Source:
UC Berkeley School of Public Health: https://www.saferemr.com/2015/09/effect-of-mobile-phones-on-sperm.html

Monday, January 26, 2026

Effect of Mobile Phones on Sperm Quality

See the bottom of this page for links to more than 60 studies.

Gautam R, Arora T. Radio Frequency Electromagnetic Radiation (RF-EMR) Emitted from Mobile Phone and its Impact on Male Reproductive Health. EIACP: Diversity and Impact on the Environment. 28(3):8-11. 2023.

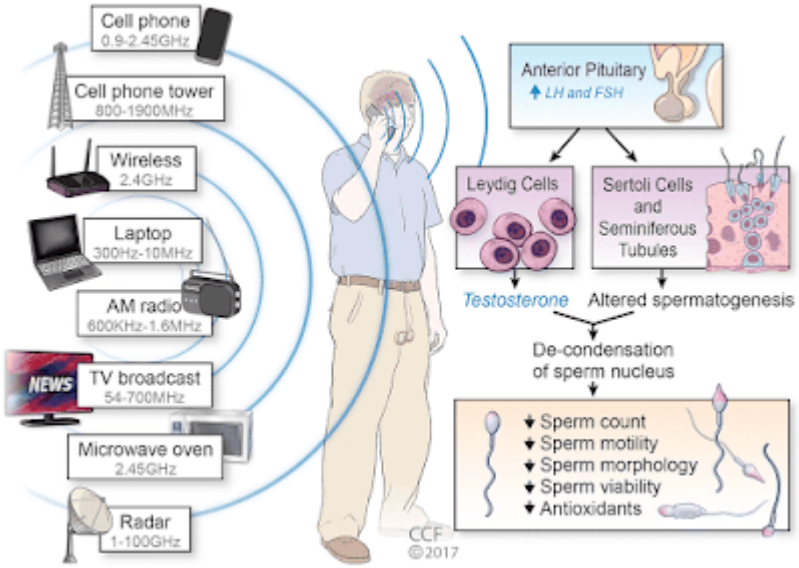


Diagram representing various sources of RF EMF exposure effect on brain and testicular organ and deleterious outcomes (Kesari, Agarwal & Henkel, 2018)

Summary

In the past decade, 15 reviews of the research on the effects of mobile phone radiation published in peer-reviewed journals found systematic evidence of harmful effects from radio frequency radiation on sperm count, mobility, morphology, and/or viability (see abstracts below). Most of these reviews recommended keeping cell phones away from our bodies, especially our reproductive organs.

In contrast, one systematic review that excluded 60% of the studies concluded, "RF-EMF may affect testicular tissue and sperm quality but the evidence is uncertain" (Cordelli et al., 2024). This review was commissioned by the WHO for an upcoming **monograph on the effects of radio frequency radiation**.

Review Papers

Non-thermal biological effects of radiofrequency electromagnetic radiation:
Mechanistic insights into male reproductive vulnerability in the era of ubiquitous exposure

Jangid P, Rai U, Ahmed S, Singh S, Singh R. Non-thermal biological effects of radiofrequency electromagnetic radiation: Mechanistic insights into male reproductive vulnerability in the era of ubiquitous exposure. Reproductive Toxicology, Volume 138, 2025. doi:10.1016/j.reprotox.2025.109087.

Abstract

The rapid proliferation of wireless technologies has led to continuous, low-intensity exposure to radiofrequency electromagnetic radiation (RF-EMR) from devices such as mobile phones, Wi-Fi routers, and wearable electronics. Although RF-EMR is non-ionizing, a growing body of evidence indicates that chronic exposure can induce non-thermal biological effects with significant implications for male reproductive health. This review synthesizes current findings on the mechanistic pathways through which RF-EMR may impair fertility, focusing on oxidative stress, mitochondrial dysfunction, DNA damage, apoptosis, autophagy dysregulation, and hormonal disruption via hypothalamic-pituitary-gonadal (HPG) axis interference. Experimental and clinical studies consistently link RF-EMR exposure to reduced sperm count and motility, altered testicular architecture, blood-testis barrier compromise, and suppressed testosterone synthesis, often at specific absorption rates below current safety thresholds. These outcomes are underpinned by redox imbalance, mitochondrial collapse, and steroidogenic impairment, with emerging evidence for epigenetic and transgenerational effects. Existing regulatory frameworks, based largely on thermal safety limits, fail to address the complexity of real-world, multi-source, long-term exposures. The review highlights critical knowledge gaps, particularly regarding 5 G and millimeter-wave frequencies, and underscores the need for standardized research protocols, biologically relevant exposure metrics, and precautionary public health measures to mitigate reproductive risks in an increasingly wireless environment.

Highlights

- RF-EMR triggers oxidative stress in male reproductive cells.
- Leydig cell mitochondria are highly sensitive to RF exposure.
- RF-EMR impairs testosterone synthesis and steroidogenesis.
- Sperm quality declines after non-thermal RF-EMR exposure.
- ROS and autophagy mediate RF-EMR-induced cell damage.

Limitations of SAR-based regulatory paradigms

Regulatory bodies like the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the Federal Communications Commission (FCC) still rely on SAR as the main safety benchmark for RF-EMR exposure [14], [74]. But SAR mainly reflects how much tissue heats up over short periods, it was originally designed to prevent thermal damage in lab settings [15]. While that works for avoiding immediate overheating, it doesn't capture the kinds of long-term, non-thermal effects that research is now increasingly reporting. For example, oxidative stress, hormonal imbalances, mitochondrial dysfunction, and even DNA fragmentation have been observed at SAR levels still considered "safe" under current guidelines [4], [19]. These kinds of findings make it clear that we need to rethink how exposure is measured, especially for reproductive health, and move toward including more biologically relevant markers like oxidative stress indicators, endocrine changes, and genotoxic outcomes.

The need for a precautionary framework

A proactive, precautionary approach is essential to safeguard public health amid ongoing scientific uncertainty. The absence of acute thermal injury must not be equated with biological safety. Multiple expert groups have advocated for the inclusion of non-thermal biological endpoints, such as oxidative stress, hormonal disruption, and reproductive toxicity, into current safety standards [5], [17].
To align public health policy with emerging evidence, reforms should prioritize:

- Mandatory RF-EMR labeling on consumer electronics;
- Promotion of low-exposure practices (e.g., using speaker mode or wired headphones, maintaining device distance, limiting phone use in low-signal areas, etc.);
- Creation of low-EMF zones in schools, hospitals, and transport systems;
- Dedicated funding for longitudinal studies on fertility and epigenetic impacts;
- Regular RF exposure mapping and transparent public communication.

Incorporating these elements into policy will better reflect biological realities and ensure protection for high-risk populations. Without such action, regulatory frameworks may continue to underestimate the long-term reproductive risks of chronic low-intensity RF-EMR exposure.

Conclusion

With wireless technologies now embedded in almost every part of daily life, we're constantly exposed to low levels of RF-EMR, often without even realizing it. This kind of ongoing exposure has raised real concerns about biological effects that go well beyond just heating tissues. Studies using cell lines, animals, and even human subjects have pointed to consistent changes in things like redox balance, mitochondrial health, programmed cell death pathways, autophagy, and hormonal regulation, and

these effects seem especially pronounced in the male reproductive system. These disturbances have been linked to reduced sperm quality, disrupted testicular architecture, and compromised fertility, with some studies pointing to potential impacts on future generations.

Existing safety standards, primarily based on thermal effects, do not capture the complexity of these non-thermal, long-term exposures. As technologies like 5 G introduce novel frequencies and modulations, there is a critical need for biologically relevant models, standardized endpoints, and human-focused cohort studies. A multidisciplinary approach integrating mechanistic research and policy updates is essential to ensure reproductive safety amid expanding RF-EMR exposure.

https://www.sciencedirect.com/science/article/pii/S0890623825002588

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The effects of radiofrequency radiation on male reproductive health and potential mechanisms

Bektas H, Dasdag S. The effects of radiofrequency radiation on male reproductive health and potential mechanisms. Electromagn Biol Med. 2025 Mar 19:1-26. doi: 10.1080/15368378.2025.2480664.

Abstract

Recent studies have demonstrated that radiofrequency (RF) radiation emanating from devices such as mobile phones and Wi-Fi may have adverse effects on male reproductive health. This radiation can elevate testicular temperature, potentially compromising sperm quality and DNA integrity, and influence the specific absorption rate (SAR) across different body regions, leading to detrimental reproductive outcomes. Furthermore, exposure to RF radiation has been linked to conditions that could affect male reproductive function, such as oxidative stress, alterations in ion transitions across cell membranes, and inflammation. The article reviews research conducted on both humans and animal models regarding the effects of electromagnetic radiation on sperm quality, DNA damage, oxidative stress, hormone levels, and testicular function, suggesting that exposure to electromagnetic radiation could have harmful implications for male reproductive health. However, further research is necessary to fully understand the mechanisms and implications of non-ionizing electromagnetic radiation on male infertility.

Plain-language Summary

In this review, the effects of RF on male reproduction and the mechanisms related to them were examined and the results were discussed. “The effects of RF on sperm, reproductive hormones and testis, occupational exposure and male reproductive health, mechanisms of RF effects on reproductive system” were discussed here. In conclusion, further research is necessary to fully understand the mechanisms and implications of non-ionizing electromagnetic radiation on male infertility.

Excerpts

A total of 90 articles were evaluated in this review.

The effects of RF radiation on sperm

In conclusion, despite an incomplete understanding of the precise mechanisms underlying the impact of non-thermal RF radiation on sperm and testicular function, research across animal and human studies consistently suggests a connection between increased levels of ROS and/or DNA damage and negative impacts on fertility factors. This indicates that the negative effects of RF radiation on sperm parameters may primarily be linked to the induction of ROS. Furthermore, the variability in study outcomes underscores the complexity of RF radiation’s effects, which may be influenced by factors such as exposure duration, frequency, and individual susceptibility. Therefore, limiting mobile phone use may be advisable to mitigate the incidence of male infertility. However, further research is warranted to explore the long-term effects of mobile phone radiation on male fertility and the generalizability of these findings (). Future studies should aim to clarify the specific biological pathways affected by RF radiation and standardize experimental protocols to resolve inconsistencies in the literature.

The effects of RF radiation on DNA

In conclusion, these studies highlight the harmful effects of RF radiation on male reproductive health, including DNA damage, decreased sperm mobility and vitality, increased DNA fragmentation, and oxidative stress. The variability in the findings, driven by differences in study design, exposure parameters, and biological models, suggests that the biological impact of RF radiation may be multifactorial, involving complex interactions between ROS production, DNA repair mechanisms, and cellular apoptosis pathways. It is advisable to limit RF exposure by keeping mobile phones away from the pelvic region and minimizing the use of RF-emitting electronic devices. However, given the inconsistent outcomes across various studies, future research should focus on standardizing experimental conditions and exploring the dose-response relationship to better understand the threshold levels

at which RF radiation becomes detrimental to reproductive health. Further research is necessary to fully understand the long-term implications of RF radiation on human reproductive health.

The effects of RF radiation on reproductive hormones and testis

In conclusion, the research discussed in this section indicates that RF radiation exposure could negatively affect male reproductive health, leading to changes in hormone levels, testicular morphology, and sperm count and viability (). Prolonged exposure to wireless internet and mobile phones has been associated with alterations such as increased abnormalities in sperm heads and reduced weight of reproductive organs. Additionally, RF radiation can impact testicular parenchyma in rats, resulting in irregularly shaped seminiferous tubules with epithelial cell abnormalities. The complexity of these findings suggests that RF radiation may induce a cascade of biological responses, including oxidative stress, hormonal imbalances, and apoptotic processes, which collectively contribute to testicular damage and compromised reproductive health. The observed effects appear to be dose-dependent, with longer durations and higher intensities of RF exposure correlating with more severe reproductive outcomes. These findings emphasize the importance of avoiding long-term exposure to RF radiation emissions, particularly from wireless technologies, to prevent potential harm to male reproductive health. Future research should focus on elucidating the precise mechanisms by which RF radiation affects the reproductive system and identifying potential protective strategies to mitigate these effects.

Occupational exposure and male reproductive health

In conclusion, the diverse findings from these studies shed light on the complex relationship between occupational exposure, particularly to radiofrequency radiation, and male reproductive health outcomes (). The variability in study outcomes highlights the challenges in establishing a clear causal link, suggesting that individual susceptibility, exposure duration, and the specific characteristics of RF equipment used in different occupational settings may play significant roles. Further research is warranted to elucidate the underlying mechanisms and to inform occupational health guidelines and practices. Future studies should focus on standardizing exposure assessment methods and consider long-term monitoring of workers in high-risk occupations to better understand the cumulative effects of RF radiation. Additionally, exploring potential protective strategies, such as shielding technologies and exposure limits, could be critical in mitigating the reproductive risks associated with occupational RF exposure.

Conclusion

This study comprehensively examined the mechanisms by which RF radiation may impact male reproductive health, focusing on both thermal and non-thermal pathways. The findings indicate that RF exposure, particularly through increased oxidative stress, ionic imbalances, and inflammation, can disrupt spermatogenesis and impair sperm quality. While thermal effects highlight the role of testicular temperature elevation, non-thermal mechanisms such as ROS generation and ionic dysregulation further emphasize the multifaceted nature of RF-induced reproductive toxicity. Despite the robust body of evidence, inconsistencies across studies warrant standardized research protocols to resolve methodological discrepancies. Future investigations should prioritize long-term exposure assessments and explore protective strategies to mitigate the risks associated with RF radiation. These efforts are critical for informing public health guidelines and ensuring reproductive health safety in the era of pervasive wireless communication technologies. Findings underline the importance of revisiting current regulatory standards to better protect reproductive health.

https://pubmed.ncbi.nlm.nih.gov/40108785/

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

Msaye AE, Mohammed AS. Histopathologic effects of mobile phone radiation exposure on the testes and sperm parameters: a systematic literature review of animal studies. Frontiers in Reproductive Health. Vol. 6, 2025. 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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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

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

- Systematic review of experimental studies on RF-EMF effects on male fertility.
- 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.

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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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. 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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Genotoxic Risks to Male Reproductive Health from Radiofrequency Radiation

Kaur P, Rai U, Singh R. Genotoxic Risks to Male Reproductive Health from Radiofrequency Radiation. Cells. 2023; 12(4):594. https://doi.org/10.3390/cells12040594.

Abstract

During modern era, mobile phones, televisions, microwaves, radio, and wireless devices, etc., have become an integral part of our daily lifestyle. All these technologies employ radiofrequency (RF) waves and everyone is exposed to them, since they are widespread in the environment. The increasing risk of male infertility is a growing concern to the human population. Excessive and long-term exposure to non-ionizing radiation may cause genetic health effects on the male reproductive system which could be a primitive factor to induce cancer risk. With respect to the concerned aspect, many possible RFR induced genotoxic studies have been reported; however, reports are very contradictory and showed the possible effect on humans and animals. Thus, the present review is focusing on the genomic impact of the radiofrequency electromagnetic field (RF-EMF) underlying the male infertility issue. In this review, both in vitro and in vivo studies have been incorporated explaining the role of RFR on the male reproductive system. It includes RFR induced-DNA damage, micronuclei formation, chromosomal aberrations, SCE generation, etc. In addition, attention has also been paid to the ROS generation after radiofrequency radiation exposure showing a rise in oxidative stress, base adduct formation, sperm head DNA damage, or cross-linking problems between DNA & protein.

Conclusions

The present review reveals a better understanding of the genotoxic effects of radiofrequency radiation on male reproductive health emitted from mobile phones, laptops, microwaves, wireless networks, etc. The study focused on different endpoints such as DNA damage, micronuclei formation and genomic instability, SCE & chromosomal aberrations covering both in vitro and in vivo parameters. The available information following in vitro and in vivo exposure shows that all the yielded data has both positive and negative results. In this review, studies reported DNA fragmentation, apoptosis, and elevated protein expression in both human and animal spermatozoa, concluding a decrease in viability, mitochondrial genomic destruction and DNA strand breaks. Further micronuclei formation, SCE and chromosomal aberrations are also found to cause abnormalities, leading to the accumulation of mutations and hence causing cancer risk. While controversial investigation, on the other hand, supported with no effect on cellular apoptosis or DNA integrity. Our present study reviewed that RFR has insufficient energy production to generate genomic damage. Yet, such effects were probably found to be responsible for male infertility due to the indirect mechanism of oxidative stress via ROS generation in the exposed system. Few studies also suggested that the damage due to the cumulative effect of repeated exposure varies with physical parameters such as distance from the radiation source, short-term or long-term exposure duration, penetration depth, and frequency of exposure. Therefore, considering all data together, the present review supports the capability of radiofrequency radiation to induce genotoxicity underlying male infertility keeping some limitations in mind, since the report is a conclusion of narrative study and limited literature were found explaining the actual mechanism of micronuclei formation, sister chromatid exchange, chromosomal aberration and genomic instability. Hence, more studies are needed to elucidate the DNA damage mechanism with more robust study designs favoring potential genotoxic effects of RFR on male reproductive health.

Open access paper: https://www.mdpi.com/2073-4409/12/4/594

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Pusan National University scientists reveal links between sperm quality and cell phone use

The findings of their updated meta-analysis hint at the potential dangers of modern electronic gadgets

Pusan National University, News Release 24-Jan-2022

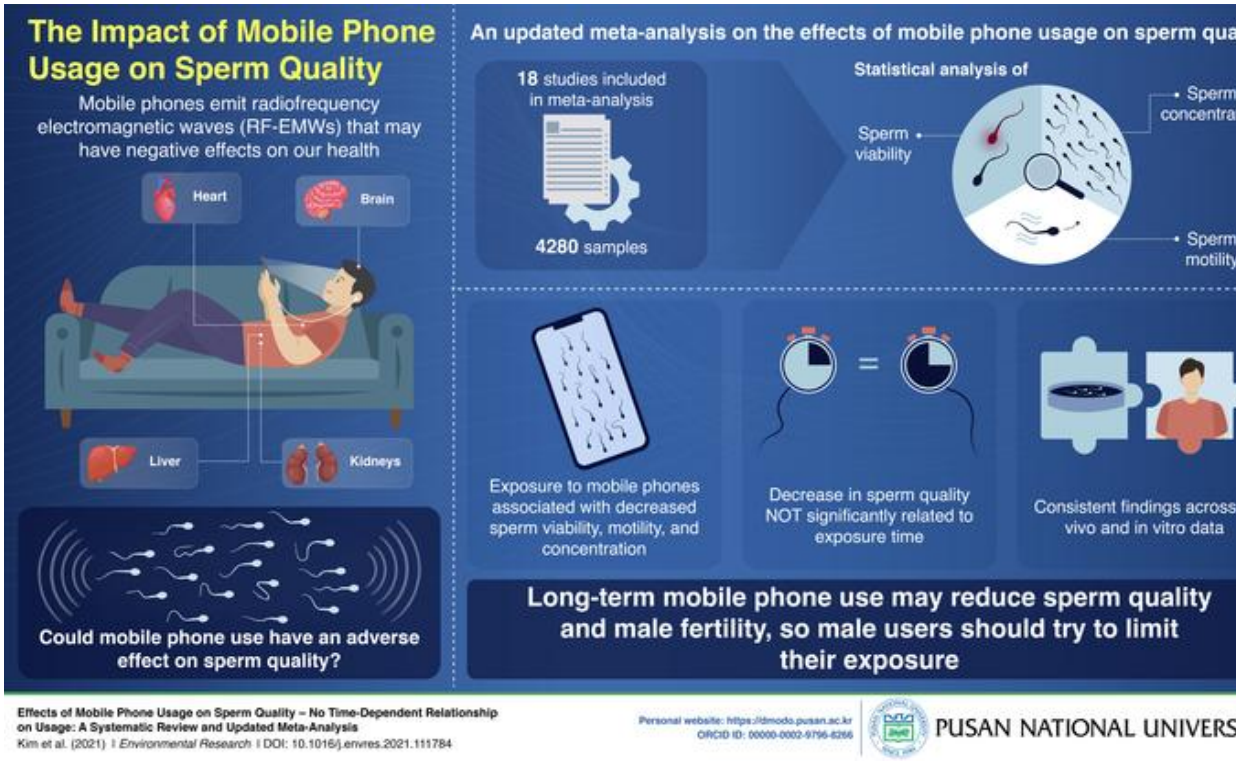


image: After examining a series of studies from 2012 to 2021, researchers have performed an updated meta-analysis that clearly indicates the connection between cell phone and decreased sperm quality. view more

Credit: Pusan National University

Cell phones have succeeded in bringing the world closer, making life tolerable during a very trying time. But cellphones also have their downsides. They can have negative effects on health. This is because cell phones emit radiofrequency electromagnetic waves (RF-EMWs), which are absorbed by the body. According to a meta-analysis from 2011, data from previous studies indicate that RF-EMWs emitted by cell phones degrade sperm quality by reducing their motility, viability, and concentration. However, this meta-analysis had a few limitations, as it had low amounts of in vivo data and considered cell phone models that are now outdated.

In an effort to bring more up-to-date results to the table, a team of researchers led by Assistant Professor Yun Hak Kim from Pusan National University, Korea, conducted a new meta-analysis on the potential effects of cell phones on sperm quality. They screened 435 studies and records published between 2012 and 2021 and found 18—covering a total of 4280 samples—that were suitable for the statistical analyses. Their paper was made available online on July 30, 2021 and was published in Volume 202 of Environmental Research in November, 2021.

Overall, the results indicate that cell phone use is indeed associated with reduced sperm motility, viability, and concentration. These findings are more refined than those from the previous meta-analysis thanks to a better subgroup analysis of the data. Another important aspect that the researchers looked into was if higher exposure time to cell phones was correlated to lower sperm quality. However, they found out that the decrease in sperm quality was not significantly related to exposure time—just to exposure to mobile phones itself. Considering the results were consistent across both in vivo and in vitro (cultured sperm) data, Dr. Kim warns that “Male cell-phone users should strive to reduce mobile phone use to protect their sperm quality.”

Knowing that the number of cell phone users is most likely going to increase in the future, it’s high time we start considering exposure to RF-EMW as one of the underlying factors causing a reduction in sperm quality among the male population. Moreover, seeing how technologies evolve so quickly, Dr. Kim remarks that “additional studies will be needed to determine the effect of exposure to EMWs emitted from new mobile phone models in the present digital environment.” The bottom line is, if you’re worried about your fertility (and potentially other aspects of your health), it may be a good idea to limit your daily cell phone use.

https://www.eurekalert.org/news-releases/941005

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Effects of mobile phone usage on sperm quality – No time-dependent relationship on usage: A systematic review and updated meta-analysis

Sungjoon Kim, Donghyun Han, Jiwoo Ryu, Kihun Kim, Yun Hak Kim. Effects of mobile phone usage on sperm quality – No time-dependent relationship on usage: A systematic review and updated meta-analysis. Environmental Research. 202:111784, 2021. doi:10.1016/j.envres.2021.111784.

Abstract

Background Mobile phones emit radiofrequency (RF) electromagnetic waves (EMWs), a low-level RF that can be absorbed by the human body and exert potential adverse effects on the brain, heart, endocrine system, and reproductive function. Owing to the novel findings of numerous studies published since 2012 regarding the effect of mobile phone use on sperm quality, we conducted a systematic review and updated meta-analysis to determine whether the exposure to RF-EMWs affects human sperm quality.

Methods This study was conducted in accordance with the PRISMA guidelines. The outcome measures depicting sperm quality were motility, viability, and concentration, which are the most frequently used parameters in clinical settings to assess fertility.

Results We evaluated 18 studies that included 4280 samples. Exposure to mobile phones is associated with reduced sperm motility, viability, and concentration. The decrease in sperm quality after RF-EMW exposure was not significant, even when the mobile phone usage increased. This finding was consistent across experimental in vitro and observational in vivo studies.

Discussion Accumulated data from in vivo studies show that mobile phone usage is harmful to sperm quality. Additional studies are needed to determine the effect of the exposure to EMWs from new mobile phone models used in the present digital environment.

Excerpts

"... 18 studies fulfilled all inclusion criteria and were included in the meta-analysis (Table 1 and Fig. 1) (Agarwal et al., 2008, 2009; Ahmad and Baig, 2011; Al-Bayyari, 2017b; De Iuliis et al., 2009; Ding et al., 2018a; Dkhil et al., 2011; Erogul et al., 2006; Falzone et al., 2008; Fejes et al., 2005; Kaya et al., 2020; Malini, 2017b; Rago et al., 2013; Sajeda and Al-Watter, 2011; Veerachari and Vasan, 2012; Wdowiak et al., 2018; Yildirim et al., 2015; Zalata et al., 2015). Nine studies from a previous meta-analysis and nine new studies that included 4280 samples were used for analysis. One conference paper included in the previous study was excluded. The sperm quality parameters established in each paper varied and were subjected to a meta-analysis; 16 papers provided data on sperm motility, 6 provided data on sperm viability, and 12 provided data on sperm concentration. All in vitro studies were experimental, whereas all in vivo studies were observational. We identified the MD values of the entire 4280 samples and analyzed the MD values of each group after classifying them according to four criteria: control group setting (non-exposure vs. less exposure), study design (in vivo and in vitro), participant group (fertility clinic and population), and storage location (trousers or not)."

Conclusion

"Mobile phone use decreased the overall sperm quality by affecting the motility, viability, and concentration. It was further reduced in the group with high mobile phone usage. In particular, the decrease was remarkable in in vivo studies with stronger clinical significance in subgroup analysis. Therefore, long-term cell phone use is a factor that must be considered as a cause of sperm quality reduction. Additional studies are needed to determine the effect of the exposure to EMWs emitted from new mobile phone models in the present digital environment."

https://www.sciencedirect.com/science/article/pii/S0013935121010781

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Romualdo Sciorio, Luca Tramontano, Sandro C Esteves. Effects of mobile phone radiofrequency radiation on sperm quality. Zygote. 2021 Aug 13;1-10. doi: 10.1017/S096719942100037X

Abstract

In the last decades, the universal use of mobile phones has contributed to radiofrequency electromagnetic radiation environmental pollution. The steady growth in mobile phone usage has raised concerns about the effects of phone radiation on male reproductive health. Epidemiological studies report a sharp decline in sperm counts in developing countries, and worldwide with c. 14% of couples having difficulties to conceive, many of which are attributed to a male infertility factor. Environment and lifestyle factors are known to contribute to male infertility. Exposure to heat, radiation, or radioactivity might induce damage to

biological tissue organs, including the testis. Given the ubiquitous use of mobile phones, the potential adverse effects of the resulting environmental radiation needs to be elucidated further. It seems to be an apparent relationship between the increased exposure to mobile phone radiofrequency and sperm quality decline, but the evidence is not conclusive. Our review summarizes the evidence concerning the possible adverse effects of cell phone radiation on the male reproductive system, with a focus on sperm quality. Also, we critically analyze the effects of elevated testicular temperature and oxidative stress on male fertility and how these factors could interfere with the physiological activities of the testis.

https://pubmed.ncbi.nlm.nih.gov/34384508/

Future perspectives and conclusions

The rapid technological advances in personal computers and communication devices might pose a risk for human health. Cell phone devices emit radiofrequency electromagnetic waves that seem to affect male reproductive health and other body functions (McClelland 3rd and Jaboin, 2018; Sage and Burgio, 2018; Wall et al., 2019). Although the current data are not unequivocal, it seems sound to speculate that mobile phone exposure might be contributing to subfertility. However, the existing evidence primarily relates to adverse effects on sperm motility and morphology, which are limited endpoints for evaluating the male fertility potential.

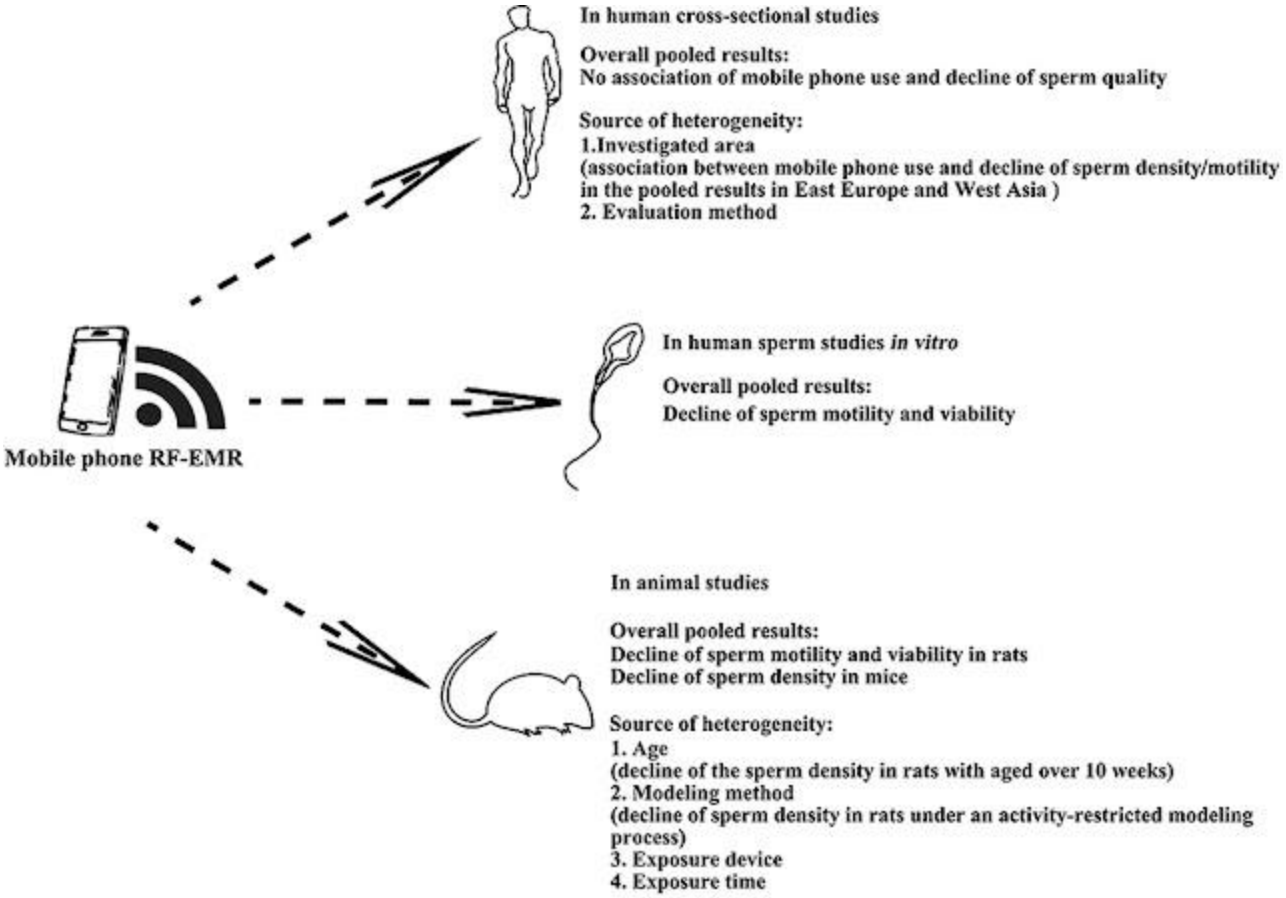
The exact mechanisms of how RF-EMR might affect the testis, epididymis, and sperm have not yet been fully understood. Additional studies are warranted, particularly prospective studies assessing sperm functional markers, such as sperm DNA integrity and OS, in fertile and subfertile men. Equally important will be to analyze whether the decreased sperm quality associated with mobile phone exposure translates into impaired pregnancy chances. The effects of short-term and long-term exposure and energy intensity should be also investigated in more detail, taking into account relevant confounders. Only then will scientific societies and regulatory bodies be able to provide users with transparent information concerning the risks and guidance for proper use.

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Gang Yu, Zhiming Bai, Song Chao, Qing Cheng, Gang Wang, Zeping Tang, Sixing Yang. Current progress on the effect of mobile phone radiation on sperm quality: an updated systematic review and meta-analysis of human and animal studies. Environmental Pollution. Published online: 30 March 2021. https://doi.org/10.1016/j.envpol.2021.116952.

Highlights

- Mobile phone use was related to sperm quality decline of men in some areas.
- Mobile phone RF-EMR directly impaired mature sperm of men in vitro.
- Mobile phone RF-EMR affected some parameters of sperm quality in experiment animals.
- Experiment conditions affected pooled results of animal experiments.
- More studies should be conducted to investigate this issue in new era.



Abstract

Potential suppression of fertility due to mobile phone radiation remains a focus of researchers. We conducted meta-analyses on the effects of mobile phone radiation on sperm quality using recent evidence and propose some perspectives on this issue. Using the MEDLINE/PubMed, Embase, WOS, CENTRAL, and ClinicalTrials.gov databases, we retrieved and screened studies published before December 2020 on the effects of mobile phone use/mobile phone RF-EMR on sperm quality.

Thirty-nine studies were included. Data quality and general information of the studies were evaluated and recorded. Sperm quality data (density, motility, viability, morphology, and DFI) were compiled for further analyses, and we conducted subgroup, sensitivity, and publication bias analyses.

The pooled results of human cross-sectional studies did not support an association of mobile phone use and a decline in sperm quality. Different study areas contributed to the heterogeneity of the studies. In East Europe and West Asia, mobile phone use was correlated with a decline in sperm density and motility. Mobile phone RF-EMR exposure could decrease the motility and viability of mature human sperm in vitro.

The pooled results of animal studies showed that mobile phone RF-EMR exposure could suppress sperm motility and viability. Furthermore, it reduced sperm density in mice, in rats older than 10 weeks, and in rats restrained during exposure. Differences regarding age, modeling method, exposure device, and exposure time contributed to the heterogeneity of animal studies. Previous studies have extensively investigated and demonstrated the adverse effects of mobile phone radiation on sperm.

In the future, new standardized criteria should be applied to evaluate potential effects of mobile phone RF-EMR dosages. Further sperm-related parameters at the functional and molecular levels as well as

changes in biological characteristics of germ cells should be evaluated. Moreover, the impact of mobile phone RF-EMR on individual organs should also be examined.

Conclusion

The results of our meta-analysis indicated that in East Europe and West Asia, mobile phone use is associated with a decline in human sperm density and motility. Mobile phone RF-EMR can reduce motility and viability of mature human sperm *in vitro*, and it can also reduce sperm motility and viability in male animals and decrease sperm density of sexually mature restrained rats. Some important factors that affect the results of animal experiments are study setup and radiation device as well as age and exposure time. Our study is an extension of previous studies and has scientific value for future studies on effects of mobile phone RF-EMR associated with sperm quality.

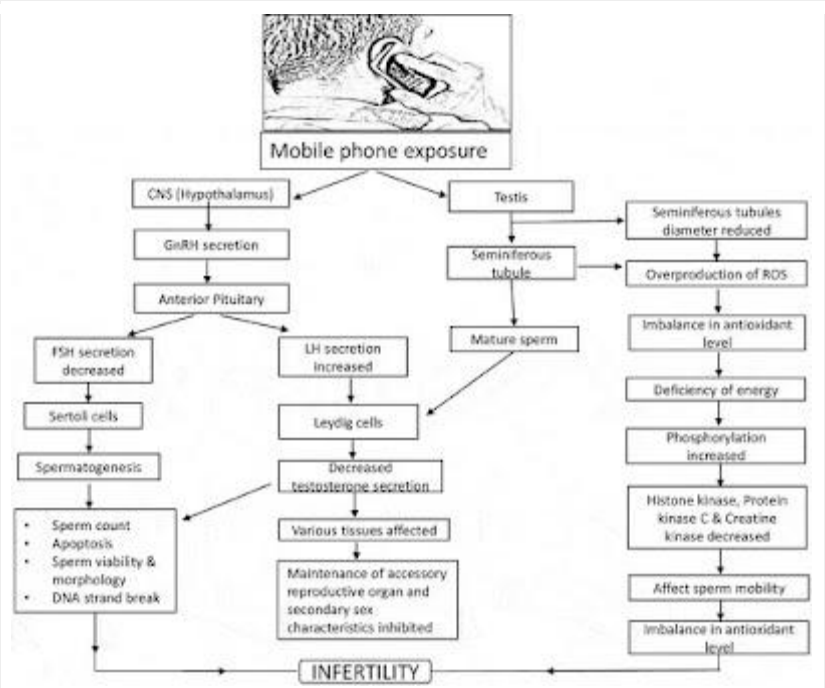
https://www.sciencedirect.com/science/article/abs/pii/S0269749121005340

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Pooja Negi, Rajeev Singh. Association between reproductive health and nonionizing radiation exposure. Electromagnetic Biology and Medicine. Published online: 20 Jan 2021. DOI: 10.1080/15368378.2021.1874973.

Abstract

Recently, a decreasing rate of fertility has to be credited to an array of factors such as environmental, health and lifestyle. Male infertility is likely to be affected by the strong exposure to heat and radiations. The most common sources of nonionizing radiations are cell phones, laptops, Wi-Fi and microwave ovens, which may participate to the cause of male infertility. One of the major sources of daily exposure to non-ionizing radiation is mobile phones. A mobile phone is now basically dominating our daily life through better services such as connectivity, smartphone devices. However, the health consequences are linked with their usage are frequently ignored. Constant exposure to non-ionizing radiations produced from a cell phone is one of the possible reasons for growing male infertility. Recently, several studies have shown that cell phone users have altered sperm parameters causing declining reproductive health. Cell phone radiation harms male fertility by affecting the different parameters like sperm motility, sperm count, sperm morphology, semen concentration, morphometric abnormalities, increased oxidative stress along with some hormonal changes. This review is focusing on the prevailing literature from in vitro and in vivo studies suggesting that non-ionizing exposure negatively affects human male infertility.



Negi & Singh, 2021

Conclusion

Generally, the outcome of the studies has indicated that mobile phone usage changes different sperm parameters in both ways in-vitro (human) and in-vivo (animals). Several studies disclose that the exposure to cell phones produces harmful effects on the testes, which may affect sperm motility, sperm number, sperm concentration, and morphology and an increased DNA damage, causing micronuclei formation and reactive oxygen species within the cell. So many evidences showed that exposure from cell phones results in elevated oxidative stress with disintegrated DNA and it is directly and indirectly dependent on the time of cell phone use. Further researches are required to provide strong evidence that the use of mobile phones may disturb sperm and testicular activity. Several evidences suggest that the irregularities reported due to RF-EMF-exposure depend on physical parameters such as utilized RF wavelength, penetration range into the object, and transmission length of the radiation. Unfortunately, existing studies are not able to suggest a true mechanism between the harmful effects of RF-EMF radiation and the male reproductive system. To conclude all of the above, government bodies and agencies should form strong guidelines against cell phone exposure and take preventive actions such as in the usage of mobile phones, preventing chatting, reducing the overall contact time, and holding the gadget away from the groin may be of significant help to people pursuing fertility. Moreover, very limited studies are available on protective actions so far so a large-scale analysis is also required to determine the reproductive parameters.

https://www.tandfonline.com/doi/abs/10.1080/15368378.2021.1874973?src=&journalCode=iebm20

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Chidiebere Emmanuel Okechukwu. Does the Use of Mobile Phone Affect Male Fertility? A Mini-Review. J Hum Reprod Sci. Jul-Sep 2020;13(3):174-183. doi: 10.4103/jhrs.JHRS_126_19.

Abstract

Presently, there is a rise in the use of mobile phones, laptops, and wireless internet technologies such as

Wi-Fi and 5G routers/modems across the globe; these devices emit a considerable amount of electromagnetic radiation (EMR) which could interact with the male reproductive system either by thermal or nonthermal mechanisms. The aim of this review was to examine the effects of mobile phone use on male fertility. Related studies that reported on the effects of EMR from mobile phones on male fertility from 2003 to 2020 were evaluated. PubMed database was used. The Medical Subject Heading system was used to extract relevant research studies from PubMed. Based on the outcomes of both human and animal studies analyzed in this review, animal and human spermatozoa exposed to EMR emitted by mobile phones had reduced motility, structural anomalies, and increased oxidative stress due to overproduction of reactive oxygen species. Scrotal hyperthermia and increased oxidative stress might be the key mechanisms through which EMR affects male fertility. However, these negative effects appear to be associated with the duration of mobile phone use.

Conclusion

Based on the outcomes of both human and animal studies examined in this review, animal and human spermatozoa exposed to EMR emitted by mobile phones had reduced motility, structural anomalies, and increased oxidative stress due to the production of ROS. Scrotal hyperthermia and increased oxidative stress might be the key mechanisms by which EMR affects male fertility. However, these negative effects appear to be associated with the duration of mobile phone use.

Open access paper: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7727890/

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Jaffar FHF, Osman K, Ismail NH, Chin KY, Ibrahim SF. Adverse Effects of Wi-Fi Radiation on Male Reproductive System: A Systematic Review. Tohoku J Exp Med. 2019;248(3): 169-179. doi: 10.1620/tjem.248.169. (Note: Smartphones emit Wi-Fi, Bluetooth and various types of cellular radiation.)

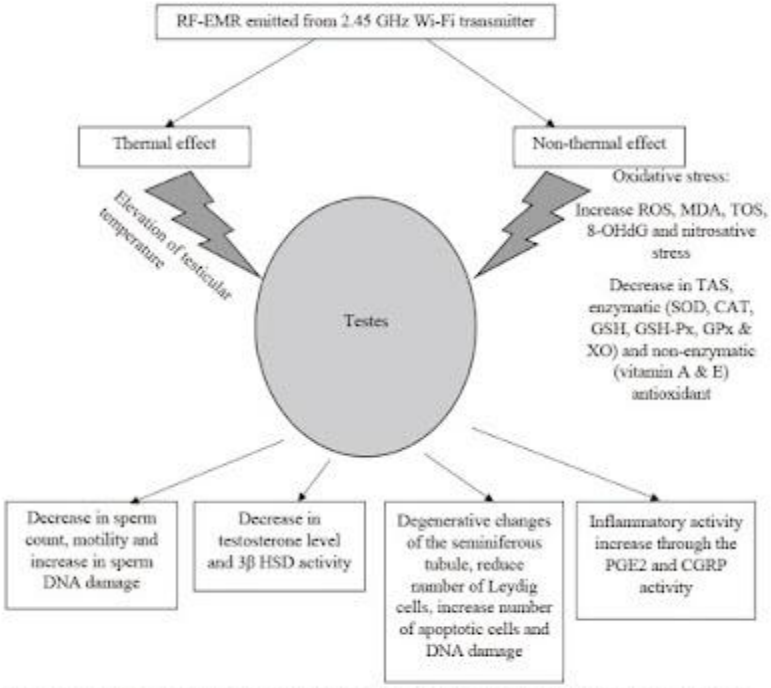


Fig. 2. Mechanisms of RF-EMR exposure emitted from 2.45 GHz Wi-Fi transmitter action on the testes.

Abstract

Extensive use of Wi-Fi has contributed to radiofrequency electromagnetic radiation (RF-EMR) pollution in environment. Various studies have been conducted to evaluate the effect of RF-EMR emitted by Wi-Fi transmitter on male reproduction health. However, there are conflicting findings between studies. Thus, this review aims to elucidate the possible effects of 2.45 GHz Wi-Fi exposure on both animal and human male reproductive system. A computerized database search performed through MEDLINE via Ovid and PUBMED with the following set of keywords: 'Wi-Fi or WiFi or wireless fidelity or Wi-Fi router or WiFi router or electromagnetic or radiofrequency radiation' AND 'sperm or spermatozoa or spermatogenesis or semen or seminal plasma or testes or testis or testosterone or male reproduction' had returned 526 articles. Only 17 studies conformed to pre-set inclusion criterion. Additional records identified through Google Scholar and reviewed article further revealed six eligible articles. A total of 23 articles were used for data extraction, including 15 studies on rats, three studies on mice, and five studies on human health. Sperm count, motility and DNA integrity were the most affected parameters when exposed to RF-EMR emitted by Wi-Fi transmitter. Unfortunately, sperm viability and morphology were inconclusive. Structural and/or physiological analyses of the testes showed degenerative changes, reduced testosterone level, increased apoptotic cells, and DNA damage. These effects were mainly due to the elevation of testicular temperature and oxidative stress activity. In conclusion, exposure towards 2.45 GHz RF-EMR emitted by Wi-Fi transmitter is hazardous on the male reproductive system.

Open access paper: https://www.jstage.jst.go.jp/article/tjem/248/3/248_169/_article

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Kesari KK, Agarwal A, Henkel R. Radiation and male fertility. Reprod Biol Endocrinol. 2018 Dec 9;16(1):118. doi: 10.1186/s12958-018-0431-1.

Abstract

During recent years, an increasing percentage of male infertility has to be attributed to an array of environmental, health and lifestyle factors. Male infertility is likely to be affected by the intense exposure to heat and extreme exposure to pesticides, radiation, radioactivity and other hazardous substances. We are surrounded by several types of ionizing and non-ionizing radiations and both have recognized causative effects on spermatogenesis. Since it is impossible to cover all types of radiation sources and their biological effects under a single title, this review is focusing on radiation deriving from cell phones, laptops, Wi-Fi and microwave ovens, as these are the most common sources of non-ionizing radiation, which may contribute to the cause of infertility by exploring the effect of exposure to radiofrequency radiation on the male fertility pattern. From currently available studies it is clear that radiofrequency electromagnetic fields (RF-EMF) have deleterious effects on sperm parameters (like sperm count, morphology, motility), affects the role of kinases in cellular metabolism and the endocrine system, and produces genotoxicity, genomic instability and oxidative stress. This is followed with protective measures for these radiations and future recommendations. The study concludes that the RF-EMF may induce oxidative stress with an increased level of reactive oxygen species, which may lead to infertility. This has been concluded based on available evidence from in vitro and in vivo studies suggesting that RF-EMF exposure negatively affects sperm quality.

Open access paper: https://rbej.biomedcentral.com/articles/10.1186/s12958-018-0431-1

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Ford-Glanton BS, Melendez DA. Male reproductive toxicants: Electromagnetic radiation and heat. Reference Module in Biomedical Sciences, 2018.

Abstract

Human population in today's world lives surrounded by radiofrequency fields (RF) and electromagnetic radiation (EM) fields, transmitting almost all forms of electronic communication and data that humans produce every second. Mobile devices and laptop computers are EMR-emitting devices. The effect of mobile phone emitted radiation and heat on fertility is the subject of recent interest and investigations.

Many studies have found a decrease in semen quality which has increased the focus on male reproductive health. Infertility affects approximately 15% of couples of reproductive age, and nearly half of these cases are linked to male fertility (Sharlip et al., 2002). Different harmful environmental influences have led to changes in semen analysis standards by reducing the lower limits of normal ranges, which were declared by the World Health Organization (2010). The possible negative impact of mobile phone radiation on sperm quality has been well established. While no certain conclusions can be drawn from current evidence, a growing number of studies indicate a decrease in male fertility associated with increased cellular phone usage (Agarwal et al., 2011) and laptop computers using Wi-Fi (Avendaño et al., 2012a). Here we review the current evidence regarding the effects of electromagnetic radiation and heat in male fertility.

https://www.sciencedirect.com/science/article/pii/B9780128012383645361

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Yahyazadeh A, Deniz OG, Kaplan AA, Altun G, Yurt KK, Davis D. The genomic effects of cell phone exposure on the reproductive system. Environ Res. 2018 Nov;167:684-693. doi: 10.1016/j.envres.2018.05.017.

Abstract

Humans are exposed to increasing levels of electromagnetic fields (EMF) at various frequencies as technology advances. In this context, improving understanding of the biological effects of EMF remains an important, high priority issue. Although a number of studies in this issue and elsewhere have focused on the mechanisms of the oxidative stress caused by EMF, the precise understanding of the processes involved remains to be elucidated. Due to unclear results among the studies, the issue of EMF exposure in the literature should be evaluated at the genomic level on the reproductive system. Based on this requirement, a detail review of recently published studies is necessary. The main objectives of this study are to show differences between negative and positive effect of EMF on the reproductive system of animal and human. Extensive review of literature has been made based on well known data bases like Web of Science, PubMed, MEDLINE, Google Scholar, Science Direct, Scopus. This paper reviews the current literature and is intended to contribute to a better understanding of the genotoxic effects of EMF emitted from mobile phones and wireless systems on the human reproductive system, especially on fertility. The current literature reveals that mobile phones can affect cellular functions via non-thermal effects. Although the cellular targets of global system for mobile communications (GSM)-modulated EMF are associated with the cell membrane, the subject is still controversial. Studies regarding the genotoxic effects of EMF have generally focused on DNA damage. Possible mechanisms are related to ROS formation due to oxidative stress. EMF increases ROS production by enhancing the activity of nicotinamide adenine dinucleotide (NADH) oxidase in the cell membrane. Further detailed studies are needed to elucidate DNA damage mechanisms and apoptotic pathways during oogenesis and spermatogenesis in germ cells exposed to EMF.

Conclusion

This paper reviews the current literature and is intended to contribute to a better understanding of the genotoxic effects of EMF emitted from mobile phones and wireless systems on the human reproductive system, especially on fertility. The current literature reveals that mobile phones can affect cellular functions via non-thermal effects (Diem et al., 2005; Hanci et al., 2013 ; Odaci et al., 2016a). Although the cellular targets of GSM-modulated EMF are associated with the cell membrane, the subject is still controversial (Eberhardt et al., 2008). Studies regarding the genotoxic effects of EMF have generally focused on DNA damage (Mortelmans and Rupa, 2004; Young, 2002; Zeiger, 2004; Panagopoulos, 2012 ; Turedi et al., 2016). Possible mechanisms are related to ROS formation due to oxidative stress (Moustafa et al., 2004; Hanukoglu et al., 2006). EMF increases ROS production by enhancing the activity of NADH oxidase in the cell membrane (Friedman et al., 2007b). In this context, EMF affected spermatozoa may have a high degree rate of infertilization. It seems that previous genomic studies do not

show definitive evidence regarding EMF affected cells in the fertilization. Although we evaluated broadly the genomic effects of cell phone exposure on the reproductive system using both animal and human studies, one of the weaknesses of this work is insufficient review of human studies. This may come from limited number of EMF based human studies in the literature. Further detailed studies are needed to elucidate DNA damage mechanisms and apoptotic pathways during oogenesis and spermatogenesis in germ cells that are exposed to EMF.

https://www.ncbi.nlm.nih.gov/pubmed/29884549

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Altun G, Deniz OG, Yurt KK, Davis D, Kaplan S. Effects of mobile phone exposure on metabolomics in the male and female reproductive systems. Environ Res. 2018 Nov;167:700-707. doi: 10.1016/j.envres.2018.02.031.

Highlights

• Long-term exposure to EMF decreases sperm motility and fertilization.
• Effects of EMF emitted from mobile phones are related to protein synthesis.
• Oxidative stress based EMF exposure modulates nitric oxide level in the germ cells.
• Oxidative stress based EMF exposure inhibits antioxidant mechanisms in the germ cells.

Abstract

With current advances in technology, a number of epidemiological and experimental studies have reported a broad range of adverse effects of electromagnetic fields (EMF) on human health. Multiple cellular mechanisms have been proposed as direct causes or contributors to these biological effects. EMF-induced alterations in cellular levels can activate voltage-gated calcium channels and lead to the formation of free radicals, protein misfolding and DNA damage. Because rapidly dividing germ cells go through meiosis and mitosis, they are more sensitive to EMF in contrast to other slower-growing cell types. In this review, possible mechanistic pathways of the effects of EMF exposure on fertilization, oogenesis and spermatogenesis are discussed. In addition, the present review also evaluates metabolomic effects of GSM-modulated EMFs on the male and female reproductive systems in recent human and animal studies. In this context, experimental and epidemiological studies which examine the impact of mobile phone radiation on the processes of oogenesis and spermatogenesis are examined in line with current approaches.

Conclusion

EMF emitted by mobile phones has a number of well-documented adverse metabolomic effects on the male and female reproductive systems and can lead to infertility by increasing ROS production and reducing GSH and other antioxidants. The primary target of the EMF emitted by mobile phones may be the cell membrane (Pall in press, this volume). This then results in accelerated activity of membrane NADH oxidase and, consequently, greater rates of ROS formation that cannot be easily conjugated or detoxified. Although many studies have reported morphological and functional deteriorations in testis and ovary following EMF exposures, as well both structural and functional deficits in reproductive health, the underlying mechanisms have not been fully elucidated. To assist in further clarification of these processes and mechanisms, Table 1 summarizes key studies on the metabolomic effects of EMF on reproductive systems. Future studies will benefit greatly from standardized exposure protocols and evaluations of key metabolomic indicators.

https://www.ncbi.nlm.nih.gov/pubmed/29884548

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Sepehrimanesh, M. & Davis, D.L. Proteomic impacts of electromagnetic fields on the male reproductive system. Comp Clin Pathol. 26(2):309-313. 2017. doi:10.1007/s00580-016-2342-x.

Abstract

The use of mobile phones and other wireless transmitting devices is increasing dramatically in developing and developed countries, as is the rate of infertility. A number of respected infertility clinics in Australia, India, USA, and Iran are reporting that those who regularly use mobile phones tend to have reduced sperm quantity and quality. Some experimental studies have found that human sperm exposed to electromagnetic fields (EMF), either simulated or from mobile phones, developed biomarkers of impaired structure and function, as well as reduced quantity. These encompass pathological, endocrine, and proteomic changes. Proteins perform a vast array of functions within living organisms, and the proteome is the entire array of proteins—the ultimate biomolecules in the pathways of DNA transcription to translation. Proteomics is the art and science of studying all proteins in cells, using different techniques. This paper reviews proteomic experimental and clinical evidence that EMF acts as a male-mediated teratogen and contributor to infertility.

Conclusions

As among the most rapidly proliferating human cells, spermatogenesis and associated activities offer an important endpoint for evaluation. More than 60 different compounds or industrial processes have been identified as increasing defects in human sperm or testicular tissue and possibly increasing the risk to offspring from male-mediated exposures. In this study, we reviewed structural and functional proteomic changes related to EMF exposure. Reported changes are categorized based on main affected tissue and also the most important adverse effects. Overall, these results demonstrate significant effects of radio frequency-modulated EMF exposure on the proteome, including both structural and functional impacts such as a decrease in the diameter and weight of the seminiferous tubules and the mean height of the germinal epithelium (Ozguner et al. 2005) and/or pathological and physiological changes in key biochemical components of the testicular tissues (Luo et al. 2013). These structural and functional changes may account for the pathological impact of EMF on the male reproductive system reported in the experimental work that we and others have conducted. While EMF is currently being used for a number of therapeutic applications (REF), the work we have reviewed here clearly indicates a range of harmful effects, especially on genital systems.

https://link.springer.com/article/10.1007/s00580-016-2342-x

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Houston B, Nixon B, King BV, De Iuliis G, Aitken RJ. The effects of radiofrequency electromagnetic radiation on sperm function. Reproduction. 2016 Dec;152(6):R263-R276.

Abstract

Mobile phone usage has become an integral part of our lives. However, the effects of the radiofrequency electromagnetic radiation (RF-EMR) emitted by these devices on biological systems and specifically the reproductive systems are currently under active debate. A fundamental hindrance to the current debate is that there is no clear mechanism of how such non-ionising radiation influences biological systems. Therefore, we explored the documented impacts of RF-EMR on the male reproductive system and considered any common observations that could provide insights on a potential mechanism.

Among a total of 27 studies investigating the effects of RF-EMR on the male reproductive system, negative consequences of exposure were reported in 21. Within these 21 studies, 11 of the 15 that investigated sperm motility reported significant declines, 7 of 7 that measured the production of reactive oxygen species documented elevated levels and 4 of 5 studies that probed for DNA damage highlighted

increased damage, due to RF-EMR exposure. Associated with this, RF-EMR treatment reduced antioxidant levels in 6 of 6 studies that studied this phenomenon, while consequences of RF-EMR were successfully ameliorated with the supplementation of antioxidants in all 3 studies that carried out these experiments.

In light of this, we envisage a two-step mechanism whereby RF-EMR is able to induce mitochondrial dysfunction leading to elevated ROS production.

A continued focus on research which aims to shed light on the biological effects of RF-EMR will allow us to test and assess this proposed mechanism in a variety of cell types.

https://www.ncbi.nlm.nih.gov/pubmed/27601711

Conclusion

To date, contradictory studies surrounding the impacts of RF-EMR on biological systems maintain controversy over this subject. Nevertheless, research into the biological responses stimulated by RF-EMR is particularly important given our ever-increasing use of mobile phone technology. While clinical studies are identifying possible detrimental effects of RF-EMR, it is imperative that mechanistic studies are conducted that elucidate the manner in which RF-EMR perturbs biological function, thus supplying a rational cause. A focus on the male reproductive system may experience as consequences of the personal storage of mobile devices, the unique vulnerability of the highly specialised sperm cell, and the future health burden that may be created if conception proceeds with defective, DNA-damaged spermatozoa. While this subject remains a topic of active debate, this review has considered the growing body of evidence suggesting a possible role for RF-EMR induced damage of the male germ line. In a majority of studies, this damage has been characterized by loss of sperm motility and viability as well as the induction of ROS generation and DNA damage. We have therefore given consideration to the potential mechanisms through which RF-EMR may elicit these effects on spermatozoa, which we utilized as a sensitive model system. We propose a mechanistic model in which RF-EMR exposure leads to defective mitochondrial function associated with elevated levels of ROS production and culminates in a state of oxidative stress that would account the varying phenotypes observed in response to RF-EMR exposure. With further complementary data, this model will provide new impetus to the field and stimulate research that will allow us to confidently assess the reproductive hazards of mobile phone usage.

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Adams JA, Galloway TS, Mondal D, Esteves SC, Mathews F. Effect of mobile telephones on sperm quality: A systematic review and meta-analysis. Environ Int. 2014 Sep;70:106-12. doi: 10.1016/j.envint.2014.04.015.

Summary

Mobile phones are owned by most of the adult population worldwide. Radio-frequency radiation (RFR) from these devices could affect sperm development and function. Around 14% of couples in high- and middle-income countries have difficulty conceiving. Male infertility is involved approximately 40% of the time. Several countries have reported unexplained declines in semen quality.

Animal research has found that RFR can affect the cell cycle of sperm, increase sperm cell death and produce histological changes in the testes. Research on humans has found that prolonged mobile phone use is associated with decreased motility, sperm concentration, morphology and viability suggesting a likely impact on fertility.

The authors of this peer-reviewed study conducted a systematic review of the research and a quantitative analysis to determine whether exposure to mobile phone radiation affects human sperm quality. Participants were from fertility clinics and research centers.

The study examined the sperm quality outcome measures most frequently used to assess fertility in clinical settings: motility (the ability to move properly through the female reproductive tract), viability (the ability to fertilize the egg), and concentration (the number of sperm in a milliliter of ejaculate).

Ten studies were examined including 1,492 human sperm samples. Exposure to mobile phones was found to be associated with a significant eight per cent average reduction in sperm motility and a significant nine per cent average reduction in sperm viability. The effects on sperm concentration were more equivocal. The results were consistent across experimental laboratory studies and correlational observational studies.

The authors concluded that the overall results suggest that mobile phone exposure negatively affects sperm quality in humans. The clinical importance of these effects in this study may be limited to subfertile men and to men at the lower-end of the normal spectrum.

Open access paper: http://bit.ly/cellphonespermdamage.

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Liu K, Li Y, Zhang G, Liu J, Cao J, Ao L, Zhang S. Association between mobile phone use and semen quality: a systemic review and meta-analysis. Andrology. 2014 Jul;2(4):491-501.

Abstract

Possible hazardous health effects of radiofrequency electromagnetic radiations emitted from mobile phone on the reproductive system have raised public concern in recent years. This systemic review and meta-analysis was prepared following standard procedures of the Cochrane Collaboration and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement and checklist. Relevant studies published up to May 2013 were identified from five major international and Chinese literature databases: Medline/PubMed, EMBASE, CNKI, the VIP database and the Cochrane Central Register of Controlled Trials in the Cochrane Library. Eighteen studies with 3947 men and 186 rats were included in the systemic review, of which 12 studies (four human studies, four in vitro studies and four animal studies) with 1533 men and 97 rats were used in the meta-analyses. Systemic review showed that results of most of the human studies and in vitro laboratory studies indicated mobile phone use or radiofrequency exposure had negative effects on the various semen parameters studied. However, meta-analysis indicated that mobile phone use had no adverse effects on semen parameters in human studies. In the in vitro studies, meta-analysis indicated that radiofrequency radiation had detrimental effect on sperm motility and viability in vitro [pooled mean difference (MDs) (95% CI): -4.11 (-8.08, -0.13), -3.82 (-7.00, -0.65) for sperm motility and viability respectively]. As for animal studies, radiofrequency exposure had harmful effects on sperm concentration and motility [pooled MDs (95% CI): -8.75 (-17.37, -0.12), -17.72 (-32.79, -2.65) for sperm concentration and motility respectively]. Evidence from current studies suggests potential harmful effects of mobile phone use on semen parameters. A further multicentred and standardized study is needed to assess the risk of mobile phone use on the reproductive system.

https://www.ncbi.nlm.nih.gov/pubmed/24700791

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