential of the cell membrane, and thus can have a significant impact on the properties of the cell.

Abstract

This review is intended to contribute to the evidence of the effects of static magnetic field on cells and tissue, as well as to present research results that will elucidate the complex matters involved in the formation and remodeling of cells. The cell characteristics studied in the papers that are reviewed include cell viability and proliferation, aggregation and their differentiation, structure and membrane potential. A moderate static magnetic field in the most commonly used range of 2-80 mT has potential application in the formation and remodeling of plant and human cells. However, in the case of cancer cells, the range of fields commonly used was 0.2-9 T. Magnetism promotes changes in plant cell growth, which prompts the cell to proliferate, thereby ensuring an increased rate of biomass production. Some research presented the enhancement of the differentiation of plant cells and skeletal muscle tissue by over 30% at 80 mT static magnetic field. Changes in the cell cycle and growth reflect directly on the cell number and viability and provide useful information to detect modifications in the cell machinery. Static magnetic field, depending on its intensity, enhances cell proliferation and thus may improve, among other processes, tissue regeneration, wound healing and the inhibition of cancer cell proliferation. Researchers showed, among other things, that cells under the influence of static magnetic field changed their shape, had a larger chloroplast, stiffer cell wall, density of the cytoskeleton and cytoplasm contained several mitochondria. Numerous studies also discussed the behavior of the cell membrane of plant and animal organisms, including humans, under the influence of a static magnetic field. The effects of static magnetic field on the cell membrane of plant and human cells were similar. The research results indicate that static magnetic fields can significantly change membrane depolarization and its potential that regulates ion movement and thus can have a significant impact on the properties and biological functionality of the cell. Studies have shown that continuous application of static magnetic field caused deformation and damage of cell membrane. Based on the theoretical analyses presented also in this review, it can be concluded that static magnetic field affects cells and tissue, giving them changes in properties and behaviors and modulates, e.g. in the activity of ion channels. Thus it may produce effects leading to changes in the functioning of the cell. It is possible to formulate directions for further research aimed at using static magnetic fields for the non-invasive remodeling and formation of plant and human cells.

Open access paper: http://www.international-agrophysics.org/Static-magnetic-fields-as-a-factor-in-modification-of-tissue-and-cell-structure-a,176998,0,2.html

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The biological effects of terahertz wave radiation-induced injury on neural stem cells

Wang Y, Xiong Y, Chen M, Liu F, He H, Ma Q, Gao P, Xiang G, Zhang L. The biological effects of terahertz wave radiation-induced injury on neural stem cells. iScience. 2023 Jul 18;26(10):107418. doi: 10.1016/j.isci.2023.107418.

Abstract

Terahertz (THz) is an electromagnetic wave with a radiation wavelength range of 30-3000 μm and a frequency of 0.1-10 THz. With the development of new THz sources and devices, THz has been widely applied in various fields. However, there are few studies on biological effects of THz irradiation on the human neural stem cells (hNSCs) and mouse neural stem cells (mNSCs), which need to be further studied. We studied the biological effects of THz radiation on hNSCs and mNSCs. The effects of THz irradiation time and average output power on the proliferation, apoptosis, and DNA damage of NSCs were analyzed by flow cytometry and immunofluorescence. The results showed that the proliferation and apoptosis of NSCs were dose-dependently affected by THz irradiation time and average output power. The proliferation of hNSCs was more vulnerable to damage and apoptosis was more serious under the same terahertz irradiation conditions compared to those of mNSCs.

Open access paper: https://www.cell.com/iscience/fulltext/S2589-0042(23)01495-5