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Effects of Electromagnetic Radiation from a Cellular Phone on Human Sperm Motility: An *In Vitro* Study

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Background. There has been growing public concern on the effects of electromagnetic radiation (EMR) emitted by cellular phones on human health. Many studies have recently been published on this topic. However, possible consequences of the cellular phone usage on human sperm parameters have not been investigated adequately.

Methods. A total number of 27 males were enrolled in the study. The semen sample obtained from each participant was divided equally into two parts. One of the specimens was exposed to EMR emitted by an activated 900 MHz cellular phone, whereas the other was not. The concentration and motility of the specimens were compared to analyze the effects of EMR. Assessment of sperm movement in all specimens was performed using four criteria: (A) rapid progressive, (B) slow progressive, (C) nonprogressive, (D) no motility.

Results. Statistically significant changes were observed in the rapid progressive, slow progressive and no-motility categories of sperm movement. EMR exposure caused a subtle decrease in the rapid progressive and slow progressive sperm movement. It also caused an increase in the no-motility category of sperm movement. There was no statistically significant difference in the sperm concentration between two groups.

Conclusions. These data suggest that EMR emitted by cellular phone influences human sperm motility. In addition to these acute adverse effects of EMR on sperm motility, long-term EMR exposure may lead to behavioral or structural changes of the male germ cell. These effects may be observed later in life, and they are to be investigated more seriously.

Key Words: Mobile phone, Cellular, Electromagnetic field, Human, Sperm, Motility.

Introduction

Use of cellular phones has increased exponentially and become an important part of everyday life throughout the world. A growing concern for their possible adverse effects on human health evokes a flurry of scientific activity to evaluate this dilemma. Despite the increasing number of reports on the effects of electromagnetic radiation (EMR) in various biological systems, no satisfactory mechanism has been proposed to explain the effects of this radiation (1).

Radiofrequency (RF) energy is a type of nonionizing radiation, including EMR produced by cellular phone, and is not strong enough to cause ionization of atoms and molecules. Cellular phones emit low levels of RF in the microwave range while being used. Although high levels of RF can produce health effects (by heating tissue), exposure to low-level RF may not produce heating effects and causes no known adverse health effects. Several experimental studies demonstrated that exposure to electromagnetic or static magnetic fields had adverse effects on the reproductive system (2–10). However, it is likely that these effects were due to heating.

Recent epidemiological studies investigated the possible effects that EMR have comparing cell phone use and sperm

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quality of the individuals. Kilgallon et al. suggested that after other lifestyle variables had been accounted for, storage of cellular phones close to the testes had a significant negative impact on sperm concentration and percentage of motile sperm (11). Another important study performed by Fejes et al. suggested the effects of EMR radiated by cellular phones using *in vivo* experiments (12). It was the first human study performed on 371 healthy males. This study concluded that prolonged use of cellular phones might have negative effects on sperm motility characteristics. The other important study performed by Sun et al. investigated the effects of EMR emitted by computers on human sperm quality and did not find any adverse effects (13). However, epidemiologic studies might have many uncontrolled factors in the environment of these studies, which may reduce the reproducibility of their results.

In this study, we used an *in vitro* model in order to investigate the possible adverse effects of nonionizing radiation on semen parameters. Using this methodology, we can standardize the process and obtain reproducible results. We believe that the results of our *in vitro* tests may complement the *in vivo* studies.

Materials and Methods

Semen Samples

Study population was composed of healthy male volunteer individuals. Forty eight volunteering participants attending the urology clinic were tested for the existence of any abnormal situations including hormonal status and infections by routine blood and urine tests within the normal range of Gulhane Military Medical Academy. Subjects had no history of genitourinary abnormality or surgery. Donors were included if they had conventional sperm parameters within the normal range defined by World Health Organization (WHO) (1999) (14). Semen samples from 27 males (mean age 27 $\pm$ 3.2, range: 19−33) who satisfied these criteria were used in our experimental study. Samples were collected from the participants following the abstinence of ejaculation for a minimum of 48 h and no longer than 7 days before collection. All specimens were obtained by masturbation without using condom. Clean, wide-mouthed polypropylene containers (Sigma, St. Louis, MO) without residual chemicals were used for specimen collection, and specimens were kept at room temperature in the laboratory. The semen sample obtained from each participant was divided equally into two parts: control group (group 1) and EMR-exposed group (group 2).

Environmental Conditions

Environmental conditions were monitored in the semen analysis laboratory and the EMR exposure room throughout the study. All EMR measurements were performed using Triaxial Magnetic Meter, Model 4090 (Bell Technology, Orlando, FL). Basal and experimental levels of the environmental EMRs in the rooms were measured at the center of the working board of clean benches and on the stages of microscopes. EMR measurements of the experimental environment are shown in Table 1. The clean benches in the semen analysis laboratory and EMR exposure room are made out of marble. In the EMR exposure room, there are no other metal or ferromagnetic materials around the clean benches that would change the structure of the electromagnetic field. The use of any EMR-emitting device (such as an extra cellular phone, centrifuge, fluorescent light ballasts, and computers) was not allowed so that the EMR generated by this equipment would not interfere with the experimental environment.

Exposing Semen Samples to Electromagnetic Radiation

The method for exposing semen samples to EMR was established by modification of the technique described by Makler et al. (15). The collected semen samples for both groups were rested for 25 min without any intervention. At the end of the 25-min waiting period, the groups are separated from each other isolating the control group far from the source of the EMR. The EMR-exposure group specimens were taken to the exposure room and then exposed to the EMR emitted by a commercially available cellular telephone, GSM 900 type (900 MHz, 2 W peak power, average power density 0.02 mW/cm^2). The distance between the phone and specimen was 10 cm, and the duration of the exposure was 5 min (16).

Semen Analysis

Assessments of semen analysis were performed at the end of the 30-min period (25 min for liquefaction and 5 min for the EMR exposure or control) for both specimen groups (14). Sperm parameters of the two groups were analyzed at the same time to reduce time-dependent motility variations by using phase-contrast microscopes (Nikon, Alphaphot-2, YS-2, Tokyo, Japan) with phase objectives ($\times$20 magnification). Semen analyses were performed by two experienced and blinded observers. Semen samples were double checked by the observers to reduce interobserver variations. Concentration and motility were evaluated through a Makler counting chamber (Sefi-Medical Instrument, Haifa, Israel). WHO criteria (four categories of sperm movement; A-rapid progressive, B-slow progressive, C-nonprogressive and D-no motility) were used in the assessment of sperm movement (14).

Statistical Analysis

All results are given as mean $\pm$ SD. Sperm concentration and motility of exposure and control groups were compared by Wilcoxon Signed Ranks Test. SPSS for Windows

Table 1. Intensity of EMRs at experimental environment

	EMR value (μT)		
	Ambient level	Cell phone standby[a]	Cell phone working[a]
Semen analysis room			
On clean benches	0.1–0.3 μT	Ambient level	Ambient level
On microscopes	0.2–0.4 μT	Ambient level	Ambient level
Exposure room			
On clean benches	0.1–0.3 μT	0.1–0.2 μT	1.7–7.1 μT[b]

EMR, electromagnetic radiation; μT: microTesla.
[a]Cell phone is in the exposure room.
[b]EMR level produced by the cellular phone stays approximately constant during ringing and speaking.

(version 11.0, Windows, SPSS, Chicago, IL) was used for statistical analysis; $p < 0.05$ was considered statistically significant.

Results

Qualitative differences between the movement categories of the control and the EMR exposure groups are summarized in Table 2. We noted significant differences in percentages of rapid progressive, slow progressive, and no-motility categories of sperm movement. No significant differences were seen in nonprogressive motility between the two groups. Mean percentages of rapid progressive and slow progressive categories of sperm movement were higher in the control group. On the other hand, nonprogressive motility category of sperm movement was higher in the EMR exposure group. There was no statistically significant difference in the sperm concentration between the two groups.

There are more subjects with higher percentages of rapid progressive and slow progressive categories of sperm movement in the control group than the EMR exposure group. However, the EMR exposure group has more subjects with higher percentages of nonprogressive motility or no-motility categories of sperm movement compared to the control group.

Discussion

Available scientific evidence associates changes in semen quality with cellular phone usage. There are two important *in vivo* human studies in the literature about cellular phone usage and semen parameters. One suggests that lifestyle can influence semen quality. According to this study, the storage of mobile phones close to the testes can decrease semen quality (11). Another study claimed that the prolonged use of cell phones may have negative effects on sperm motility characteristics (12).

Radio waves of cellular phones do not have enough energy to cause ionization of atoms and molecules. Most DNA damage results from cellular phone EMR appear at the process of spermatogenesis and sperm maturation. Aitken et al. exposed mice to 900 MHz EMR for 7 days, 12 h/day to investigate the effects of EMR on sperm DNA (17). This study claimed that there is no increase in the single- or double-strand DNA breaks as a result of EMR exposure. However, the same study revealed that EMR exposure caused significant damage to both the mitochondrial genome and the nuclear β-globin locus caused by EMR exposure. These trends suggest that recent concerns over long-term exposure to electromagnetic irradiation emitted by mobile phones should be taken more seriously, given the growing trend for deterioration in the male germ line (18). Nonionizing radiation may cause hazardous effects by changing cellular molecules that lead to changes of cellular behaviors (reversibly or irreversibly). These changes may be passed to the next generation. This can be explained by the possible role of increased oxidative stress mediators (19) or some receptors such as seen in Merkel cells that can detect the EMR, show an exocytotic activity, and discharge its granules that lead the changes (20).

In this study we investigate the effects of electromagnetic radiation emitted by a typical cellular phone (900 MHz type) on sperm parameters. Semen collected from the participants was divided into two parts. Control group was kept at the laboratory where no EMR source exists. EMR exposure group was taken to another room and exposed to low-level nonionizing radiation generated by an activated cellular phone at a distance of 10 cm for 5 min. The 10-cm distance was accepted as physiologically reasonable limits for the individuals by measuring a high-dose radiation (70–140 μT) at ringing and speaking mode with the close touch position of cellular phone to the semen samples. Also, distance longer than 10 cm was not effective as measuring low-level (1–2 μT at 30 cm) EMR around the semen samples. Five-min exposure time was used as described by Panagopoulos et al. in their study about the effects 900-MHz cellular phone radiation on the reproductive capacity of *Drosophila melanogaster* during gonad development (16). The electromagnetic field applied to semen samples was about 20–70 times higher than the ambient EMR at the semen analysis laboratory where control group specimens were kept (see Table 1).

Table 2. Seminal findings in nonexposed and exposed groups

	Group 1 (not exposed to EMR)	Group 2 (exposed to EMR)	*z*	*p*
Movement categories (%)	Mean ± SD	Mean ± SD		
Rapid progressive (A)	13.6 ± 10.2	9.1 ± 7.9	−3.381	0.0007*
Slow progressive (B)	43.7 ± 19.4	33.9 ± 20.6	−3.377	0.0007*
Nonprogressive (C)	6.0 ± 2.6	6.4 ± 3.0	−0.756	0.4500
No motility (D)	35.9 ± 2.6	50.6 ± 22.7	−3.593	0.0003*
Sperm concentration ($\times 10^6$ mL^{-1})	59.8 ± 35.3	57.9 ± 37.6	−1.632	0.1028

EMR, electromagnetic radiation.
*p <0.001.

Our study controlled for semen analysis methodology. Our observers were trained to analyze semen samples using standardized protocols based on WHO guidelines. Our observers were also standardized by an internal quality control system for the semen analysis, although they may have used minimally different semen analysis techniques. The technique for the motility assessment outlined in the WHO guidelines is not a strictly quantifiable one, and it is possible that if a computer-assisted sperm analysis system had been used to assess motility, we may have found more precise sperm counts due to the reduced intra- and/or interobserver variations.

In vitro studies may play an important role when *in vivo* studies are weak or not definitive. Our *in vitro* study has a supporting or clarifying role on human studies. This study complements the work of Kilgallon and Simmons and Fejes et al. and confirms their results (11,12). Our *in vitro* method has a controllable environment and minimizes the uncontrolled subjective results of the *in vivo* tests.

In our study, exposure to EMR led to a significant decrease in sperm motility. Results of the semen analysis between the control and the EMR exposure group showed statistically significant changes in sperm motility in the progressive, slow progressive, and no-motility categories of sperm movement. Since all environmental factors, except the exposed EMR levels, were the same for the control and EMR exposure groups, we believe that the change in sperm motility between these groups was caused by the EMR produced by the cellular phone.

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