

## Impact of Cell Phone Radiations in Reproduction-A Review

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**ABSTRACT:** Cellular gadgets are crinkling the modern day society and health effects caused by the electromagnetic radiations emitted from cell phones are overlooked. Present study was designed in order to direct the attention towards reproductive health and awareness among the public regarding the effects of electromagnetic radiations emitted from cell phones on the reproductive capabilities in both males and females. For this, different research journals, scientific search engines including ISI web of knowledge, pubmed, google scholar and medline which are published since 2010 in english were searched and relevant articles were selected for the review. It has been observed that the electromagnetic radiations can enhance the excitability of the reproductive organs causing increase in testosterone, alteration in spermatogenesis, infertility among couples, apoptosis, mortality, quality of oocytes and oxidative degeneration. The damaging effect of these radiations depends upon the frequency range, distance from the source, duration of exposure and condition of the subject during exposure.

**Keywords:** Cell Phones, Electromagnetic Field, Radiofrequency Radiations, Reproductive Health.

### I. INTRODUCTION

Electromagnetic fields (EMFs) are an integral part of our life. We are being continuously exposed to EMFs as a result of progress in technology and since last three decades. All electrical and electronic devices produce damaging electromagnetic fields, which are harmful to biological systems (Ongel *et al.*, 2009, Singh *et al.*, 2012, Singh *et al.*, 2013). Among all sources, cellular phones have become obligatory devices and are essential to everyday life. Even these days, when whole world is fighting against COVID 19 and we are lockdown at our homes, our hasty lives still depends upon a variety of technological devices such as the computer, laptops, tablets and mobile phones. Among all the “Smart phones” are most crucial. The exposure to these EMF radiations increased several folds due to the introduction of latest generation mobile phones.

These cellular devices operate at diametric frequencies that vary in range and bandwidth in different parts of the world. The concerns are up burdening the possible hazardous effects of these cellular radiations emitted by cell phones on health status of human. For years, the mobile phone companies have taken the people in confidence about the safe usage of these devices. But literature and surveys has signalled the adverse effects of these Radio Frequency Electromagnetic fields (RF-EMFs), generated from mobile phones on biological systems of human and other experimental animals. A recent announcement by the World Health Organization

(WHO) assured that these radiations are the grounds of brain cancer. According to International Agency for Research on Cancer (IARC), RF EMFs have been categorised as probable carcinogenic to humans (Baan *et al.*, 2011). The expected harmful effects of cell phone technology on male and female reproductive organs were extensively investigated by many researchers (Erogul *et al.*, 2006; Wdowiak *et al.*, 2007; Agarwal *et al.*, 2009; Kesari *et al.*, 2011; Hanci *et al.*, 2013; Monfared *et al.*, 2015; Ali *et al.*, 2016).

In this review article, relevant articles or publications were searched in ISI web of knowledge, pub med and goggle scholar with zero of the restriction on publication date. 50 studies were retrieved and among them 20 studies were met with inclusion criteria (Fig. 1).

The present review concerned with the probable effect produced by EMFs on reproductive organs of male and female, infertility among couples, miscarriages, premature births, pregnancy and other reproductive prospective. Besides investigation of rising issues from various studies on human and other experimental animals, extensive forthcoming succeeding various reproductive consequences accompanying the cell phone technology has been discussed and reviewed. This will help to establish the need for various prophylactic measures to be taken to minimize the effect of EMF on the male and female reproductive system. Potential effects of cell phone RF EMF on the male and female reproduction are summarized in Table 1.

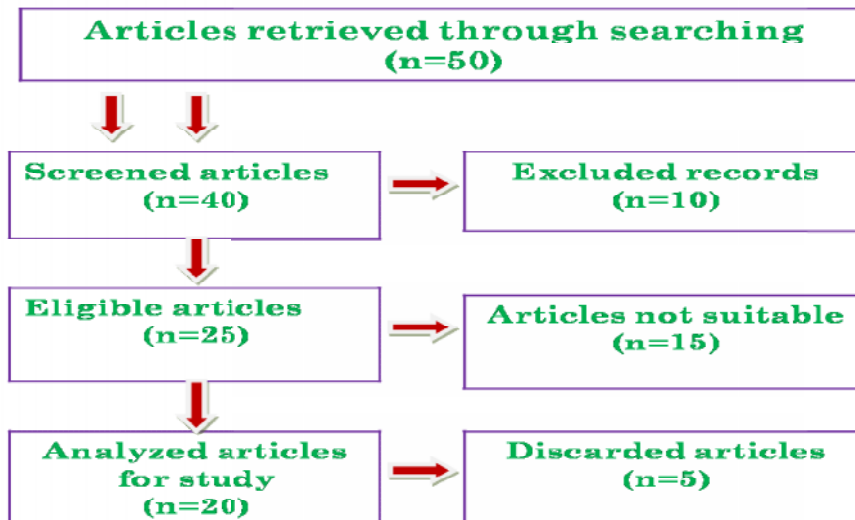


Fig. 1. Flow diagram showing selection process.

Table 1: Impending effects of cell phone RF EMF on the male and female reproduction

S. No.	Sex	Effect	References
1.	<b>Male</b>	testosterone testosterone	Dasdag <i>et al.</i> (1999); Sepehrmanesh <i>et al.</i> (2013); Hanci <i>et al.</i> , (2013)
	Leydig cell	1. altered spermatogenesis 2. maturation arrest in the spermatogenesis 3. infertility	Wang <i>et al.</i> (2003); Khillare and Behari (1998); Dasdag <i>et al.</i> , (2003); Dasdag <i>et al.</i> (1999); Kumar and Shukla (2014)
	Sertoli cell	1. Reactive oxygen species 2. Free radicals 3. Apoptosis	Aitken <i>et al.</i> (2005); Odacı and Özyılmaz (2015); Kumar <i>et al.</i> , (2014); Dasdag <i>et al.</i> , (1999); Dasdag <i>et al.</i> , (2003);
	Semen	4. Lipid peroxidation 5. Sperm count 6. Sperm DNA damage 7. Glutathione peroxidase and superoxide dismutase	Gollapudi and McFadden (1995); Aitken <i>et al.</i> , (2005); Ogawa <i>et al.</i> , (2009)
2.	<b>Female</b>		
	Ovary	1. Number of follicles 2. Oocyte DNA damage	Gul <i>et al.</i> , (2009); Hajiun (2013); Bakacak <i>et al.</i> (2015)
	Endometrium	1. Apoptosis 2. Oxidative stress	Ali <i>et al.</i> (2016); Nazıroğlu <i>et al.</i> (2013); Lavranos <i>et al.</i> (2012); Oral <i>et al.</i> (2006)
	Embryo	1. Growth retardation 2. Mortality 3. Foetal cardiac output	Batellier <i>et al.</i> , (2008); Rezk <i>et al.</i> , (2008); Bastide <i>et al.</i> , (2001)

## II. MALE REPRODUCTIVE SYSTEM

Radio frequency electromagnetic waves (RF EMW) produced by cell phones are absorbed by our body (Ozguner *et al.*, 2005). The energy emitted by these electromagnetic particles may rupture chemical bonds and seriously damage human tissue/organs (Sharma *et al.*, 2019). These radiations may produce “thermal effect” which may increase temperature in tissue and causes disturbance in cell functioning and development (Deepinder *et al.*, 2007). The eye, brain and the testes are peculiarly vulnerable to the thermal effect where maximum damage can be seen (NRBD, 2004). Due to thermal effects of RF-EMF exposure, the body temperature raised, causing disruption of

spermatogenesis (Kandeel and werdloff, 1988; Saunders *et al.*, 1991; Jung and Schill, 2000). In combination with thermal effects, non-thermal effects are also produced by RF radiations which are manifested by disruption of cell membrane integrity, endothelial dysfunction, change in the blood-brain barrier, altered cellular signal transduction, immune system and several nervous system excitability defects (WHO, 2006; Straume *et al.*, 2005; Yan *et al.*, 2007; Friedman *et al.*, 2007; Leszczynski *et al.*, 2002). Alteration in hormone secretion by follicle, due to deformation of Leydig and Sertoli cells, cause altered cell proliferation on exposure to EMF radiation (Roosli *et al.*, 2007). Literature review has shown that, there are number of studies pointing

towards increasing male infertility, sperm count alterations, sperm motility, morphology and viability of sperms as a result of excessive cell phone use (Kesari *et al.*, 2010; De luliis *et al.*, 2009; Yan *et al.*, 2007; Eroglu *et al.*, 2006). These days, unproductiveness is affecting approximately 15% of couples where approximately half of the cases results from male infertility (Thonneau *et al.*, 1991; Sharlip *et al.*, 2002), suggesting a possible link between cell phone use and infertility. A study in male Wistar rats analysed the consequences of free radical production on exposure to cellular devices (mobile phone) for 35 days (2 h/d), and their effect on male fertility pattern (Kesari *et al.*, 2011). A significant decrease in cellular enzyme levels of glutathione (GSH) peroxidase and superoxide dismutase (SOD) occurred, while a significant uprise in catalase and malondialdehyde (MAH) in the EMF exposed rats was observed. A significant change in cell cycle of sperm, a significant decrease in micronuclei and a significant gain in free radicals generation was also reported. It was concluded that the overproduction of reactive oxygen species (ROS) due to RF EMR from mobile phones might impact the potentialities of sperm fertilization (Kesari *et al.*, 2011). In another examination by Fejes *et al.* (2005) reported negative effects on the sperm motility characteristics due to prolonged use of cell phones. In a pilot human study, it has been investigated that people who keep their cell phones close to the testis has shown decrease in sperm count when compared to those who do not use cell phones at all or kept it somewhere else (Kilgallon and Simmons, 2005). A study by Adebayo *et al.*, (2019) observed that exposure of radio frequency of 1800 MHz leads to the histological changes in testis, deformation of seminiferous tubules, loss of cellular structure of epididymis and complete absence of spermatozoa in the area of inflammation, which may act as grounds of low fertility. Similarly in previous study by Eroglu *et al.* (2006), where enrollment of 27 males was done to check sperm motility has shown that the sperm motility is influenced by cellular phone. Besides, it has been observed that EMR exposure for longer duration may cause behavioural or structural changes in the male germ cell. However, no connection was shown between sperm count variation and cell phone EMF radiation (Aitken *et al.*, 2005; Dasdag *et al.*, 2003; Gutschel *et al.*, 2011; Yan *et al.*, 2007), suggesting the need for more research in this area.

A pilot study reported harmful effect of cell phone use on sperm concentration in exposed men. An increase in the level of serum testosterone, epididymal sperm motility, and sperm morphology of rats in 1800 and 900 MHz EMF exposed rats could be considered to be a cause of precocious puberty in growing rats (Gutschel *et al.*, 2011; Nisbet *et al.*, 2012). In experimentation by Meo *et al.* (2010), 34 male Albino rats were studied and out of these, 14 rats were given exposure to radiations from mobile phone daily for 30 minutes and another 14 rats were given exposure to radiations from mobile phone daily for 60 minutes for total 3 months period. A reduction in serum testosterone levels has been observed due to long-term continuous exposure to mobile phone radiation indicating withering effects on reproductive

and general health (Sepehrimanesh *et al.*, 2013). In another study on exposure of mice to EMF leads to increase in testosterone level (Wang *et al.*, 2003; Forgács *et al.*, 2006). but a significant decrease in testosterone levels was reported in mobile phone radiations exposed animals as compared to control group (Forgács *et al.*, 2006; Oyewopo *et al.*, 2017).

Several studies have concerned that the radiation emitted from mobile phones increases the production of reactive oxygen species (ROS) in human semen with dysfunctional semen quality (Agarwal *et al.*, 2009; Aitken *et al.*, 2005). From *in vitro* studies, it has been demonstrated that electromagnetic radiation stimulates ROS production which may lead to DNA damage in human spermatozoa, which further promote decrease in motility and viability of sperm cells depending on the duration of exposure to radiation (De luliis *et al.*, 2009). In spermatozoa, the DNA damage may be connected to the male infertility, premature pregnancy and mortality of offsprings (Aitken, 1999). A single study in mice was investigated where the experimental animals were exposed to RF-EMR for 12 h/d for 1 week, and the rate of DNA damage in spermatozoa of the caudal epididymal was assessed. A significant damage in the mitochondrial genome and the nuclear  $\beta$ -globin locus has been confirmed after a detailed analysis of DNA integrity. This study suggested that although RF-EMR may not generate remarkable effect on development of male germ cell, but a significant genotoxic effect may be observed in epididymal spermatozoa (Aitken *et al.*, 2005). Harmful effects on chromatin and DNA were also observed by Gollapudi and McFadden (1995) under the effect of mobile phone with SAR of 0.96W/kg. Similarly, in experimentation on mice, DNA damage in embryonic stem cells and cauda epididymal spermatozoa was observed on exposure of animals to 900 MHz (RF EMF), 1.7 GHz frequency (Aitken *et al.*, 2005; Ogawa *et al.*, 2009).

Studies on various animal models showed that EMF emitted by mobile phones have a variety of harmful effects on the sperm parameters in male reproductive system (Derias *et al.*, 2006). Several studies on varied animals observed the histopathological changes in the testis of cell phone EMW radiation exposed animals (Sepehrimanesh *et al.*, 2013; Oyewopo *et al.*, 2017; Ogawa *et al.*, 2009). These changes are directly linked with the duration and distance of cell phone exposure, specific absorption rate (SAR), and energy level of the EMW. In an experimentation on mice, it has been found that Leydig cells are most vulnerable to EMW (Forgács *et al.*, 2006; Wang *et al.*, 2003). Any injury to these cells may have an effect on spermatogenesis. Reports showed a reduction of size of testis (Desai *et al.*, 2009), decrease in epithelial thickness and reduction in the diameter of seminiferous tubules (Salama *et al.*, 2010; Dasdag *et al.*, 2003; Dasdag *et al.*, 1999; Ozguner *et al.*, 2005; Tas *et al.*, 2014; Bahodini *et al.*, 2015). It has been reported by Khayyat (2011) and Kumar and Shukla (2014), electromagnetic field emitted from cell phones leads to Leydig cell hypoplasia, wide interstitium, seminiferous tubules atrophy, maturation arrest in the sperms, decreased number of germ cell, pyknotic nuclei

in germ cell and vacuolization in spermatogenic cells; in addition along with separation of spermatogonial and sertoli cells from the basal lamina, decrement in size, residual cytoplasm and scrapping of degenerating cells in the seminiferous tubules has also been observed. Similarly in studies by Oh *et al.* (2018) and Yu and Bai (2018), a decrease in spermatogenesis and loss of sperms quality was observed when animals were exposed for long duration to electromagnetic field from mobile phones. In a study on male adult rats by Odacı and Özyılmaz (2015), the group of rats was exposed to 900 MHz EMF (1 h/30 day), and testicles were observed for malondialdehyde, superoxide dismutase, catalase and glutathione levels, apoptotic index and histopathological disruptions. Results with histopathological studies evidenced vacuoles in the seminiferous tubules basal membrane and edema in the intertubular space (Odacı and Özyılmaz, 2015; Tas *et al.*, 2014). Reduction in the thickness of seminiferous tubule and germinal epithelium were observed in EMF groups and the apoptotic index was also reported to be higher. The values of superoxide dismutase, malondialdehyde, catalase and glutathione in the EMF group were significantly lower as compared to control group. It has been concluded that 900 MHz EMF exposure altered adult rat testicular morphology and its biochemistry (Sepehrimanesh *et al.*, 2013; Odacı and Özyılmaz, 2015). In a study, Salama *et al.* (2010) investigated the compiled effects of vulnerability to electromagnetic radiation exposure discharged by a conventional mobile phone (800 MHz) on testis for 8 h/d (12 weeks). It has been discovered in the study that it affects the testicular structure and function in adult rabbit. Ozlem Nisbet *et al.* (2012) found that when rats were exposed to 900 to 1800 MHz radiations then severe vacuolar degeneration, necrosis and desquamation of the seminiferous epithelium, rise in plasma testosterone in exposed group comparable to the sham control group was reported. Kumar *et al.* (2014), has also reported that the mobile radiation adversely affect the male fertility by significantly decreasing sperm count, reduction in testicular weight, accelerating lipid peroxidation damage in sperm cells, reduction in seminiferous tubules and DNA damage. In another study by Killari and Behari (1998), changes in the ultrastructure of seminiferous tubules, Leydig cells and spermatids in rats' testis were investigated after EMW exposure. In a study when rats/mice were exposed for 3 minutes daily during 30 days using a conventional cellular telephone, a decrease in seminiferous tubule diameter was observed (Dasdag *et al.*, 1999; Dasdag *et al.*, 2003). Comparable results were also assessed by Ozguner *et al.*, (2005) with decrease in thickness of seminiferous epithelium. However, numerous studies found negative histological alteration in the animal testicular tissues when exposed to the different frequency of cell phone EMW (Dasdag *et al.*, 2003; Ribeiro *et al.*, 2007; Forgacs *et al.*, 2005; Forgacs *et al.*, 2006). In previous studies by Ozguner *et al.*, (2005) and Hanci *et al.*, (2013), a significant reduction in diameter of seminiferous tubular, serum total testosterone level and mean height of the seminiferous epithelium after exposure to 900 MHz cell

phone radiation has been observed in rat testis. The contrasting effects of RF EMF on male reproductive system reported in the literature could be assigned to difference of opinion in the power density of source, frequency of radiation, level and time of exposure (Meo *et al.*, 2010).

*In vitro* studies has also been conducted to show the impact of RF EMF on the reproductive health of individuals. The exposure of 850 MHz with SAR 1.46 W/kg for 60 minutes was given and a distance of 25 cm of antenna was kept from the samples to be studied. On determination of results, significant decrease in sperm viability and motility and also increase in ROS levels as compared to control (unexposed) group was observed (Tas *et al.*, 2014; Erogul *et al.*, 2006). These studies were also supported by Yan *et al.* (2007) where decrease in sperm fertilizing ability was observed when exposure of 900 MHz frequency from mobile phones for one hour was given. Also, decrease in sperm fertilizing ability and increase in DNA fragmentation was observed in *in vitro* studies of human sperm (Avendaño *et al.*, 2012).

### III. FEMALE REPRODUCTIVE SYSTEM

Female reproductive organs have crucial purpose with number of functions in the organism. But there is scarcity in the literature as well as data lying on the outcome of RF- EMF on the female reproductive system. The female genital system consists of a uterus, a pair of ovaries, a pair of fallopian tubes, germinal and other somatic cells. Abnormal embryo development may occur, as a result of damage to reproductive tissues.

Records in humans and various other animals signalled a drastic adverse impact of RF-EMR on granulosa cells, numbers of ovarian follicle, and endometrial tissue, quality of oocytes and embryos; even alterations in the physiology of foetus heart at the time of pregnancy. Jung *et al.*, (2007) recommended that irradiation of female mice to 20 kHz EMF may have an effect on the oestrous cycle due to disruption of the endocrine physiology of female reproductive system. It has been suggested by Poulletier de Gannes *et al.*, (2012) that on exposure to non-ionizing EMR there is a potential risk factor for infertility. In studies by many researchers, it has been investigated that EMFs causes neuroendocrine changes which is a major component of hormonal imbalance and infertility symptoms in females (Nelson *et al.*, 1995). A number of researchers have been focused on the damaging effects of EMFs on the granulosa of oocytes, whereas apoptosis is a major concern in several articles (Nelson *et al.*, 1995). The attention of many researchers was also drawn by two interrelated issues of spontaneous abortion and fetal abnormalities (Schnorr *et al.*, 1991). Bastide *et al.*, (2001) reported the highest level of embryonic death (64%) in the eggs placed near the telephone compared to 11% in controls. Grigoryev (2003) exposed the embryos of chick to electromagnetic field radiated from GSM mobile phone during embryonic development period. The increase in mortality rate of 75% is reported in the embryos during incubation period than 16% in control group. It has been evaluated by Diem *et al.*, (2005) that RF EMF exposure induced DNA single- and double strand breaks. In a



study by Zareen *et al.*, (2009), different doses of RF-EMR were studied, the effect of RF-EMR on general growth, survival rate and development stages of chick embryos (incubation for 10 or 15 days) was assessed. It has been observed that on exposure of RF EMR significant decrease in the survival of chick embryos was seen which indicate retardation of embryo growth (Zareen *et al.*, 2009). In another study, the effect of RF EMR exposure on chicken's fertilized eggs was assessed. The eggs were divided into two groups, one group of 60 eggs (experimentation group) was exposed to a cell phone in the "call" position, while another group of 60 eggs (sham group) was exposed to a similar cell phone in the "off" position. The exposed group showed a significant embryo mortality mainly between 9 and 12 days of incubation (Batellier *et al.*, 2008). Increase in abnormality in foetus was observed during pregnancy period when mice was exposed to 20 KHz saw tooth EMF (6.5 MT) for 8 h/d (Jung *et al.*, 2007).

To study the consequence of RF EMR of mobile phones in rat ovaries, a study was conducted in which the pregnant rats exposed to mobile phones by keeping the cell phone underneath the cages during the pregnancy period. On the 21<sup>st</sup> day afterwards delivery, the right ovaries of the female rat pups were removed and the numbers of follicles were assessed. It has been observed that the number of follicles were lower in exposed as compared to the control group, signifying a lethal effect of RF-EMR in utero on pup ovaries (Gul *et al.*, 2009). In one of the study, Rajaei *et al.*, (2010) reported a significant increase in the height of epithelial cells of fallopian tube in the EMF group comparable to the control group. In a study, 30 female Sprague Dawley (180 g body weight and 120 days old) were used in the experiment. Among experimental groups, a group was exposed to 1800 MHz GSM radio frequency radiation radiated by a signal generator for 2 hours a day for total 30 days and 60 days, respectively. The endometrial oxidative damage was reported which might related to pathogenesis and progression of endometritis (Ali *et al.*, 2016).

Oxidative stress and formation of reactive oxygen species (ROS) took place during physiological processes. Uncontrolled ROS formation caused oxidative degeneration of nucleic acids, proteins and lipids of reproductive cells (Lavranos *et al.*, 2012; Naziroglu *et al.*, 2013). Oral *et al.*, (2006), observed apoptosis and oxidative stress caused by RF-EMR on rat endometrial tissue exposed for 30 min/day for total 30 days. It has been reported that the cell phones may cause oxidative stress and endometrial apoptosis (Oral *et al.*, 2006). In a pilot study, 90 women (aged 18–33 years) with uncomplicated pregnancies were exposed to RF-EMR produced by cell phones and 30 fully-fledged healthy newborn were analysed. It has been established that when exposure of mobile phone was given to pregnant women, a significant increase in foetal and neonatal heart rate and a significant decrease in foetal cardiac output was reported (Rezk *et al.*, 2008). In a study by Schnorr *et al.* (1991), female ovulated and mated mice were exposed to EMF (50 Hz, 4h/d, 6d/w) for 2 weeks where decrease in blastocyst and increase in DNA

fragmentation was observed which may have negative effect on embryonic development.

In a study by Ogawa *et al.*, (2009), the effect of exposure of RF EMR on embryogenesis in rats was evaluated. Absence of undesirable effects on any reproductive parameters of live foetus was observed. In an animal study where experimental animals are exposed to radiations emitted from 900 MHz cell phone, no visible morphological changes in ovarian tissues, primary follicles and corpus luteum of rat ovary have been reported (Hajiun *et al.*, 2013). Also, in a study by Gul *et al.*, (2009), a reduction of ovarian follicle after cell phone radiation exposure has been determined.

In another study by Celik and Hascalik (2004), no verifiable effect on foetal heart rate was observed on exposure to RF EMR produced by cellular phones. In a study, structural changes of the placenta were examined in the mice model after applying the cell phone radiation. The trial animals were exposed to cell phone radiations at 915 MHz, for 4 h/day constantly, during the gestation period of day 5-17. On 18<sup>th</sup> day of pregnancy, the histological studies of the placenta specimen revealed that the cell phone radiation at 915 MHz may exercise detrimental effects on the placenta in the mice model. Likewise, Bakacak *et al.*, (2015) also evaluated the effect of an electromagnetic field (EMF) on primordial follicles of ovaries and reported a significant decrease in the number of ovarian follicles in exposed rats.

In a study by Rodriguez *et al.*, (2004) where on exposure to 60 Hz, 30  $\mu$ T EMF (16 h/d), the lengthened oestrous cycles were observed in dairy cows, which may lead to delay in ovulation and thus decrease in fecundity probability. In *in vitro* studies of cultured follicles, inhibition in the formation of antrum was observed. But, in contrast to above studies, no effect on oestrous cycle was observed when female rats were exposed to 10 kHz, 0.2 mT sine wave EMF which may suggest the dependency on frequency, animal species of experimentation and energy of EMFs on oestrous cycle (Dawson *et al.*, 1998).

#### IV. CONCLUSION

In spite of the extensive research, demonstration for a damaging effect of cell phones on male and female genitals is still equivocal. The question has upraised a fundamental public concern; if cellular radiation causes any hazardous effects on human fertilization potential. The indecisive findings of the study forced us to think and to articulate our thoughts more strongly whether the sperm quality, spermatogenesis, infertility, miscarriage and fertilizing potentialities are affected by the use of cell phones or not. Still, extensive research should be conducted utilizing better study designs and models in order to explore the damage in pathophysiology campaigned in respect to EMF exposure from cell phones on the male and female reproductive system.

#### V. FUTURE SCOPE

Present review was designed to study the impact of mobile phone radiations only. Further studies can be extended to study the effects of related electronic gadgets emitting EMF and coming generations of

telecommunication devices to analyze their deleterious effects.

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**Conflict of Interest.** The authors report no conflicts of interest. The authors alone are responsible for the content, review and writing of the paper.

#### AUTHORS' CONTRIBUTIONS

All authors equally contributed to this review article equally. All authors read, collected data and authorized the final manuscript.

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