



Impact of Electromagnetic Waves Generated by Cellular Phones on Male Fertility: A Review

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ABSTRACT

There has been a manifold increase in the number of mobile phone users throughout the world in the past decade, with the current number of users exceeding 2 billion. However, this advancement in technology like many others is accompanied by a progressive boost in the intensity and frequency of emitted electromagnetic waves without consideration of their health consequences. The detrimental impact of these waves is generally classified into thermal and non-thermal effects. While the thermal effects at the present cell phone radiation level are considered negligible, most of the negative biological effects are attributed to the non-thermal effects. The male reproductive system is a highly compartmentalized and sensitive biological system that requires the interaction of extrinsic and intrinsic factors to function properly. In daily living since most men carry their mobile phones in their trouser pockets or in holders close to their reproductive organs, it is worthwhile to evaluate the effect of mobile phones on male fertility. A number of animal and human studies have been done in recent years suggesting a possible role of cell phone exposure on male infertility, but their mechanism of action remains unclear. The effects on sperm motility, concentration and viability have been evaluated in a number of studies but the results are inconclusive. Sperm motility is the only parameter which has seen to be decreased in most of the studies done on this subject so far. Electromagnetic waves may affect the sperms via an EMW-specific effect, thermal molecular effect or a combination of the two. Studies done on humans are scarce; hence further carefully designed studies are needed to determine the effect of electromagnetic waves emitted by cellular phones on male fertility.

KEY WORDS: Cellular phones, Male fertility, Radiofrequency electromagnetic waves, Sperm motility, Sperm parameters

1. INTRODUCTION

Concern about the possible health impact of mobile phones usage is growing as the number of users has increased tremendously over the past few years. There are more than 2 billion mobile cellular phones in use throughout the world. [1] Discarding the wire means that communication is through EMWs (electromagnetic waves) which could have potential hazards. Many recent studies have raised questions regarding the safety of such RF-EMR (Radiofrequency –Electromagnetic waves) exposure to humans. [2] Adverse effects studied by several clinical trials include the possible link to increased risk of vehicular accidents, leukemias, sleep disturbances and more serious brain tumours. [3] There is significant public interest and concern regarding exposure to electromagnetic fields and

increased incidence of tumours particularly acoustic neuromas because of the close association of the acoustic nerve to the handset of the mobile phone. [3] Cell phones transmit and receive microwave radiation at frequencies which excite rotation of water molecules and some organic molecules, associated with thermal effects and non-thermal effects. The thermal effects include: headache, sensation of warmth or burning around the ear, burning sensation on the facial skin and alteration of the blood-brain barrier. [4]

The vast majority of the sustained cell phone electromagnetic waves' related biological consequences can be explained by the 'non-thermal effects'. These effects include all the interactions of EMWs with biological

tissues without production of heat or a measurable rise in temperature. Specifically the magnetic field rather than the electrical field of EMWs has the most harmful potential on living organisms because of its ability to penetrate human bodies while electrical field has poor human skin penetration ability.^[5] In fact, the induced alternating currents in our bodies resulting from cell phone EMW exposure can explain the biological non thermal effects at tissue, cellular and sub-cellular levels.

The non-thermal effects include : disturbance of sleep patterns ,increase in blood pressure, effect on cognitive functions and potential carcinogenic effects of mobile phones particularly acoustic neuromas .^[4]

In daily living, a cell phone is usually kept in close proximity to the groin by men, such as in a trouser pocket, separated from the testes by multiple layers of tissue.^[6] As men usually carry mobile phones in their trouser pocket or in holders close to their reproductive organs, it is imperative to evaluate the effect of mobile phones on male fertility. Although many recent epidemiological studies have suggested that mobile phone use may play a role in male infertility , their mode of action remains unclear .^[7-11] They affect reproductive health via RF-EMR specific effect, thermal effect or a combination of the two. Exposure of the testis and secondary sex organs to RF-EMW's has shown a detrimental effect on spermatozoa. Changes on the macro-scale (morphology, motility, and count) as well as the micro-scale (protein kinase C, heat shock proteins and histone kinases) can be observed .^[12] Cell phone radiation may cause structural and functional injuries of the testis, alteration of semen parameters, reduction of epididymal sperm concentration and decline of male fertility .^[13]

Leydig cells, seminiferous tubules and spermatozoa are the main target organs of the damage caused by mobile phones on the male reproductive system. In particular cellular phone exposure reduces testosterone biosynthesis, impairs spermatogenesis and damages sperm DNA. Scrotal hyperthermia and oxidative stress are the main mechanisms by which the damage is produced. ^[14]

From this point of view the habit of keeping mobile phone in the trouser pocket or the duration of its use may have a major impact on possible generation of hyperthermia and oxidative stress as well.

Even though current research has many inconsistencies, it still has been successful in providing preliminary data and identifying trends on both sides of the argument that cell phone exposure may lead to harmful effects on human health. These studies have been handicapped by many drawbacks in design and methodology, in particular comparing animal models with humans. ^[15] Differences in

size, geometry and physiological responses between men and experimental animals imply that the results in animal studies should be interpreted with caution.

Keeping this in mind we have attempted to review the studies done in human subjects only, paying special attention to data published on the subject recently.

TECHNICAL STANDARDS OF MOBILE PHONE USE

Cellular phones are defined as devices emitting radiofrequency electromagnetic waves. These waves transmit signals from the cellular phone to the base stations and antennas. The frequency of such waves is low and ranges from 800-2200 MHz. However there is still risk to the human user because our bodies can act as antennas that absorb these waves and convert them into eddy currents. ^[16]

The earliest cellular system was TACS (total access communication system) having output of 0.63W with frequency channels of 900MHz .^[17] This has been replaced by the European digital phone standard GSM (Global System for Mobile Communications) that operates within the 900 or 1800 MHz band .^[18-19]

To increase the number of users that communicate with a base station at the same time, a technique called time division multiple access (TDMA) is employed that allows each channel to be used by eight users at the same time.

The maximum power that GSM phones transmit range between 2W(900MHz) and 1W (1800MHz).

The third generation of mobile phone technology is called UMTS (Universal mobile telecommunication system).The frequency bands identified by this system are 1,885-2,010 and 2,110-2,200 MHz. The CDMA (Code division multiple access) can be used by a number of users at the same time and the frequency channels have 5-MHz bandwidths. However in CDMA, a transmission is labelled by a coding scheme that is different for each user. Two types of CDMA's are implemented: frequency division duplex (FDD) where separate 5MHz channels are used for the two directions and time division duplex (TDD) where the same channel is used but in different time slots. ^[18]

The new terrestrial enhanced trunk radio system technology (TETRA) is not intended for public systems connected to the telephone network. It is designed for closed group's e.g for communication within a company or an organization and is coming into use for emergency services and for commercial applications. Frequency bands are available at about 400 and 800 MHz. ^[20]

EFFECTS DUE TO EXPOSURE TO ELECTROMAGNETIC RADIATIONS

The general effects of EMFs have been documented in a number of studies .They include increased incidence of headaches, fatigue, dizziness, tension, malaise, short term

memory loss and sleep disorders but no strong correlation has been found between the appearance of these symptoms and exposure to electromagnetic waves. However the sensitivity of different individuals varies to these electromagnetic waves. [21]

The effects of electromagnetic radiations can be classified into two main categories – thermal effects and non – thermal effects. Thermal effects arise from temperature rise due to energy absorption from oscillating electric fields. This can lead to damage due to heating of exposed parts of the body. The thermal effects are computed in terms of calculation of SAR (Specific absorption rate). This SAR depends mostly on antenna configuration, location and frequency. [22] The SAR in a biological body depends on several exposure parameters such as frequency, intensity, and polarization. The SAR also depends on the size, shape and electrical properties of the body. [12]

Non – thermal effects are associated with attraction between the different cell types in the presence of an electric field. The electric field polarizes each cell. The cell is then an electric dipole and attracts similarly polarized cells. These effects are therefore associated with the interaction between the radiation and metabolic and functional processes of cells and tissues. [21] Frequencies ranging between 800-1800 MHz can cause non – thermal effects on cell membrane and probably on structure and function of the cytoplasm inducing changes in the electrophysiology of the living cells.

On the other hand EMWs more than 2500 MHz and higher induce significant thermal effects of cells by increasing the cell temperature by more than 0.1°C leading to cell damage. [21]

Children are supposed to be more sensitive to EMFs because the diameter of their head is smaller and SAR is greater when compared to adults. [23]

CELL PHONE AND MALE REPRODUCTIVE SYSTEM

Despite reports from numerous groups suggesting a possible role of cell phone exposure in male infertility, the exact mechanism of the effects of EMW on male reproductive system is yet to be elucidated. [7]

Though various effects have been proposed, foolproof experimental evidences are lacking to substantiate it. [24]

The effects of cell phone exposure on male fertility have been studied exhaustively in recent years. [25]

In normal physiological conditions spermatogenesis is a balanced process of division, maturation and storage of cells which is particularly vulnerable to the chemical and physical environmental stimuli. Especially sensitive could be the cytoskeleton, composed of charged proteins: actin,

intermediate filaments and microtubules. Cytoskeleton is a functional and structural part of the cell that has important role in the sperm motility, and is actively involved in the morphological changes that occur during mammalian spermiogenesis. [26]

The induction of DNA damage in spermatozoa has been associated with male infertility, early pregnancy loss and morbidity in the offspring, including childhood cancer. [27]

Although previous studies suggested a role for cell phone use in male infertility, the mode of action of EMW emitted from cell phones on the male reproductive system is still unclear.

At high intensities, RF radiation has heating properties leading to thermal effects.

An increase in tissue or body temperature on exposure to EMW may cause reversible disruption of spermatogenesis. [28]

Exposure to RF electromagnetic radiation and mild scrotal heating can induce DNA damage in mammalian spermatozoa, although the underlying mechanisms are unclear. Several investigators have demonstrated an increase in DNA fragmentation in a variety of human and animal cells. [29-31]

The effects on sperm concentration, motility and morphology have been evaluated in many animal and human studies, but results are inconclusive.

Motility is the only parameter that the majority of studies have shown to be significantly affected. The need to further evaluate the effects of EMW on sperm morphology, viability and concentration still exists. As mentioned earlier, motility is the only parameter that consistently has been shown to decline in studies carried out by various groups.

In a study involving 371 men presenting for an infertility workup, duration of possession and daily transmission time of cell phones correlated negatively with the proportion of rapid progressive motile spermatozoa ($r = -0.12$ and $r = -0.19$, $P < 0.01$) and positively with the proportion of slow progressive motile spermatozoa ($r = 0.12$ and $r = 0.28$, $P < 0.01$). [9] The same group also concluded that low transmitter (<15 min/day) and high transmitter (>60 min/day) groups also differed in the proportion of rapid progressive motile spermatozoa (48.7% versus 40.6%, $P < 0.01$). Wdowiak et al. [10] reported that 65.7% of men not using cell phones had >50% (WHO category A + B) sperm motility, whereas only 35.4% of men who frequently used cell phones had >50% (A + B) sperm motility.

However results of in-vitro studies are conflicting. An in-vitro study divided neat semen samples from healthy

volunteers ($n = 27$) into two parts and one part was exposed to 900 MHz EMW for 5 min.

Compared with the unexposed sample, the exposed sample was found to have a significant decrease in rapid progressive motility (Grade A, $P = 0.0007$), an increase in slow progressive motility (Grade B, $P = 0.0007$) and an increase in the percentage of immotile spermatozoa (Grade D, $P = 0.0003$).^[32] Recently, Falzone *et al.* studied^[33] the effect of pulsed 900 MHz radiation on various kinetic parameters and mitochondrial membrane potential (MMP) of purified human spermatozoa (by percoll density gradient). They found significant decrease in straight-line velocity and beat-cross frequency at an SAR of 5.7 W/kg. However, at an SAR of 2.0 W/kg they found no significant change in any kinetic parameters, including MMP.

On the other hand, significant data were brought out in a study in which 15.3% of men using cell phones sporadically for 1–2 years had only 10–19% normal spermatozoa, and 15.3% had total azoospermia, whereas men frequently using cell phones for >2 years had only 8.3% normal spermatozoa, and 22.9% showed total azoospermia.^[10]

In a study done in the year 2008, 361 men undergoing fertility evaluation were selected. The subjects were divided into four groups depending on their cell phone usage – A : No use; B : < 2h/day; C : 2-4 h/day ; D : > 4h/day. It was found that use of cell phones significantly decreased the semen quality in men by decreasing the sperm count, motility, viability and sperm morphology. However this depended on the duration of daily exposure to cell phones and was independent of the initial semen quality.^[7]

Purified human spermatozoa were exposed to radio-frequency electromagnetic radiation (RF-EMR) tuned to 1.8 GHz and covering a range of specific absorption rates (SAR) from 0.4 W/kg to 27.5 W/kg.

In step with increasing SAR, motility and vitality were significantly reduced after RF-EMR exposure, while the mitochondrial generation of reactive oxygen species and DNA fragmentation were significantly elevated. It was concluded that RF-EMR in both the power density and frequency range of mobile phones enhances mitochondrial reactive oxygen species generation by human spermatozoa, decreasing the motility and vitality of these cells while stimulating DNA base adduct formation and, ultimately DNA fragmentation. These findings have clear implications for the safety of extensive mobile phone use by males of reproductive age, potentially affecting both their fertility and the health and wellbeing of their offspring.^[34]

A study was conducted to evaluate the effects of cellular phones' RF-EMW during talk mode on unprocessed (neat) ejaculated semen samples in the year 2009.

32 subjects were studied divided into two groups : healthy donors ($n=32$) and infertile patients ($n=9$). The semen samples were divided into two aliquots .One from each subject was exposed to cellular phone radiation (in talk mode) for 1 hour and the second aliquot (unexposed) served as the control sample under identical conditions. The parameters that were studied included sperm motility and viability, reactive oxygen species (ROS), total anti-oxidant capacity (TAC), ROS-TAC score and sperm DNA damage. It was concluded that radiofrequency electromagnetic waves generated from cell phones may lead to oxidative stress in human semen. Hence it was speculated that keeping the cell phone in talk mode in trouser's pocket may negatively affect spermatozoa and impair male fertility.^[35]

A total number of 27 subjects were enrolled for a study and their semen samples were divided into 2 parts .One of the semen samples was exposed to EMR emitted by cellular phones at 900MHz whereas the other was not.

Assessment of sperm movement was performed using four criteria: A: Rapid progressive; B: Slow progressive; C: Non-progressive and D: No motility. However there was no significant difference in the sperm concentration between the two groups. Their data suggested that EMR emitted by cellular phones influences human sperm motility. Long-term EMR exposure may lead to behavioural or structural changes of the human germ cell which may be observed later in life and needs to be investigated more seriously.^[32]

In a recent study done in the year 2011 to evaluate the effect of RF-EMR on sperm specific characteristics to assess the fertilising competence of sperms ,highly motile human sperms were exposed to 900-MHz mobile phone radiation at a SAR of 2W/kg for one hour examined at various times after exposure.

Their study concluded that although RF-EMR exposure did not adversely affect the acrosome reaction but it had a significant effect on sperm morphometry. In addition, a significant decrease in sperm-binding to the hemizone was observed. These results indicated a significant effect of RF-EMR on sperm fertilisation potential.^[36]

A study was conducted to examine the effect of radiation on induction of apoptosis related properties in human sperms. Ejaculated densely purified highly motile sperms were exposed to mobile phone radiation at SAR of 2 and 5.7 W/Kg. The parameters examined included caspase 3 activity, externalization of phosphatidylserine (PS), induction of DNA strand breaks and generation of reactive oxygen species. Mobile phone radiation had no statistically significant effect on any of the parameters studied.

This suggests that the impairment of fertility reported in some studies was not caused by the induction of apoptosis in spermatozoa.^[37]

In a study conducted in Poland the effect of mobile phones was seen on the fertility of males subjected to marital infertility therapy. The subjects enrolled in the study were divided into the following four groups - A : 99 patients who did not use mobile phones ;B: 157 males who have used GSM equipment sporadically for 1-2 years;C: 48 people who have been regularly using mobile phones for more than 2 years.It was seen that an increase in the percentage of sperm cells with abnormal morphology is associated with the duration of exposure to the waves emitted by GSM phones.It was concluded that a decrease in the percentage of sperm cells in vital progressive motility in the semen is correlated with the frequency of using mobile phones.^[38]

In a study done in the year 2011 a large number of subjects were studied (n=2110) attending an infertility clinic between the year 1993 to 2007.

Semen analysis was performed in all the subjects .Serum free testosterone, FSH, LH and prolactin were also measured in all the patients. The subjects were divided into two groups depending upon their usage: Group A: cell phone use (n = 991); group B: no use (n = 1119).On comparison significant difference in sperm morphology was seen in the two groups. Their results showed that cell phone use negatively affects sperm quality in men.^[39]

CONCLUSION

As highlighted above, many aspects of human health have been proposed to be affected by cell phone exposure. Ranging from mild local warmth to possible tumour induction, EMW have been suspected of involvement in many health concerns. At this time, evidence is lacking to strongly prove or disprove any of the proposed harmful effects of EMWs.

The question as to whether cell phone radiation causes any adverse effects on human fertilization potential has raised a significant public concern. Various preliminary studies, though with limitations, have suggested a use-dependent decrease in seminal quality and testicular tissue damage in men using cellphones. However, the mode of this damage to male reproductive system by EMWs is still unclear. However, the significance of these studies and their possible implications in the future cannot be ignored.

More importantly, studies must be carried out in human semen samples as data from animal studies are limited in their applicability in humans. In contrast to the scientific discussion, public discussion is not only driven by facts but also by anxiety, emotions, economic and political interests on this subject.

REFERENCES:

1. Stefanics G, Kellenyi L, Molnar F, Kubinyi G, Thuroczy G, Hernadi I. Short GSM mobile phone exposure does not alter human auditory brainstem response. *BMC Public Health* 2007; 7: 325.
2. Mailankot M, Kunnath AP, Jayalekshmi H, Koduru B, Valsalan R. Radio frequency electromagnetic radiation (RF-EMR) from GSM (0.9/1.8GHz) mobile phones induces oxidative stress and reduces sperm motility in rats. *Clinics* 2009; 64:561-5.
3. Schoemaker MJ, Swerdlow AJ, Ahlbom A, Auvinen A, Blaasaas KG, Cardis E, et al. Mobile phone use and risk of acoustic neuroma: results of interphone case-control study in five North European countries. *Br J Cancer* 2005; 93: 842-848.
4. Ozturan O, Erdem T, Miman MC, Kalcioğlu MT, Oncel S. Effects of electromagnetic field of mobile phones on hearing. *Acta Otolaryngol* 2002; 122: 289- 293.
5. Cleveland RFS, David MU, Jerry L. Evaluating compliance with FCC guidelines for human exposure to radiofrequency electromagnetic fields. *OST Bulletin* 1997; 65:97- 101.
6. Mouradi R, Desai N, Erdemir A, Agarwal A. The use of FDTD in establishing in vitro experimentation conditions representative of life like cell phone radiation on the spermatozoa. *Health Phys.* 2012; 102:54-62.
7. Agarwal A, Deepinder F, Sharma RK, Ranga G, Li J. Effect of cell phone usage on semen analysis in men attending infertility clinic: an observational study. *Fertil Steril* 2008; 89:124-8.
8. Davoudi M, Brossner C, Kuber W. The influence of electromagnetic waves on sperm motility. *Urol Urogynecol* 2002;19:18-32.
9. Fejes I, Závaczki Z, Szölloosi J, Koloszá S, Daru J, Kovács L, et al. Is there a relationship between cell phone use and semen quality? *Arch Androl* 2005; 51:385-93.
10. Wdowiak A, Wdowiak L, Wiktor H. Evaluation of the effect of using mobile phones on male fertility. *Ann Agric Environ Med* 2007; 14:169-72.
11. Baste V, Riise T, Moen BE. Radiofrequency electromagnetic fields; male infertility and sex ratio of offspring. *Eur J Epidemiol* 2008; 23:369-77.
12. 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.
13. Kang N, Shang XJ, Huang YF. Impact of cell phone radiation on male reproduction. *Zhonghua Nan Ke Xue.* 2010; 16:1027-30.

14. Deepinder F, Makker K, Agarwal A. Cell phones and male infertility: dissecting the relationship. *Reprod Biomed Online* 2007; 15:266-70.
15. Cairnie AB, Harding RK. Cytological studies in mouse testis irradiated with 2.45-GHz continuous-wave microwaves. *Radiat Res* 1981; 87: 100–108.
16. Hamada AJ, Singh A, Agarwal A. Cell phones and their impact on male fertility: fact or fiction. *The Open Reprod Sci J* 2011; 5:125-137.
17. Kaprana AE, Karatzanis AD, Prokopakis EP, Panagiotaki IE, Vardiambasis IO, Adamidis G, et al. studying the effects of mobile phone use on the auditory system and the central nervous system: a review of the literature and future directions. *Eur Arch Otorhinolaryngol* 2008; 265: 1011-1019.
18. Pederson GF , Anderson JB. RF and ELF exposure from cellular phone handsets: TDMA and CDMA systems. *Radiat Prot Dosimetry* 1999; 83: 131-138.
19. Rapacholi MH. Health risks from the use of mobile phones. *Toxicol Lett* 2001; 120 :323-331.
20. Adair ER, Cobb BL, Mylacraine KS, Kelleher SA. Human exposure at two radiofrequencies (450 and 2450 MHz): similarities and differences in physiological responses. *Bioelectromagnetics* 1999; 4; 12-20.
21. Matthes R. Response to questions and comments on ICNIRP guidelines. *Health Phy* 1998; 75: 438-439.
22. Koops FB. New ICNIRP guidelines for human exposure to 50 Hz E- and M-fields. *Health Phys* 1998; 75: 437-8.
23. Christensen HC, Schüz J, Kosteljanetz M, Poulsen HS, Thomsen J, Johansen C . Cellular telephone use and risk of acoustic neuroma. *Am J Epidemiol* 2004; 159: 277- 283.
24. Makker K, Varghese A, Desai NR, Mouradi R, Agarwal A. Cell phones: modern man’s nemesis? *Reprod Biomed Online* 2009; 18: 148-157.
25. Agarwal A, Desai NR, Ruffoli R, A. Lifestyle and testicular dysfunction: a brief update. *Biomed Pharmacother* 2008 Oct; 62:550-3.
26. Susa M, Pavčić I. Effects of radiofrequency electromagnetic fields on mammalian spermatogenesis. *Arh Hig Rada Toksikol.* 2007; 58:449-59.
27. Aitken RJ. The human spermatozoon – a cell in crisis? *J Reprod Fertil* 1999;115: 1–7.
28. Jung A, Schill WB. Current life style could be responsible for infertility. *MMW Fortschr Med* 2000; 142:31-33.
29. Diem E, Schwarz C, Adlkofer F, Jahn O, Rüdiger H. Non-thermal DNA breakage by mobile-phone radiation (1800 MHz) in human fibroblasts and in transformed GFSH-R17 rat granulosa cells in vitro. *Mutat Res* 2005; 583:178–183.
30. Stronati L, Testa A, Moquet J, Edwards A, Cordelli E, Villani P, et al. 935 MHz cellular phone radiation. An in vitro study of genotoxicity in human lymphocytes. *Int J Radiol Biol* 2006;82:339-346.
31. Panagopoulos DJ, Chavdoula ED, Nezis IP, Margaritis LH. Cell death induced by GSM 900 MHz and DCS 1800-MHz mobile telephony radiation. *Mutat Res* 2007; 626:69 –78
32. Erogul O, Oztas E, Yildirim I, Kir T, Aydur E, Komesli G. Effects of electromagnetic radiation from a cellular phone on human sperm motility: an in vitro study. *Arch Med Res* 2006; 37:840–843.
33. Falzone N, Huyser C, Fourie F, Toivo T, Leszczynski D, Franken D . In- vitro effect of pulsed 900 MHz GSM radiation on mitochondrial membrane potential and motility of human spermatozoa. *Bioelectromagnetics* 2008; 29:268–276.
34. De Iuliis GN, Newey RJ, King BV, Aitken RJ. Mobile phone radiation induces reactive oxygen species production and DNA damage in human spermatozoa in vitro. *PLoS One* 2009; 4:6446.
35. Agarwal A, Desai NR, Makker K, Varghese A, Mouradi R, Sabanegh E, et al. Effects of radiofrequency electromagnetic waves (RF-EMW) from cellular phones on human ejaculated semen: an in vitro pilot study. *Fertil Steril* 2009 ; 92:1318-25.
36. Falzone N, Huyser C, Becker P, Leszczynski D, Franken DR .The effect of pulsed 900-MHz GSM mobile phone radiation on the acrosome reaction, head morphometry and zona binding of human spermatozoa. *Int J Androl* 2011; 34:20-6.
37. Falzone N, Huyser C, Franken DR, Leszczynski D. Mobile phone radiation does not induce pro-apoptosis effects in human spermatozoa. *Rad Res* 2010; 174:169-76.
38. Fejes I, Závaczki Z, Szöllosi J, Koloszá S, Daru J, Kovács L, et al. Is there a relationship between cell phone use and semen quality? *Arch Androl.* 2005; 51:385-93.
39. Gutschi T, Mohamad Al-Ali B, Shamloul R, Pummer K, H. Impact of cell phone use on men’s semen parameters . *Andrologia* 2011; 43: 312–316.