

Possible Health Risk of Electromagnetic Fields

Teslime Esra Sari¹, Feyza Kelleci¹, Mohammad Charehsaz¹, Ahmet Aydın^{1*}

¹Yeditepe University, Faculty of Pharmacy, Department of Pharmaceutical Toxicology, 34100 Istanbul, TURKEY

ABSTRACT

Electromagnetic field (EMF) is a kind of radiation and is emitted to environment from some medical diagnostic equipment, radio and television, communication devices such as cell phones, and other electrical appliances. It can have some risks to biological systems. There are some published documents on the possible human health risks of it including epidemiologic, *in vivo*, and *in vitro* studies. This review article focuses on the adverse health effects of electromagnetic fields on reproductive and developmental system, psychological system, nervous system, genotoxic effects, carcinogenesis, ear and vestibular system, ocular system, melatonin production and circadian rhythms. Although there are some studies which indicated some possible effects on these physiological systems, the data is limited to reach exact conclusion. Further studies are needed to prove safety and biological effects of EMF.

Key words: Electromagnetic field, electromagnetic radiation, health risks

INTRODUCTION

Electromagnetic fields (EMFs)

Electromagnetic fields (EMFs) are emitted to environment from radio and television, communication devices such as cell phones, and other electrical appliances at homes and workplaces. EMF composed of waves of electric and magnetic energy moving together through space. It is a type of radiation which is emitted by all cell phones. Different types of electromagnetic energy are categorized by their wavelengths and frequencies and comprise the electromagnetic spectrum. Different technologies use different radiation frequency. During recent years, people exposed to EMF radiation with widespread use of cell phones or their

*Corresponding author: Ahmet Aydın

E-mail address: ahmet.aydin@yeditepe.edu.tr; Tel: +90 216 578 22 42

base station. This station could affect people's health^{1,2}. Electromagnetic radiation (EMR) is radiated from the electrically charged particles and also called electromagnetic wave (EMW). They travel through air and in other substances³.

Classification of EMWs

EMWs can be classified as ionizing and non-ionizing radiation according to their frequency and energy. Non-ionizing radiation refers to any type of EMR that does not carry enough energy to remove an electron from an atom or a molecule. Sources of non-ionizing radiation include microwaves, radio waves, cordless phones, wireless networks (Wi-Fi), power lines and magnetic resonance imaging (MRIs). Ionizing radiation has high-frequency waves with enough energy to release electrons from molecules. It can damage the structure of cells in the body (including DNA). It has well-documented effects on human health. Ionizing radiation is emitted by radon, uranium, and other naturally occurring radioactive elements and is used for X-rays, nuclear medicine, and CT ("cat") scans³.

Specific Absorption Rate (SAR)

When an organism is exposed to EMFs, it absorbs energy. The amount of absorbed energy depends on many factors such as the frequency of the radiation, the power density, the electrical properties of the exposed tissues and the orientation and possible attenuation of the fields. Exposure to radiofrequency (RF) energy is determined by the SAR, a measure of the rate at which energy is absorbed by the body when exposed to RF. It is defined as the power absorbed per mass of tissue, measured in watts per kilogram (W/kg)⁴.

The SAR is commonly used to measure the power absorbed during MRI scans and from cell phones. The allowable SAR limit for the head is 2 W/kg⁴.

Health Risks of EMFs

Previous studies reported that low-level exposure to EMF radiation could cause a wide range of health effects, including behavioral changes, effects on the reproductive system effects, changes in hormone levels, headaches, and cardiovascular effects.

Reproduction and Developmental Disorders

Infertility is worldwide problem. It is affected by not only medical problem but also a psychological stress, including anxiety, depression and problems in maintaining the marital relationship. Chromosomal abnormalities, micro deletions, cystic fibrosis, transmembrane conductance regulator mutations, genetic factors, environmental factor are major causes of infertility. Also life style like smoking and drinking may partake to infertility. Besides, radio and television

which transmit radiofrequency electromagnetic waves (RF EMWs) with frequency ranging from 0.5 MHz in the Amplitude Modulation (AM) radio band up to 30,000 MHz in radar band can have some effects on the fertility. In addition, hair dryers, X-ray equipment, laboratory equipment (incubators, centrifuge), computers and cell phones are EMF producers⁵.

Male infertility disorders

It is important to investigate the effect of EMR on male fertility. A possible link between EMR emitted from cell phone and infertility were seen in several studies^{5,6}.

Exposure to radiofrequency electromagnetic radiation (RF EMR) and mild scrotal heating can induce DNA damage in mammalian spermatozoa, although the underlying mechanisms are unclear. The induction of DNA damage in spermatozoa has been associated with male infertility, early pregnancy loss and morbidity in the offspring, including childhood cancer.

EMF released by cell phone can have adverse effects on human fertilization potential. Various preliminary studies, though with limitations, have suggested a use-dependent decrease in seminal quality and testicular tissue damage in men using cell phones. However, the mode of this damage to male reproductive system by EMF is still unclear. At high intensities, EMF may cause reversible disruption of spermatogenesis because of heating properties of RF radiations lead to thermal effects. High-quality research is still needed in this field⁶.

Wang et. al. reported that Leydig cells injury may affect spermatogenesis on mice⁷. These cells are among the most susceptible cells in to EMF. On the other hand, 890-915 MHz EMF exposure to rats for 20 min per day for 1 month resulted as no effects on the testis of rats⁸.

The first human study was designed to evaluate the infertility problem on men, the duration of cell phone use was correlated negatively with the proportion of rapidly progressive motile spermatozoa. The prolonged use of cell phone might have negative effects on the sperm motility⁹.

Another experimental study was done to determine the biological and morphological effects of 900 MHz EMF on male rat testes for 4 weeks. The results revealed a decrease in seminiferous tubular diameter and epithelium thickness without effect on spermatogenesis after applying of 900 MHz. There was also a significant decrease in serum total testosterone level and not a statistically significant decrease in luteinizing hormone and follicle stimulating hormone levels¹⁰.

Significant damage to mitochondrial and nuclear genome was observed in a study conducted on epididymal spermatozoa of mice with 900 MHz EMF for 7 days and 12 h a day¹¹.

An another study was designed on semen samples of 27 healthy men exposed to 900 MHz cell phone at distance of 10 cm for 5 min. Significant decrease in rapid progressive motility, increase in slow progressive motility and increase in the percentage of immotile spermatozoa were observed in that study¹².

The effect of cellular phone use on the fertility of males subjected to marital infertility therapy was assessed by Wdoviak et.al. A decrease in the percentage of live sperm cells in a vital, progressive motility in semen is correlated with the frequency of use of cell phones. An increase in the percentage of sperm cells with abnormal morphology is associated with the duration of exposure to the waves emitted by GSM equipment¹³.

The use of cell phones adversely affected the quality of semen by decreasing the sperm counts, motility, viability and morphology in related to daily active cell phone use and talking time of man¹⁴.

To see microscopic changes in the seminiferous tubules, male rats were exposed to EMF (1835 to 1850 MHz) from cell phones. Each cage was provided with 8 cell phone sets in active silent mode. These cell phones were kept in a small metal cage with a wooden bottom in order to address concerns that the effects of exposure to the phones could be due to heat emitted by phones rather than to RF EMW alone. These small cages which were then placed in the plastic cages of rats. It was resulted histological and morphological effects of testes. This investigation showed that number of seminiferous tubules were decreased significantly in exposed subgroups day by day after 110 day. At the same time diameter of seminiferous tubules were decreased⁵.

In contrast to possible adverse effect of EMF, the main bio functional sperm parameters in healthy men exposed to the different use of the cell phone were investigated. The results showed that none of the conventional sperm parameters examined were significantly altered. The trousers users showed a higher percentage of sperm DNA fragmentation compared to other groups¹⁵.

Female sexual function and fertility disorders

There is limited data on the association between EMF exposure during pregnancy and reproductive outcomes. Some studies have reported increased risk of spontaneous abortions and congenital malformations¹⁶.

The effect of EMF on early development of chick embryos was investigated. EMF

exposed groups were influenced the mortality ratio when the exposure duration and the power level was increased. High frequency electromagnetic field can be responsible for the alterations in growth and development *in ovo* amniotic vertebrates¹⁷.

EMF emitted by Wi-Fi (2.45 GHz) and cell phone (900 and 1800 MHz) were studied to evaluate the effects on oxidative stress and trace element levels in the kidney and testes of growing rats from pregnancy to 6 weeks of age. Lipid peroxidation and oxidizable iron content increased and antioxidant trace elements (copper and zinc), and glutathione levels decreased during kidney and testis development¹⁸.

Psychological Disorders

Babadi-Akashe et. al. studied the behavior of cell phone addicts and mental health of university students. They found that the rates of students' addiction to cell phones reduced in related to increased and improved mental health¹⁹.

Nervous System Disorders

Narayanan et. al studied the brain effects of the EMF emitted from the cell phones in rat and the quite substantial hazard on passive avoidance behavior and hippocampal morphology in rats was detected²⁰. EMF from cellular phones did not lead to anxiety or not cause impairment of the working memory, but it may cause stressful behavior pattern in rats²¹. Decreased immobility and increased locomotor activity were seen in rats after exposure to EMF²². The spatial learning and memory function of mice were affected after exposure to EMF³³.

Fragopoulou et. al. found out no significant differences in the spatial memory test, and morphological assessment of the brain of rats after EMF exposure. However, in some exposed animals, there were decreased locomotor activity, increased grooming and tendency of increased basal corticosterone levels. These findings suggested that EMF exposure may lead to abnormal brain functioning²⁴.

The possible link between cellular telephone use and risks for various diseases of the CNS such as Alzheimer's disease, migraine, or vertigo was investigated. It was found a weak, but a statistically significant association between cell phone use and migraine and vertigo²⁵.

The blood brain barrier (BBB) damage

The human brain is surrounded by a layer of specialized cells which act as a barrier between brain and the contents of bloodstream. This barrier prevents toxins from reaching brain and maintains a healthy environment for brain tissue. Nittby et. al. studied the effect of EMF on BBB permeability in rats. It was found that the EMF exposure reduced memory functions²⁶.

Genotoxic Effects/Cell Damage

The potential of RF EMF to cause changes in a cell's genetic material (DNA) and/or to damage the genome is an important research area. Genotoxic substances can potentially cause mutations or cellular damage that can contribute to the development of malign tumors. It was reported a positive correlation among EMF exposure from mobile phones and DNA damage, chromosomal aberration, increased sister chromatide exchange frequencies in humans^{27,28,29}.

Ferreira et. al. investigated the effects of ultra high frequency-electromagnetic field (UHF-EMF) on micronucleus formation in erythrocytes and imbalances in free radical metabolism in liver and blood of rat offspring whose mothers were irradiated during the pregnancy. The study was resulted that UHF-EMF was indeed able to generate cell chromosome damage transplacentally. However the effects of free radical metabolism on this damage was not clear³⁰.

Gandhi and Singh reported an increased micronucleated buccal cells and cytological abnormalities in cultured lymphocytes of individuals exposed to EMF from mobile phones^{31,32}.

EMF induced DNA single-strand and double-strand breaks in human diploid fibroblasts and in rat granulosa cells in culture were also reported³³.

Carcinogenic Effects

Several studies showed that long-term exposures to EMF caused an increase in the risk of some types of tumors, but experimental studies were not available to explain the exact association. Overall, the epidemiological studies on the possible relationship between EMF exposure from mobile communicating devices and cancer have been conducted. Most of these studies have focused on brain tumors. Some have found a risk of cancer with long-term exposure while others have not.

Due to head exposure to EMF released from mobile communicating devices, studies mainly focused on the relationship between EMF exposure and brain tumors³⁴.

International Agency for Research on Cancer (IARCH) coordinated a study in 1998 and 1999. They concluded that the relationship between cell phone use and brain tumor risk would be feasible and informative³⁵.

Holding a cell phone to the ear can result in high SAR values in the brain depending on the EMF released from mobile communicating devices, their holding places in the body and the quality of the link between the base station and device. Cancer risk is limited for two types of brain tumor: glioma and neuroma. Although there was some statistically significant evidence about the association

between EMF from cell phone use and brain tumor risks, most studies showed no association³⁶.

Long term epidemiological studies for an association between long-term cell phone use and the risk of brain tumor showed a link between prolonged cell phone use and ipsilateral brain tumor, but the observed effect was not extended to meningiomas^{37,38}.

Hardel et. al. evaluated the risk of brain tumors with long-term use of cell phone. The result showed that long-term use (10 years or more) of cell phones was associated with increased risk of brain tumors (ipsilateral glioma and acoustic neuroma). However, no association was found for contralateral tumours³⁹.

Lagario et. al. assessed the intracranial tumors and cell phone use and they reported the occurrence of intracranial tumors. In addition, they stated the combined relative risk in long-term cell phone users (≥ 10 years) for meningioma⁴⁰.

Relationship between glioma and use of cell phones and cordless phones was assessed by Hardel et.al. The risk of glioma with use of cell phones in the >25 year latency group and increased risk was observed with the use of cordless phones in the >15-20 year⁴¹.

On the other hand there were some studies showing no association between brain tumors and cell phone use, but a possible association was established between heavy cell phone use and brain tumors⁴². The study conducted to evaluate the risk of malignant melanoma in the head and neck regions was resulted no association on long term cell phone use of more than 10 years and total wireless use⁴³.

Although there were some studies on the risk of brain tumor, there were limited data about the other cancer risks. Paulsen et. al. conducted a cohort study to evaluate skin cancer risk and mobile phone use. They reported no correlation⁴⁴.

Ear and Vestibular System Disorders

Cell phones are usually held in close proximity to the ear. These exposures could have an adverse effect on hearing function either at the level of inner ear or on the central auditory pathways.

Hutter et.al. reported that high intensity and long duration of cell phone use might be associated with tinnitus⁴⁵. After long-term and intensive cell phone use, inner ear damage and hearing loss may be seen^{46,47,48}.

The effect of long term cell phone use on auditory brainstem evoked responses was studied and it was resulted in no effect on auditory pathways from cochlear nerve to auditory brainstem⁴⁹.

Ocular Effects

Eyes are unprotected by the skull and comprised of cells that are extremely sensitive to electromagnetic energy. The eyes can absorb electromagnetic energy very quickly.

The possible effects of long term use of cell phone on eyes of human was studied. Blurred vision, eye inflammation, lacrimation, redness in the eyes, visual disturbance and increased secretion of the eyes were reported⁵⁰.

Effects on Melatonin Production and Circadian Rhythms

Melatonin is a hormone that controls circadian (sleep/wake) rhythms. It is secreted at night by the pineal gland and produces many biological effects. It also reduces risk of neurodegenerative diseases⁵¹.

Burch et. al. investigated the relationship between cellular telephone use and excretion of the melatonin. It was found that prolonged use of cellular telephones might lead to reduced melatonin production. Moreover elevated EMR exposures may potentiate the effect⁵².

Organ Damage

Oktem et. al. examined 900-MHz cell phone-induced oxidative stress on renal tubular damage and the role of melatonin to protect kidney tissue against oxidative damage in rats. It was found the increase in malondialdehyde levels of renal tissue and N-acetyl- β -D-glucosaminidase in urine and also the decrease in renal superoxide dismutase, catalase, and glutathione peroxidase activities. They demonstrated the role of oxidative stress induced by EMR, and the protective effect of melatonin against oxidative tissue injury in rat kidney⁵³.

Erdem et. al. studied the effect of continuous exposure to 50 Hz EMF on the levels of trace elements in serum and different organs of Guinea pigs. They reported that Cu and Mg levels were affected in serum and tissue samples of these animals⁵⁴.

CONCLUSION

As a conclusion, EMR emitted from different devices including communication technologies such as mobile phones, wireless equipments, television, electrical appliances can have different health risks to human. Users should be careful about the potential health risks and should control them to use of these devices. The time spent with the cellular devices should be reduced as low as possible. If possible speakerphone or a wired headset use could be recommended to reduce the exposure to EMR. The cell phone and other wireless devices should be kept

several feet from the bed. Carrying a cell phone in pants or shirt pocket will emit EMR to nearby tissues. For this reason cell phones should carry away from body parts if it is possible.

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