

# Does the Use of Mobile Phone Affect Male Fertility? A Mini-Review

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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.

**KEYWORDS:** *Electromagnetic fields, male reproductive health, mobile phone, wireless technology*

## INTRODUCTION

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. EMR might alter male reproductive-endocrine mechanisms by affecting testicular functions necessary for testosterone and sperm production. Most studies conducted in this field were based on animal experimentation. The human testis is very subtle to radiation and heat. Short-term exposure of male Wistar rats to mobile phone radiation caused a slight decrease in serum testosterone levels and testicular weight.<sup>[1]</sup>

Samples of human ejaculated semen exposed to EMR emitted by a cell phone showed a significant reduction in sperm motility and viability and increase in reactive

oxygen species (ROS) level; this was achieved by the collection of semen samples from 23 healthy controls and 9 patients at an infertility clinic, where semen samples were collected through masturbation after an abstinence period of 48–72 h and allowed to liquefy completely for 15–30 min at 37°C. Ensuing liquefaction, the semen samples were categorized into two groups: control group (sample not exposed to mobile phone radiation) and exposed group (sample exposed to cell phone radiation). Semen samples in the exposed group were exposed to EMR emitted from a mobile phone in talk mode (the mobile phone device was Sony Ericsson w300i; the service provider was AT and T; Global System for Mobile communications network; 850 MHz frequency; maximum power <1 W; specific absorption rate 1.46 W/kg), the distance between the cell phone antenna and each

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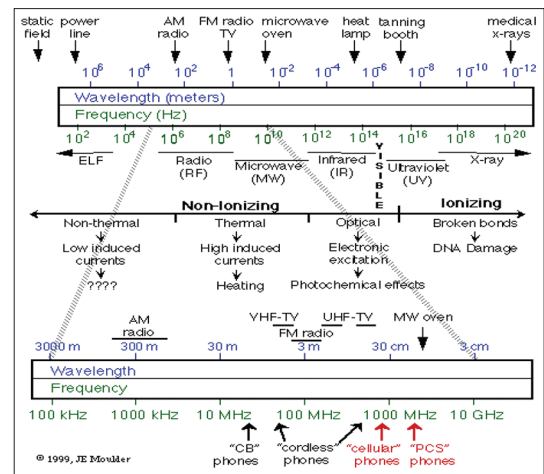
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specimen was kept at 2.5 cm, and the duration of exposure was 60 min, however the power density of the mobile phone was observed during basal condition (no cell phone radiation) and experimental condition (cell phone in talk mode) in the laboratory throughout the experiment. Power density in the control state was 0.01–0.1  $\mu\text{W}/\text{cm}^2$ , while power density in the experimental condition (during cell phone in talk mode and at 2.5 cm from cell phone antenna) was 1–40  $\mu\text{W}/\text{cm}^2$ , and the frequency discharged by the cell phone was checked with radiofrequency (RF) spectrum analyzer (Tektronix, Beaverton). Both groups were kept at room temperature to avoid the effect of temperature on ROS formation and semen parameters. After exposing the semen in the exposed group to mobile phone radiation, the semen samples from both groups (control and exposed) were examined for sperm concentration, motility, and viability. ROS was measured in the exposed and control groups after 1 h through chemiluminescence assay using luminol.<sup>[2]</sup>

There was a statistically significant decrease in the laboratory values of mean sperm count, morphology, motility, and quality/viability, among four different mobile phone user groups, exposed to mobile phone EMR daily.<sup>[3]</sup> EMR induced a significant genotoxic effect on epididymal spermatozoa.<sup>[4]</sup> Normal sperm samples exposed to a laptop computer connected to Wi-Fi for 4 h exhibited a significant reduction in sperm motility and an upsurge in sperm deoxyribonucleic acid (DNA) disintegration.<sup>[5]</sup> There was a significant association between exposure to RF electromagnetic field (EMF) with higher rate of childlessness among military men working for the Royal Norwegian Navy.<sup>[6]</sup>

RF-EMF in the power density and frequency range of cell phones increases mitochondrial ROS production in human spermatozoa and DNA damage.<sup>[7]</sup> Long-term exposure to EMR, both high and low frequency, might affect the male germ cell in humans.<sup>[8]</sup> However, exposure to EMR altered pituitary function in rats.<sup>[9]</sup> Constant exposure to EMR affected the Leydig and Sertoli cells in male rats, thereby altering male fertility.<sup>[10,11]</sup> There was an increase in free radicals and subsequently oxidative stress, decrease in sperm concentration, and decrease in motility and viability among men that were exposed to EMR.<sup>[12]</sup> Long-term exposure to mobile phone EMR may cause reductions in serum testosterone levels.<sup>[13]</sup> EMR alters normal reproductive processes in male rats; the same might occur in male humans exposed to RF-EMF over a long period of time.<sup>[14,15]</sup> The internal circuits of laptops and mobile phones used by male individuals regularly generates EMR [Figure 1]. The aim of this review was to examine the effects of mobile phone use on male fertility.



**Figure 1:** Electromagnetic radiation spectrum (Copyright 1999, the Radiation Research Society)

## MATERIALS AND METHODS

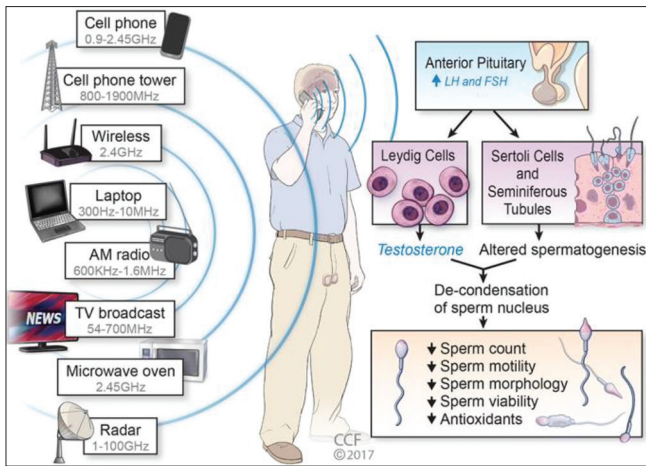
Related studies that reported on the effects of EMR from mobile phones on male fertility from 2003 to 2020 were evaluated. PubMed database was used. The Medical Subject Heading system was used to extract relevant research studies from PubMed using the following keywords: mobile phone, cellular phone, laptop computers, wireless technology, male reproductive health, electromagnetic fields, and radiowaves.

### Recent findings from human experimentation

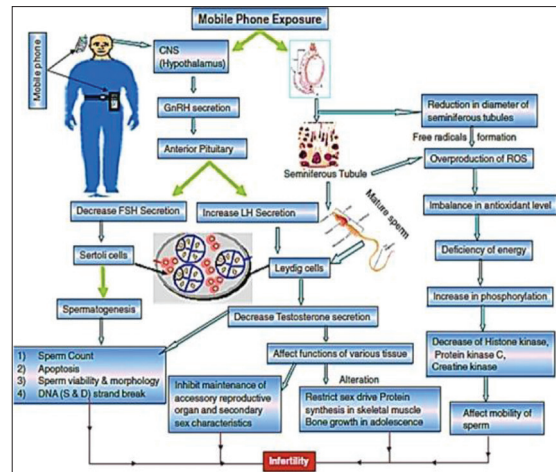
Long-term exposure to EMR emitted by mobile phones and Wi-Fi devices, might play a role in male infertility because of an increased production of ROS in exposed cells [Figures 2-5].<sup>[16]</sup>

RF-EMF increases ROS production by augmenting the action of nicotinamide adenine dinucleotide oxidase in the human cell membrane.<sup>[17]</sup> An examination of 468 men attending an infertility clinic from 1993 to 2007 with the aim of assessing if there is a combined effect of varicocele and carrying mobile phones in trouser pockets on semen and hormonal parameters was conducted during clinical checkup and the patients were questioned on mobile phone use. Their semen samples, serum testosterone, luteinizing hormone (LH), and follicle-stimulating hormone (FSH) were analyzed, and the results of the analysis showed that there was a consequence of keeping mobile phones in trouser pockets. Mobile phone storage in trouser pockets presented a statistically significant decrease in the percentage of normal sperm morphology and LH (both  $P < 0.001$ ), however varicocele and keeping mobile phone in trouser pocket did not show a combined effect ( $P = 0.76$ ).<sup>[18]</sup>

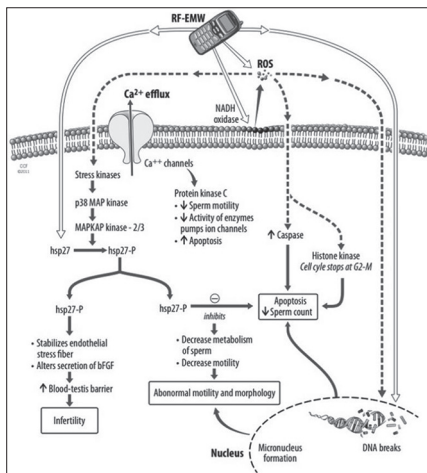
Zalata *et al.* exposed 124 human semen samples to mobile phone EMR, and they observed significant



**Figure 2:** Possible effects of electromagnetic radiation exposure on testicular function<sup>[16]</sup>



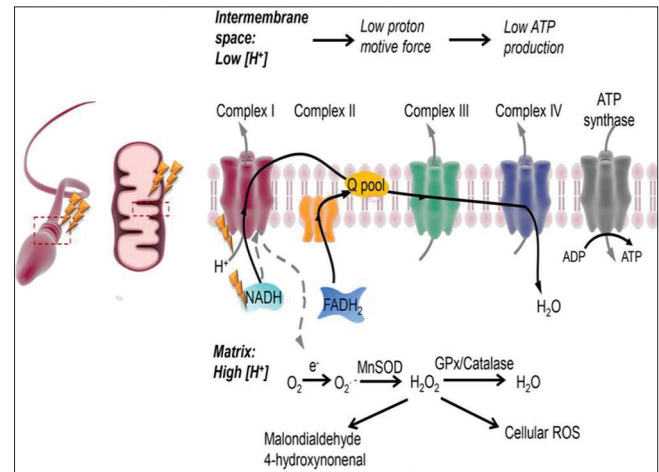
**Figure 3:** Biological effects of radiofrequency-electromagnetic field exposure on male fertility. (Kesari KK, Kumar S, Nirala J, Siddiqui MH, Behari J. Biophysical evaluation of radiofrequency electromagnetic field effects on male reproductive pattern. *Cell Biochem Biophys* 2013;65:85-96.)



**Figure 4:** Effects of electromagnetic radiation exposure on testicular cells. (Agarwal A, Singh A, Hamada A, Kesari K. Cell phones and male infertility: A review of recent innovations in technology and consequences. *Int Braz J Urol* 2011;37:432-54.)

decrease in sperm motility, sperm linear velocity, sperm linearity index, and sperm acrosin activity, moreover there was a significant increase in sperm DNA fragmentation in the exposed semen samples to RF-EMF compared with nonexposed samples.<sup>[19]</sup>

Zhang *et al.* examined the mobile phone use data of 794 young men which they obtained from the 2013 Chongqing College students cohort study on male reproductive health, they also extracted the mobile phone use data of 666 and 568 young men from the Chongqing College students cohort study in 2014 and 2015, respectively, they found that the number of time spent talking on the mobile phone was significantly associated with low volume of semen, sperm concentration and total sperm count, and that constant use of mobile phone internet service was linked to reduced sperm concentration and total sperm count in



**Figure 5:** Possible effects of radiofrequency-electromagnetic field on the mitochondrial electron transport chain of male spermatozoa. (Houston BJ, Nixon B, King BV, De Iulius GN, Aitken RJ. The effects of radiofrequency electromagnetic radiation on sperm function. *Reproduction* 2016;152:R263-76.)

2013 and reduced semen volume in 2015, these shows that a significant association exist between mobile phone internet use and poor sperm quality, the summary of the outcomes of the cohort studies was that EMR from mobile phone harmfully affect sperm quality by lowering the semen volume, sperm concentration, and sperm count thus affecting male fertility.<sup>[20]</sup>

Zilberlicht *et al.* worked on the association between mobile phone use and semen quality. Surveys designed with reference to demographic information on mobile phone use were filled by 106 men referred for semen analysis; the outcomes were analyzed, which showed that talking time of more than 1 h per day was related to a higher percentage of abnormal sperm concentration than



speaking <1 h per day (60.9% vs. 35.7%,  $P < 0.04$ ). The use of cell phone while charging it was associated with a higher percentage of abnormal sperm concentration compared to not using it while charging (66.7% vs. 35.6%,  $P < 0.02$ ); this might be because while charging a mobile phone, the external power source emits energy and owing to the unceasing supply of energy from the external source, the device transmits at a higher power, without the need for energy saving, which is different when compared to the usual talking mode. Concerning the location of the mobile phone, while it was not in use, 87.6% of the participants stated that the device was constantly held at a distance of <50 cm from the groin (47.5% in trouser pocket, 22.6% in their hands or on their belt, 2.5% in their shirt pocket, and 15% in other place), however the percentage of abnormal sperm concentration was not significant among participants who kept their mobile phones at a distance  $\leq 50$  cm from the groin compared with participants who kept their cell phones at a distance  $> 50$  cm from the groin (47.1% vs. 11.1%).<sup>[21]</sup> However, Kilgallon and Simmons observed that men who carried their cell phones in their hip pocket and on their belt had lower sperm motility ( $49.3\% \pm 8.2\%$ ) than men who did not carry a cell phones or who carried their cell phones phone in other places in the body ( $55.4\% \pm 7.4\%$ ;  $P < 0.0001$ ).<sup>[22]</sup>

Low RF-EMF of 15 Hz with a peak intensity of 8 Gauss, and a square waveform of 50 Hz, at a duration of few hours or less did not affect sperm quality, motility, and fertility.<sup>[23]</sup> It is very important to minimize the time spent on the mobile phone browsing the Internet or making a phone call in order to minimize the negative effects of cell phone EMR. A summary of the recent findings on the effects of RF-EMF on male fertility is summarized in Table 1.

## DISCUSSION

The evidences on the harmful effects of mobile phone EMR on male fecundity are still ambiguous and the biological effects of RF-EMF emitted by these devices on human reproductive system are not fully determined because most of the studies carried out on EMR exposure were mainly conducted on rats. Increased use of mobile phones worldwide has made mobile phone base positions to be sited in houses, schools, and hospitals. This has raised public concerns especially on the latest 5<sup>th</sup> generation mobile communication technology (5G technology), regarding the safety of inhabitants exposed to radiation from these devices.

Because of the advancement in mobile telecommunication technology, there is a need to conduct more research on the

interactions between this latest and popular smartphones and human health. A reduction in the proportion of sperm cells in the semen was associated with the frequency of using mobile phones, however, in a meta-analysis study comprising 1492 samples, constant use of mobile phones was linked to reduced sperm motility. This advocates that mobile phone exposure undesirably affects sperm quality, thus promoting male infertility.<sup>[29]</sup> Exposure to mobile phone EMR decreases sperm viability, motility, and sperm total antioxidant capacity in rats and results in oxidative stress.<sup>[30]</sup> EMR exposure caused an injury in the blood–testis barrier and induced immune infertility in male mice.<sup>[31]</sup> However, there is a need to conduct more investigations to determine the thermal and nonthermal effects of the 5G smartphones RF emissions on cell membrane structures and immune system.<sup>[32]</sup>

## Personal protective measures to reduce electromagnetic radiation

Humans should limit their rate of exposure to RF-EMF-emitting devices including laptop computers, Wi-Fi, and mobile base stations. In order to minimize the exposure to EMR emitted by cell phones, male individuals should avoid keeping their cell phones inside their trouser pocket for a long period of time because of the thermal effect of mobile phone radiation and proximity to the testes, and the use of hand-free materials and gadgets that limit direct contact of cell phones with the body should be encouraged. An example is the Bluetooth earpiece, and the use of shield case or purse should be encouraged by cell phone manufacturers in order to minimize cell phone EMR emission.<sup>[1]</sup> However, Vitamins C and E and some natural supplements have been shown to be effective in protecting the testis against RF-EMF effects [Table 2].

## Limitations of studies that investigated the effects of mobile phone electromagnetic radiation emission on human and animal physiology

According to Kostoff *et al.*, most laboratory studies conducted on humans and animals were not designed to identify the more severe adverse effects of RF-EMF exposure.<sup>[37]</sup> Numerous experimentations did not include the real-life pulsing and modulation of the 5G mobile technology carrier signal.<sup>[37]</sup> Many of the experimental studies did not investigate the merged harmful effects of other toxic environmental stimuli with wireless EMR and their mechanism of interactions to diminish male fertility [Figure 6].<sup>[37]</sup>

## Future directions

More funded laboratory experimental studies should be conducted to determine the effects of the latest 5G mobile technology devices and equipment (smartphones, Wi-Fi, 5G router, and masts) on male reproductive

**Table 1: Recent findings on the effects of radiofrequency electromagnetic field on male fertility**

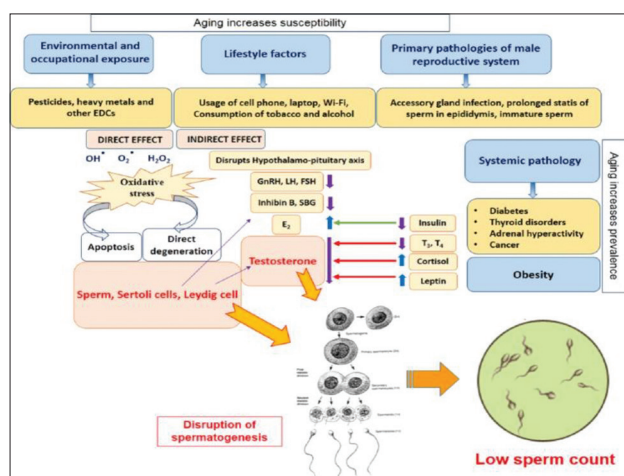
References	Objective	Study design	Materials and methods	Results
Houston <i>et al.</i> <sup>[24]</sup>	To determine the effects of whole-body exposures to RF-EMF on DNA of mouse spermatozoa	Rats	Unrestrained male mice were exposed to RF-EMF generated via a steadfast waveguide (905 MHz, 2.2 W/kg) for 12 h per day for a period of 1, 3 or 5 weeks	5 weeks of RF-EME exposure adversely affected the vitality and motility profiles of mature epididymal spermatozoa. These spermatozoa also had an increased mitochondrial generation of ROS after 1 week of exposure, with high DNA oxidation and fragmentation across all exposure periods
Yu <i>et al.</i> <sup>[25]</sup>	To determine whether the EMR emitted by 4 <sup>th</sup> generation mobile communication technology (4G) smartphones could affect male fertility by directly affecting the testes	Rats	A well-designed exposure model utilizing a 4G smartphone as the EMR emitting device was used. There was an exposure of the scrotum of the rats to the mobile phone device for 6 h each day (the smartphone was kept on active talk mode and received an external call for 1 min over 10 min intervals)	The results of the experiment showed that EMR exposure for 150 days decreased sperm quality and pup weight, followed by testicular injury. Sequencing laboratory analysis and western blotting suggested Spock3 overexpression in the testes of rats exposed to EMR for 150 days. Meanwhile, the inhibition of Spock3 overexpression improved sperm quality decline and alleviated testicular injury in the exposed rats. Moreover, EMR exposure suppressed MMP2 activity, while increasing the activity of the MMP14–Spock3 complexes and decreasing MMP14–MMP2 complexes; these results were reversed by Spock3 inhibition. Thus, long-term exposure to EMR emitted by a 4G smart phone reduced male fertility by directly disrupting the Spock3–MMP2–BTB axis in the testes of adult rats
Górski <i>et al.</i> <sup>[26]</sup>	To determine the effects of low RF-EMF exposure at a frequency of 50 Hz on human sperm motility	<i>In vitro</i> (Human semen)	Semen samples of twenty patients were exposed to the influence of an extremely low RF-EMF. After 5, 15 and 30 min, sperm motility was analyzed using a computer-assisted sperm motility analysis system. Velocity straight linear motility, cross-beat frequency, lateral head displacement and homogeneity of progressive motility velocity, were examined	A significant decrease in sperm motility speed and a significant increase in lateral head deviation values were observed under the influence of RF-EMF
Gautam <i>et al.</i> <sup>[27]</sup>	To determine the effects of 3G smart phone radiations on the reproductive system of male Wistar rats	Rats	Adult Wistar male rats which are 10 weeks old were used for the study. The rats were divided into two groups: control and exposed (eight rats in each). The rats were exposed to	Histopathological examination revealed a reduction in spermatogenic cells and alterations in sperm membrane. Significant increase in ROS and lipid peroxidation level with simultaneously decrease in sperm count, alterations in

Contd...

Table 1: Contd...

References	Objective	Study design	Materials and methods	Results
Oh <i>et al.</i> <sup>[28]</sup>	To study the effect of long period exposure to RF-EMF from mobile phones on spermatogenesis in rats using 4G-LTE device	Rats	3G mobile phone radiation for 45 days (2 h/day) in a specially designed Plexiglas rectangular box. sperm count, sperm morphology, mitochondrial activity, lipid peroxidation, ROS level, and histopathological state were analyzed  Twenty Sprague–Dawley male rats were placed into four groups corresponding to the intensity and exposure duration: Group 1 (sham procedure), Group 2 (3 cm distance+6 h exposure daily), Group 3 (10 cm distance+18 h exposure daily), and Group 4 (3 cm distance+18 h exposure daily). After 1 month, the results of sperm parameters and histopathological analysis of the testis were compared between the groups	sperm tail morphology were observed in the exposed group. Exposure to mobile phoneradiations induces oxidative stress in male Wistar rats which may lead to alteration in sperm parameters and reductions in male fertility  The observed mean spermatid count ( $\times 10^6/\text{mL}$ ) was 398.6 in Group 1, 365.40 in Group 2, 354.60 in Group 3, and 298.60 in Group 4 ( $P=0.041$ ). The mean count of spermatogonia in Group 4 (43.00) was significantly lower than in Group 1 (57.00) and Group 2 (53.40) ( $P<0.001$ and $P=0.010$ , respectively). The sum of the germ cell counts was decreased in Group 4 compared to Groups 1, 2, and 3 ( $P=0.032$ ). The mean Leydig cell count was significantly decreased in Group 4 ( $P<0.001$ )  This implies that the longer the exposure duration to RF-EMF, the more the decrease in spermatogenesis

EMF=Electromagnetic field, RF=Radiofrequency, EMR=Electromagnetic radiation, ROS=Reactive oxygen species, 3G=3<sup>rd</sup>-generation mobile communication technology



**Figure 6:** Possible environmental factors that might synergize with electromagnetic radiation in decreasing male fertility. (Sengupta P, Dutta S, Krajewska-Kulak E. The Disappearing Sperms: Analysis of Reports Published Between 1980 and 2015. *Am J Mens Health* 2017;11:1279-304.)

function with emphasis on the speed, power, latency, and carrier frequencies of the 5G signals and their interactions with other toxic environmental stimuli in

disrupting male reproductive-endocrine physiology.<sup>[28]</sup> Any adverse effect associated with 5G wireless radiation should be well established. Stationing 5G mobile technology equipment in an environment that have been marked for harmful wireless radiation might aggravate the adverse health effects associated with RF-EMF; more studies are needed to determine the synergistic effects of RF-EMF emitted by 5G mobile technology facilities and RF-EMF emitted from other facilities such as power stations for optimum environmental health assessment and protection.<sup>[37]</sup> However, mobile telecommunication companies and manufactures should endeavor to fund large-scale epidemiological studies with personal dosimeters for precise dose measurement and rate of tissue exposure, by determining the adverse effects of RF-EMF emitted by 4G and 5G mobile technology. This will enable the creation of future plans in order to lessen the risk of adverse health effects from unintentional human harm due to exposure to RF-EMF from mobile telecommunication devices and equipment.<sup>[38]</sup> There is a need to conduct vast laboratory experimentations in order to investigate and determine the adverse effects of

**Table 2: Supplements that can protect the testes against electromagnetic radiation**

References	Objective	Study design	Materials and methods	Results
Al-Damegh <sup>[33]</sup>	The objective of this study was to examine the possible effects of EMR emitted by mobile phone on the oxidant and antioxidant status in rat blood and testicular tissue and to determine the possible protective role of Vitamins C and E in preventing the harmful effects of EMR on the testes	Rats	In this experiment, the treatment groups were exposed to RF-EMF only, RF-EMF in addition to the administration of Vitamin C (40 mg/kg/day), and RF-EMF in addition to Vitamin E administration (2.7 mg/kg/day), respectively. All groups were exposed to the same electromagnetic frequency for 15, 30, and 60 min daily for 2 weeks	There was a significant increase in the diameter of the seminiferous tubules with disjointed seminiferous tubule sperm cycle. The serum and testicular tissue conjugated diene, lipid hydroperoxide, and catalase activities increased 3-fold, whereas the total serum and testicular tissue GSH and glutathione peroxidase levels decreased 3-5-fold in the RF-EMF exposed animals. However, the level GSH and catalase in the Vitamins C and E supplemented groups were significantly lower than those in the EMR exposed group  These results show that the adverse effects of the emitted RF-EMF had negative impacts on testicular architecture and enzymatic activities. However, Vitamins C and E might play a key role in modifying the oxidative stress levied on the testes by RF-EMF through scavenging the EMR-induced oxidative stress in the testes, hence restoring testicular tissue architecture and function by suppressing testicular lipid peroxidation and restoring the levels of Glutathione S-transferases and GSH to normal physiological levels
Bin-Meferij and El-Kott <sup>[34]</sup>	The objective of this study was to examine the capability of polyphenolic-rich <i>M. oleifera</i> leaf extract in protecting rat testis against EMR-induced impairments based on assessment of sperm count, viability, motility, sperm cell morphology, anti-oxidants, oxidative stress marker, testis tissue histopathology, and PCNA immunohistochemistry	Rats	Sixty male Wistar rats were divided into four equal groups  The first group (the control) received only standard diet, while the second group was supplemented daily and for 8 weeks with 200 mg/kg aqueous extract of <i>Moringa</i> leaves. The third group was exposed to 900 MHz fields for 1 h a day and for (7) days a week. The fourth group was exposed to mobile phone radiation and received the <i>Moringa</i> extract	The results of this experiment indicates that the EMR-treated group exhibited a significantly decrease sperm parameters. Furthermore, concurrent exposure to EMR and treatment with <i>M. oleifera</i> leaf extract significantly enhanced sperm parameters. However, histological results in EMR group showed irregular seminiferous tubules, few spermatogonia, giant multinucleated cells, degenerated spermatozoa and the number of Leydig cells was significantly reduced. PCNA labeling indices were significant in EMR group when compared to the control group.

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Table 2: Contd...

References	Objective	Study design	Materials and methods	Results
Ma and Jia <sup>[35]</sup>	To assess the protective effects of polydatin against the adverse effects of EMR on the testes of male rats	Rats	Male wild-type C57BL/6 mice (8 weeks old) were exposed to ionizing radiation. At different times after irradiation, their testes were isolated and subjected to H and E staining and TUNEL staining, as well as related quantification. ELISA assay was used to measure the level of inflammatory cytokines, and apoptosis proteins were detected by Western blot assay. Intracellular ROS was measured by DCFH-DA flow cytometry method	EMR affects spermatogenesis and contributes to cellular apoptosis due to its thermal effects and other stress-related EMR factors in testicular tissue. Chronic exposure to EMR induced testicular injury was prevented by the administration of <i>M. oleifera</i> leaf extract. Polydatin successfully decreased testicular injury and maintained sperm viability. Polydatin pre-treatment also inhibited cell apoptosis caused by irradiation. Radiation-induced decrease of FSH and testosterone was also inhibited by polydatin treatment. polydatin reduced the ROS level, which was measured using DCFH-DA method, and reduced the concentration of the oxidative products malondialdehyde and 8-hydroxydeoxyguanosine. polydatin also inhibited apoptosis-related proteins such as Bax and caspase 3. This study shows that polydatin is effective in alleviating testicular injury after irradiation, mainly through reducing ROS and oxidative stress. therefore, polydatin is a potential radioprotector for testes radiation damage
Ding <i>et al.</i> <sup>[36]</sup>	The aim of this study was to examine the biological impacts of apoptosis caused by 50 Hz power line EMF and the protective effects of Vitamins C and Vitamin E	<i>In vivo</i> (B <sub>95-8</sub> and Balb/c-3T3 cells)	B <sub>95-8</sub> and Balb/c-3T3 cells were divided into a sham group, an exposure group and three exposure groups in which the cells were preincubated with various concentrations of Vitamin C and Vitamin E. Then, all the cells were exposed to 50 Hz power line EMF and analyzed for apoptosis. The cells were collected for apoptosis detection after exposure	Vitamin C and Vitamin E produced a significant protective effect toward 50 Hz EMF radiation. The ideal protective concentrations of Vitamins C and Vitamin E are 10 µmol/L and 25 µmol/L, respectively. The protective effect of Vitamins C and E was more obvious for Balb/c-3T3 cells than B <sub>95-8</sub> cells

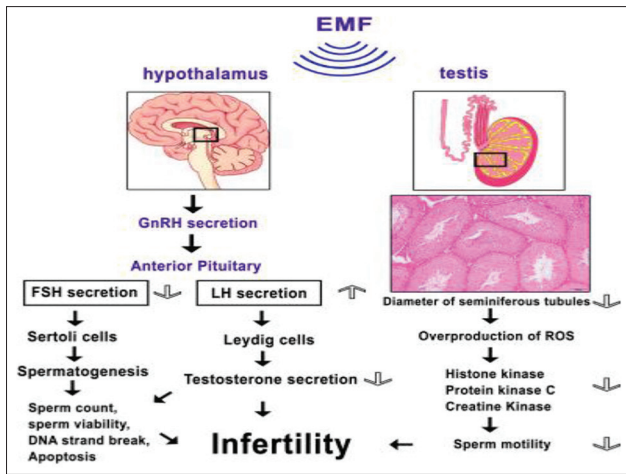
EMF=Electromagnetic field, RF=Radiofrequency, EMR=Electromagnetic radiation, GSH=Glutathione, PCNA=Proliferating cell nuclear antigen, HE=Hematoxylin-eosin, ELISA=Enzyme-linked immunosorbent assay, DCFH-DA=Dichloro-dihydro-fluorescein diacetate, ROS=Reactive oxygen species, FSH=Follicle-stimulating hormone, *M. oleifera*=*Moringa oleifera*

RF-EMF exposure on the hypothalamus most especially gonadotropin-releasing hormone and anterior pituitary gland with respect to FSH, LH, and prolactin secretions. This will contribute immensely in establishing the harmful effects of EMR exposure on male fertility [Figure 7].

## 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





**Figure 7:** Potential interaction between mobile phone radiofrequency-electromagnetic field, hypothalamus, anterior pituitary gland, and the testis. (Altun G, Deniz ÖG, Yurt KK, Davis D, Kaplan S. Effects of mobile phone exposure on metabolomics in the male and female reproductive systems. *Environ Res* 2018;167:700-7.)

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.

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Nil.

### Conflicts of interest

There are no conflicts of interest.

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