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REVIEW ARTICLE

The Effect of Microwave and Radiofrequency Waves of Mobile phones on Male Reproductive Cells: A Systematic Review of Recent Evidence

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ABSTRACT

Background: The increasing global use of mobile phones has raised concerns about the potential effects of microwave (MW) and radiofrequency (RF) radiation on male reproductive health. This systematic review aims to evaluate recent evidence (2015–2024) regarding the impact of mobile phone exposure on male reproductive cells.

Methods: A comprehensive search was conducted in databases including PubMed, Scopus, and Web of Science using keywords such as "mobile phones" ,"sperm" and "reproduction." Studies were screened based on predefined inclusion criteria, and data were extracted by year, geographic location, exposure frequency, and reproductive outcomes.

Results: The review revealed that sperm motility and morphology were the most frequently examined parameters. Experimental studies—particularly those involving animal models—dominate the literature, with a notable concentration of research originating from Asian countries such as India. However, a striking lack of cohort studies remains, limiting insights into long-term, real-world effects on human fertility.

Conclusion: This review highlights potential adverse effects of mobile phone exposure on male reproductive cells but emphasizes the need for standardized methodologies and additional cohort studies to fill existing gaps. Future research should prioritize well-controlled, longitudinal cohort studies to clarify associated risks and guide public health recommendations, ensuring a comprehensive understanding of mobile phone use.

KEYWORDS: *Microwaves, Radiofrequency, Cell phone, Reproductive, Male fertility, Sperm*

INTRODUCTION

Technological advances and the increased use of electronic devices—particularly mobile phones—have significantly transformed daily human life. Mobile phones have become the focus of substantial scientific investigation due to their emission of radiofrequency (RF) and microwave (MW) radiation. These waves, which are part of the electromagnetic spectrum, may have potential effects on human health [1]. With infertility affecting 8–12% of the global population, understanding the role of environmental factors, including RF electromagnetic radiation (RF-EMR), has become a critical research priority [2]. Given the essential role of the reproductive system in the survival and continuity of future generations, one of the primary concerns is the impact of these waves on the health of

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male reproductive cells. In this context, parameters such as sperm count, motility, and morphology as well as the function of reproductive stem cells have drawn increasing attention from researchers [3].

The male reproductive system is highly sensitive to environmental stressors, including radiation. The testes, which are responsible for spermatogenesis and hormone production, are exposed to radiation when mobile phones are carried in pockets or used for extended periods. Studies have shown that RF and MW radiation can penetrate tissues to a depth of 4–5 cm, reaching the testes and potentially disrupting their function [4]. RF and MW radiation at relevant frequencies are emitted by various sources, including mobile phones, wireless devices, and antennas. These waves interact with body tissues and can transfer energy to cells in either thermal or non-thermal forms [5]. Mobile phones emit non-ionizing radiation in the RF range, which is absorbed by biological tissues, including the testes. The testes are particularly vulnerable due to their high metabolic activity, continuous cell division, and limited capacity to dissipate heat. Over the past decade, numerous studies have examined the effects of mobile phone exposure on male reproductive cells, identifying potential mechanisms such as oxidative stress, DNA damage, and hormonal imbalances [6]. Despite these findings, the evidence remains inconclusive, underscoring the need for a systematic review of recent literature to present current insights and identify gaps in the existing knowledge base.

Recent studies have consistently demonstrated that exposure to mobile phones and other wireless devices can negatively impact male germ cells, leading to DNA damage, reduced sperm count, and impaired sperm motility. In vitro studies on human spermatozoa exposed to Wi-Fi radiation have shown significant increases in DNA fragmentation and reductions in motility and vitality [7]. Animal models have further corroborated these findings, with mobile phone exposure resulting in decreased sperm count and viability, as well as increased germ cell apoptosis—factors critical to successful fertilization [8]. A study by Dong et al. aimed to determine the effects of long-term exposure to electromagnetic radiation from mobile phones (MPs) on semen quality in healthy dogs. The study concluded that there were no indications of harmful effects on semen quality after 10 weeks of exposure to mobile phone radiation [9].

In summary, the debate surrounding the health effects of mobile phone use remains unresolved due to inconsistencies in the existing evidence. While some studies suggest potential health risks, others find no compelling indications of harm. The scientific community continues to advocate for further research to improve health risk assessments and provide more definitive conclusions regarding exposure. This review aimed to examine the global distribution of research, study methodologies, and reported adverse health effects. By systematically evaluating the existing body of evidence, this review seeks to inform ongoing discourse on mobile phone exposure and male reproductive health, offering valuable insights for policymakers, researchers, and healthcare professionals.

MATERIALS AND METHODS

This systematic review examines studies investigating the impact of MW and RF waves emitted by mobile phones on male reproductive cells over the last 10 years (2015–2024). A comprehensive search for eligible studies was conducted using the PubMed, Scopus, and Web of Science databases. The search strategy was based on keywords related to mobile phones and male reproductive cells.

The first group of keywords included: "Cell Phone*", "Mobile phone*", "Mobile Telephone*", "Transportable Cellular Phone", and "Cellular Phones" (Group 1). The second group included: "DNA damage" (DNA AND damage*), "DNA repair" (DNA AND repair*), "DNA replication" (DNA AND replicate*), "DNA injury" (DNA AND injury*), "DNA fragmentation" (DNA AND fragmentation), "sperm DNA fragmentation", "sperm DNA damage", "Leydig cell*", "fertility", "fecundability", (sperm AND nuclear AND DNA), "reproduction", and "sperm" (Group 2).

The final search strategy in each database was applied as: (Group 1) AND (Group 2). Figure 1 presents a PRISMA flowchart illustrating the selection process of included studies.

Studies that fulfilled the following criteria were included in our research: the study had to be original, written in English, and specifically investigate the effect of mobile phone exposure on male germ cell damage. To ensure a comprehensive review, sample size, exposure level, and sample type were not used as exclusion criteria. Data extraction was independently performed by two researchers using a standardized table. Information such as the article title, year of publication, study design, type of observed effects, sample type, exposure

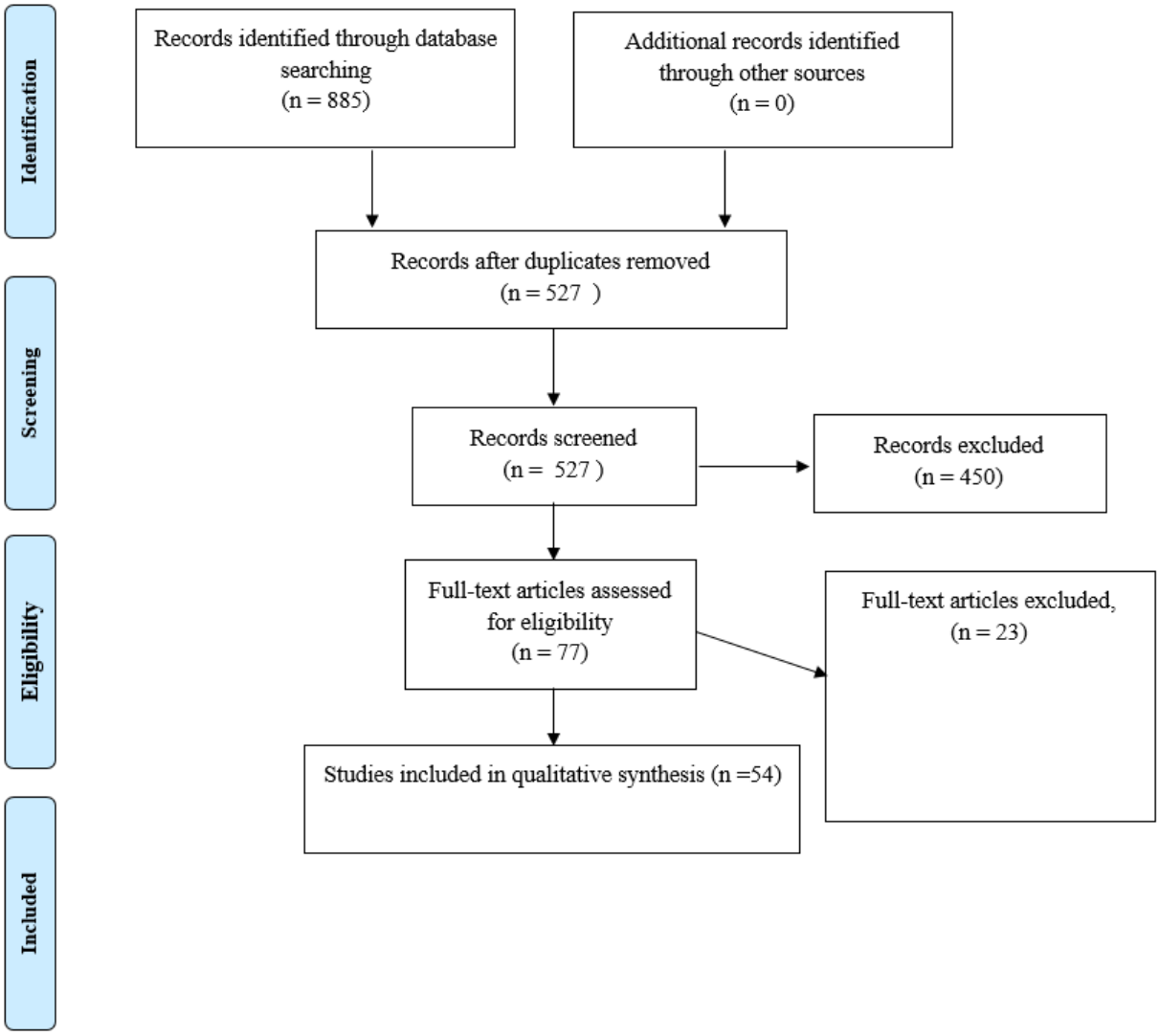


Figure 1. PRISIMA Chart

magnitude, and country of origin was extracted from each study. A third researcher reviewed the extracted data, compared the two tables, and resolved any discrepancies by consulting the original articles.

RESULTS

The present systematic review included the analysis of the various studies on the effects of mobile phone exposure on male reproductive cells. The findings suggest that exposure to electromagnetic waves at frequencies associated with mobile phones may have adverse effects on male reproductive cells.

The studies reviewed showed that exposure to mobile waves can reduce sperm quality and motility, increase sperm DNA damage, and reduce reproductive capacity. However, the findings were methodologically inconsistent and the observed effects strongly depended on various factors such as duration and intensity of exposure, distance from the source of the waves, and laboratory or animal model. The relevant studies and the effects examined are summarized in Table 1.

Table 1 illustrates the distribution of adverse effects associated with mobile phone exposure as reported in the reviewed studies. Table 1 represents the number of studies investigating each specific effect. Among the reported outcomes, sperm motility and morphology are the most extensively studied, with the highest number of publications focusing on these areas. Sperm count and sperm viability also emerge as frequently explored effects. Other notable areas include sperm quality and semen volume, which also receive significant attention in the literature. Conversely, topics such as sperm linear velocity, apoptosis, and immature sperm cells are the least studied, indicating potential gaps in the research.

Table 1. Studies investigating the adverse effect of mobile phone exposure with male reproductive cells

Adverse effect	References
DNA damage	[3, 10-24]
Sperm motility	[3, 8, 10-12, 16, 18, 20, 23, 25-37]
Sperm count	[3, 12, 17, 25, 26, 28, 30, 35, 37-45]
Semen volume	[12, 26, 31, 33, 35]
Sperm viability	[3, 8, 10, 18, 28, 36, 37, 43, 46]
Sperm quality	[45, 47-49]
Sperm linear velocity	[11]
Violation of sperm activity	[13]
Acrosomal reaction	[10, 11]
Apoptosis rate of sperm cells	[10, 22, 50]
Changes in the testes	[15, 27, 30, 51-55]
Number of apoptotic cells in epithelium	[56]
Morphology	[3, 10, 12, 14, 17, 23, 25-28, 33-35, 38, 40, 42-44, 46, 52, 53]
Immature sperm cells	[57]
Damage of germ cells and leydig cells	[15, 51, 58-60]
Decreased spermatid count or spermatogonia	[58]
Thickness of germinal epithelium	[61]

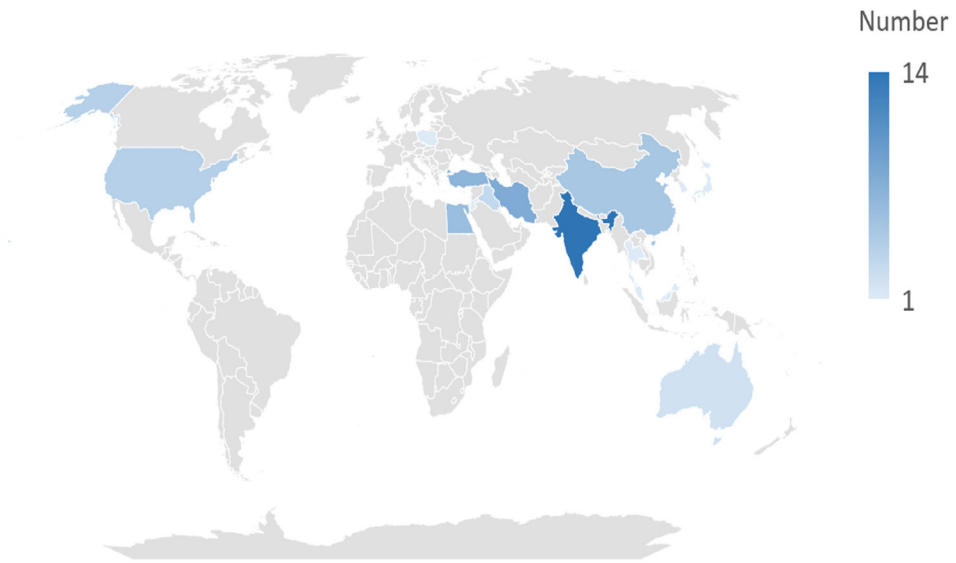


Figure 2. Geographical distribution of studies

The table underscores a prioritization of effects while highlighting the need for further exploration of less frequently investigated outcomes, such as sperm linear velocity and apoptosis effects.

Research activity is predominantly concentrated in Asia and the United States, indicating differing levels of scientific interest and regulatory focus, as illustrated in Figure 2. This figure depicts the geographical distribution of the studies included in this review. In Japan and several other countries, including Australia and Poland, limited research has been conducted.

The year of publication of the relevant studies was examined, and the results are presented in Figure 3. A review of the publication years showed that the distribution of articles over time was not uniform. As shown in the figure, the highest and lowest numbers of studies were from 2017 and 2023, respectively.

Also, as can be seen from the figure, the trend of studies is almost now declining. The decreasing trend in the number of articles may be due to various reasons, such as the time period covered by the present study or the shift in the focus of researchers to other areas related to health and electromagnetic waves. Also, technological advances and improved safety standards for mobile devices may have reduced the need for new research in this area. However, the results of this review show that although the number of articles has decreased in recent years, attention to this topic still exists among

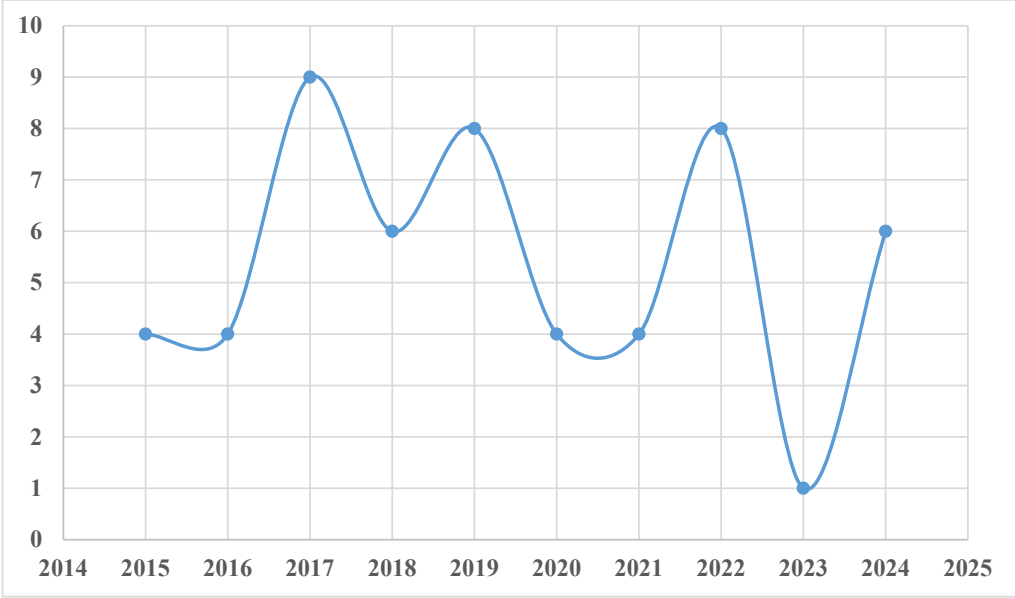


Figure 3. Time distribution of studies

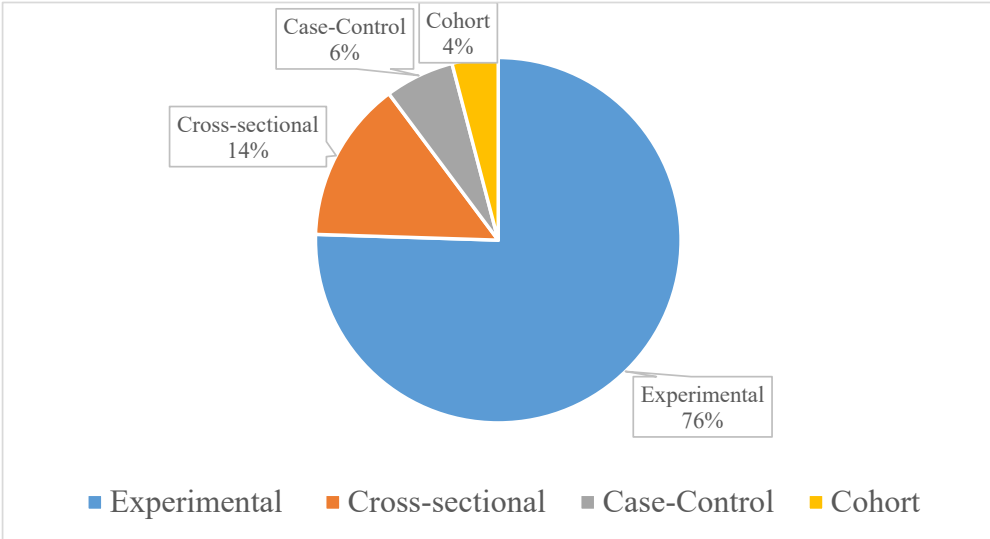
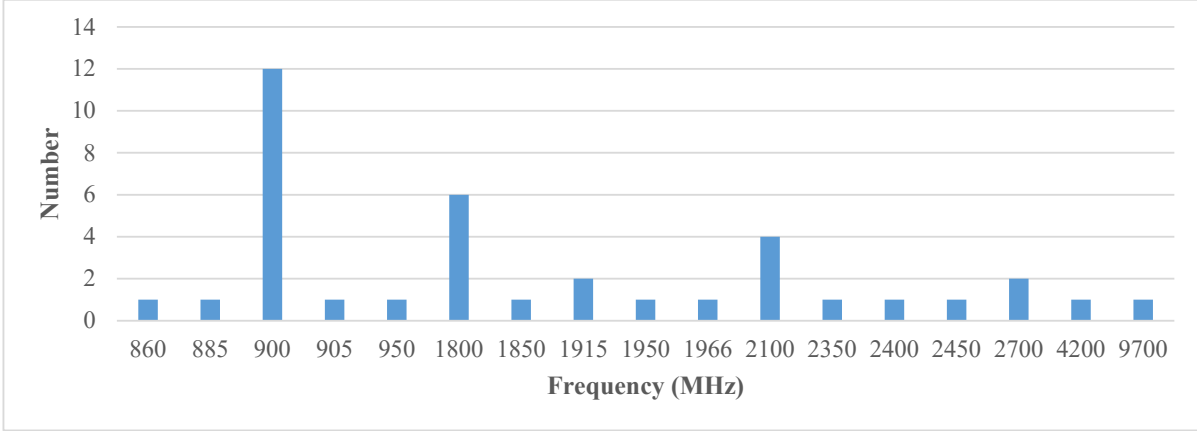


Figure 4. Type of studies

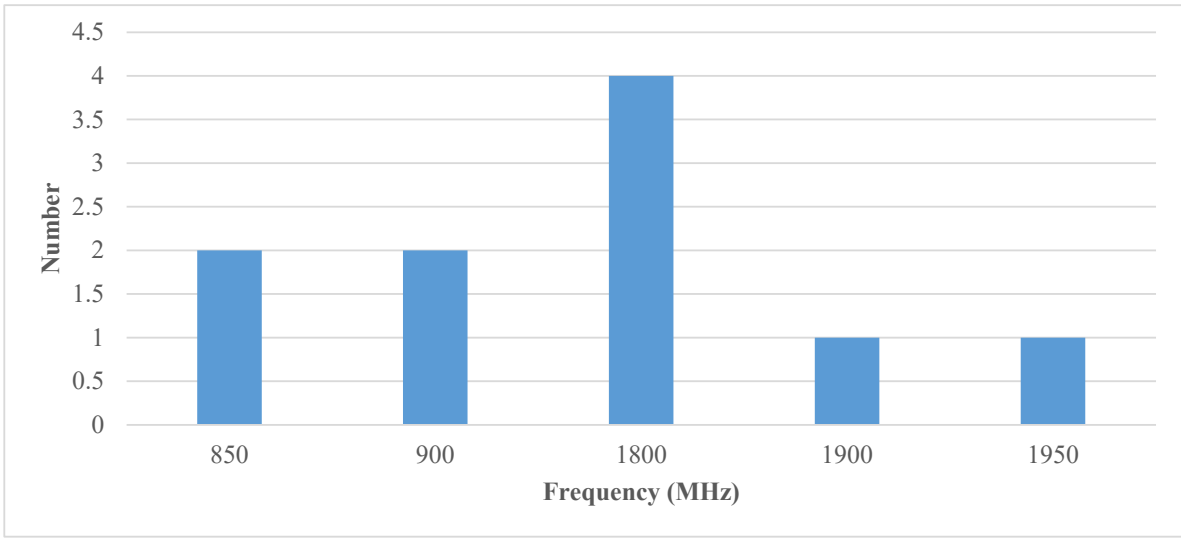
researchers and has been examined at different time intervals.

Experimental studies offer controlled environments that facilitate the exploration of causal mechanisms, particularly at the cellular and molecular levels. Epidemiological studies provide valuable insights into population-level trends; however, they often encounter challenges such as exposure misclassification and confounding variables. While case-control studies are useful for identifying associations, they may be susceptible to recall bias, particularly when evaluating long-term exposure. Notably, the majority of the studies (76%) fall under experimental designs, whereas cohort studies represent the smallest proportion (4%). Figure 4 categorizes the studies according to their methodologies, including epidemiological, experimental, and case-control designs.

The diversity of study types reflects the efforts of researchers to gain a comprehensive understanding of the effects of mobile phone radiation on male germ cells. Although laboratory and animal studies provide useful information about biological mechanisms, human studies are essential to confirm the results in real-world settings and provide practical recommendations. This



(a)



(b)

Figure 5. Number of frequencies studied in animals (a) and humans (b)

suggests that further research, particularly robustly designed longitudinal human studies, is still needed.

The studies reviewed in this systematic review used a variety of frequencies to assess the effects of mobile phone radiation on male germ cells. These frequencies include a range associated with different generations of mobile devices and other sources of radiation. The number of frequencies studied in animals and humans is presented in Figure 5. In animals, the highest number was at a frequency of 900 MHz. In humans, the highest number was at a frequency of 1800 MHz. It should be noted that in most studies, multiple frequencies were examined, which was taken into account.

An examination of the reviewed articles showed that the use of different Specific Absorption Rate (SAR) ranges in studies varied depending on the research objectives and the type of model used (animal or human). As shown in the figure 6, the most used SAR was in the range of 0 to 0.5 (W/Kg).

DISCUSSION

This systematic review underscores the importance of understanding the potential effects of mobile phone exposure on male reproductive health, particularly in the context of increasing global mobile phone usage. The findings highlight the need for further research to elucidate the mechanisms underlying RF-induced reproductive damage and to establish evidence-based exposure guidelines. This review aims to inform public

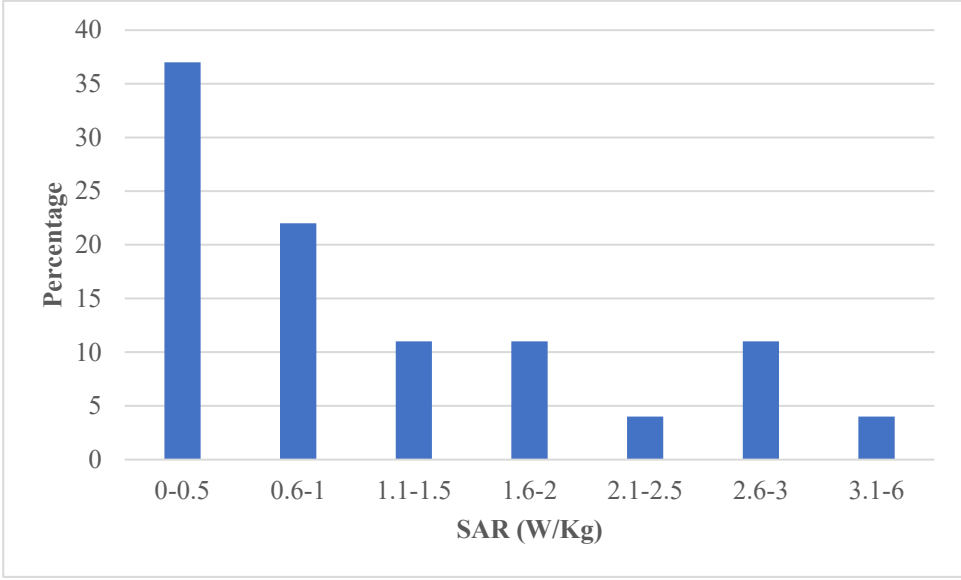


Figure 6. Percentage of specific absorption rate range in studies

health policies and contribute to the development of strategies to mitigate potential risks.

The systematic review highlights that the most significant effects of MW and RF waves on male reproductive cells were observed in sperm motility and morphology. These parameters were consistently reported across multiple studies as being adversely affected by mobile phone exposure, with reductions in motility being particularly pronounced. In contrast, the lowest effects were noted in sperm linear velocity and spermatogonia count, which showed minimal or inconsistent changes across studies. Various mechanisms may be related to these effects. Okechukwu reviewed various studies and found that human and animal spermatozoa exposed to electromagnetic radiation (EMR) from mobile phones exhibited reduced motility, structural anomalies, and increased oxidative stress due to the overproduction of reactive oxygen species (ROS). Elevated oxidative stress and scrotal hyperthermia might be key mechanisms by which EMR affects male fertility [62]. Iuliis et al. believe that RF-EMR can damage sperm function through mechanisms that include electron leakage from mitochondria and the creation of oxidative stress. Exposure to RF-EMR from sources like mobile phones could be a significant environmental factor that triggers sperm mitochondria to generate elevated levels of ROS [63].

While this systematic review provides a comprehensive analysis of the effects of MW and RF waves on male reproductive cells, it is important to acknowledge that the findings are not entirely consistent across all studies. Some investigations included in this review reported no significant effects of exposure on reproductive cells, such as semen quality [9]. These conflicting results may be attributed to differences in study design, exposure duration, frequency, and SAR values, as well as variations in sample size and population characteristics. Additionally, biological variability and individual susceptibility to RF exposure could play a role in these discrepancies. The presence of both positive and null findings underscores the complexity of this research area and highlights the need for further well-controlled, standardized studies to clarify the potential risks and mechanisms of RF-induced effects on male reproductive health. Key factors include variations in SAR (Specific Absorption Rate) values, frequency, duration, and proximity of exposure. Moreover, experimental studies often use controlled settings that may not fully replicate real-world exposure, while human studies are prone to confounding factors such as lifestyle, occupational exposure, and pre-existing health conditions. The lack of standardized methodologies across studies further complicates direct comparisons. Addressing these discrepancies through harmonized protocols and rigorous cohort studies is crucial for achieving more conclusive findings.

The review identified a fluctuating trend in the number of published articles on this topic between 2015 and 2024. The highest number of studies was published in 2017, reflecting a peak in research interest during this period. In contrast, the lowest number of articles

was recorded in 2023, indicating a possible decline in research activity or a shift in focus to other areas of reproductive health. This decreasing trend may also reflect the challenges in conducting high-quality experimental studies with rigorous exposure characterization and outcome assessment. The majority of studies included in this review were conducted in Asian countries, with India and Iran being the most prominent contributors. This geographic concentration may be attributed to the high prevalence of mobile phone usage in these regions, coupled with growing concerns about the potential health impacts of mobile phone exposure. The frequency of exposure varied significantly between animal and human studies. In animal models, frequencies ranged from 860 MHz to 9700 GHz, with 900 MHz being the most commonly used frequency. Human studies, on the other hand, often focused on frequencies associated with mobile phone technologies, such as 850 MHz to 1950 MHz. This variation in frequency highlights the need for standardized exposure protocols to enable meaningful comparisons across studies.

The majority of studies included in this systematic review were laboratory-based experiments, primarily conducted on animal models such as rats and mice, with a smaller subset involving human sperm samples in vitro. These laboratory studies provided valuable insights into the potential mechanisms of MW and RF wave effects on male reproductive cells, including DNA damage and alterations in sperm parameters. However, there is a notable scarcity of cohort studies, which are critical for understanding the long-term and real-world implications of RF exposure on male fertility. Cohort studies, particularly those involving human populations with documented exposure levels, are essential for establishing causal relationships and assessing cumulative effects over time. The lack of such studies represents a significant gap in the current evidence base, limiting the ability to draw definitive conclusions about the risks posed by mobile phone use. Addressing this gap through well-designed cohort studies is crucial for informing public health guidelines and ensuring a more comprehensive understanding of the reproductive health risks associated with mobile phone exposure.

Several limitations were identified in the reviewed studies, including variability in exposure protocols, inconsistent SAR values, and a lack of long-term follow-up data. Additionally, many studies were conducted in animal models, which may not fully replicate human exposure scenarios or biological responses. The heterogeneity in study designs and outcome measures further complicates the synthesis of evidence, highlighting the need for standardized methodologies in future research. In conclusion, while this review provides valuable insights into the effects of RF exposure on male reproductive cells, the limitations of the existing evidence base underscore the need for further high-quality studies to address these gaps and inform public health recommendations.

CONCLUSION

This systematic review presents the effects of MW and RF waves from mobile phones on male reproductive cells, highlighting significant impacts on sperm motility, count, and morphology. Most studies were laboratory-based, primarily using animal models, with a notable concentration of research in Asian countries like India and Iran. However, the lack of cohort studies represents a critical gap, limiting our understanding of long-term, real-world effects on human fertility. Addressing these gaps will enhance our understanding of mobile phone exposure's reproductive health implications and support strategies to mitigate potential risks. Given the widespread and increasing use of mobile phones globally, there is an urgent need for well-controlled, standardized studies particularly longitudinal cohort studies to clarify risks, establish causal relationships, and inform public health guidelines. Addressing these gaps is essential for developing evidence-based regulatory policies to mitigate potential reproductive health risks and ensure safer mobile phone usage practices.

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