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The Effects of 4.5G Compatible Cell Phone Radiofrequency Radiation on Intraocular Pressure

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ABSTRACT

In recent years, mobile phone usage duration has increased rapidly and this has raised concerns about the toxic effects of exposure to radio frequency radiation. Many studies have shown that exposure to radiofrequency radiations may be associated with effects on the endocrine, nervous, ocular, cardiovascular and reproduction systems. The main aim of this study is to investigate the effect of 4.5 G compatible mobile phones radiation on intraocular pressure. A total of 32 Wistar albino male rats, 16 sham and 16 experimental groups, were used in the experiments. The rats in the experimental group were exposed to a 4.5G compatible mobile phone for 2 hours a day for 45 days. The rats in the Sham group were kept in the same environment for the same period of time with the mobile phone turned off. The specific absorption rate (SAR) value, skin temperature and intraocular pressure of rats were measured as analysis parameters. The maximum SAR value was calculated as 0.006 W/kg per 10 g of tissue. No significant difference was observed between the sham and experimental groups in terms of body temperature. Intraocular pressure decreased significantly in the experimental group compared to the control group. As a result of the study, it was thought that the use of 4.5 G compatible smartphones may cause a decrease in intraocular pressure and may pose a significant risk for visual function.

Keywords: Cell phone, 4.5 G, intraocular pressure, radiofrequency radiation

Introduction

The development of cellular mobile communication technologies started in the 1980s and has continued to develop rapidly since the beginning. While fast data transfer is not possible with 1G mobile phones using cellular network system and analog data connection system, a data transfer rate of about 100 Mbit/s can be reached in widespread use with 4.5 G systems. With this speed capacity, it has become possible to make voice calls, send e-mails, watch multi-channel high-definition TV broadcasts, videos, movies, run many web-based operations, and control home appliances (1). This increase in the usage areas of mobile phones has brought with it the increase in the number of users and usage time. The number of subscribers using 4.5 G technology, which was first introduced in Turkey in April 2016, exceeded 76 million in January 2020 (2). The average daily usage time of mobile phones in young people and adolescents has been reported to be approximately 5 hours (3).

Mobile phones mostly use 900-2600 MHz radio frequency (RF) fields for the services they provide (1). RF waves interacting with tissues; causes changes in cells depending on the energy, wavelength and intensity of the RF wave. These changes can be in the form of thermal or non-thermal changes. In thermal interaction, RF energy is absorbed by biological systems and this absorption can lead to an increase in temperature (4). Conversly, the temperature increase has no role in non-thermal effects. In different studies, it has been reported that mobile phone use causes deterioration in physiological functions such as; impair memory (5), increase parasympathetic nerve activity (6), worsen thyroid functions (7), increase oxidative stress (8), axon and myelin damage (9), weaken the immune system (10), increased permeability of blood-brain barrier (11), oxidative stress in peripheral nerves and morphological changes (12). However, some studies suggest that RF energy does not cause any harmful effects on biological systems (13-15).

Vision is a very important sense for humans and animals. About 70-80% of environmental information is acquired through vision. In a study, it was reported that a smartphone subscriber looks at his smartphone an average of 2617 times a day (3) Since the act of looking takes place through the eye, and most of the

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time it is directly facing the phone without any obstacles in between, the eye is likely to be exposed to and negatively affected by the RF fields emitted by smartphones. In animal studies, it has been reported that RF fields cause cataract formation in the eye (16-17), transient conjunctival and corneal edema, pupillary contraction, pupillary obstruction (18), iris inflammation, optic nerve damage (19) and changes in the lens (20). However, there are contrary opinions in the literature. In a study conducted in rabbits, it was reported that RF fields did not cause any ocular effects such as cataracts (21). In addition to animal studies, there are also studies investigating the effects of RF radiation on the human eye. In studies conducted mostly with workers working in the RF industry, sub-clinical changes in the lens (22), increased retinal lesion and lens opacity (23), and increased risk of uveal melanoma (24) were observed.

Changes in intraocular pressure can cause irreversible effects on the eye. While there are studies examining the effect of RF radiation on various parts of the eye in the literature, there are limited studies examining the effect on intraocular pressure (25, 26). In this study, we aimed to investigate the effect of a 4.5 G compatible smartphone on intraocular pressure using a rat model. The rat eye is a good model for measuring intraocular pressure with a tonometer (27).

Materials and Methods

Experimental Animals: Thirty-two Wistar albino male rats weighing approximately 200-250 g were used as experimental animals. Rats were obtained from University Experimental Research Center. Before the experiments, the rats were kept for 1 week in the laboratory with a temperature of 25±1.5 °C and a humidity of 55%, in 12 hours night and 12 hours day cycle, in order to adapt to the environment. Rats housed in wire cages were fed standard pellet chow and watered *ad libitum*. Ethical approval of the study was obtained from University Animal Experiments Local Ethics Committee (Ethics Committee decision dated 22/08/2016 and numbered 2016/32).

Experiment Protocol: Rats were divided into two groups as experimental (n=16) and sham (n=16) at the beginning of the study. A cylindrical experiment chamber was designed with a radius of 30 cm and a height of 30 cm, with ventilation holes on the sides and on the top, a notch at the center of the top surface for the mobile phone to be placed, together with a hole large enough for the mobile phone screen to be fully visible to rats inserted and manufactured from transparent Plexiglas material (Figure 1). Animals in the experimental group were placed in the chamber and for 45 days, 2 hours for each day, a 4.5 G compatible mobile phone (Samsung brand SM-G600F Galaxy On7 model) with a SAR value of 0.384 W/kg was stood in its place with the screen facing rats. The length of the communication was determined to mimic the regular daily phone usage of a person looking at the phone screen. Video calls were made via Skype application on the phone. In this Skype video call, there was an office computer with a wired internet connection at the other end of the call (Skype is preferred due to the built-in Windows application on this computer side, but there would be no difference on the exposed 4.5G radiation in case of other video communication apps since all would use 4.5G channel for video communication.). During the study, a mobile phone line (Turkcell, Turkey) capable of uninterrupted and continuous data exchange in the 800-2600 MHz bandwidth was used in the Skype call. The rats in the Sham group were kept in the same chamber for the same period of time, provided that the other conditions remained the same, only when the mobile phone was turned off. Before starting the experiments, electric and magnetic field values were measured to determine whether the environment is affected by environmental electromagnetic fields. A portable electric field probe (TES 593, TES Electrical, Electronic Co, Taipel, Taiwan) and a gauss/teslameter (Sypris 6010, F.W. Bell, San Diego, CA) were used to measure the electric field and magnetic field, respectively. The average electric field value in the experimental environment was measured as 0.35±0.002 V/m, and the average magnetic field value was measured as 0.028±0.002 mT.

Measuring Skin Temperature in the Eye Area: A thermal camera (Fluke Ti100, Everett, Washington) was used to measure the skin temperature of rats in the experimental and sham groups. In both groups, skin temperature was recorded before and after the application. The obtained images in thermal camera were transferred to the computer via USB cable and analyzed using the Smartview 3.5 program. As a result of the analysis, the average temperature values of the experimental and sham groups before and after the application were obtained.

Electric Field Distribution and Calculation of SAR Value: During the experiment, electric field measurements were made using the electric field probe in different parts of the experimental chamber. While the system is active, the electric field value of the environment was calculated by taking the average of these measured values. The average electric field value is used to determine the distribution of the electric field and to calculate the SAR value. Since it is not possible to directly measure the electromagnetic field distribution numerically inside the body, the electromagnetic field simulation program CST Microwave Studio® 2018 (Computer Simulation Technology, Darmstadt, Germany) was used to calculate the electric field distribution and SAR value in this study. Finite integration technique (FIT) in the time domain is used in solving the field problem in CST program. In this method, the geometric objects in the model are divided into pieces in the form of a mesh and converted into a computer-operable structure (28). In order to calculate the electric field and SAR distribution in rats, a voxel rat model was first created from computed tomography sections of rats using the CST program. The model was divided into 6-sided small cells and SAR values for 1 g and 10 g tissue mass were calculated using the IEEE/IEC 62704-1 averaging method.

Measuring Intraocular Pressure: At the end of the 45-day experimental period, the intraocular pressure of the rats in the experimental and sham groups was measured using Riester No. 5112 Schiötz C brand tonometer. This tonometer is an indentation tonometer which measures the corneal indentation produced by a known weight. The tonometer shows the results on a scale of 1-20. The values it displays are converted to mmHg according to the conversion table. This tonometer is used in human and animal medicine and although it is the oldest method, it is still valid (29). However, it has some limitations such as being a little difficult to use, sterilization requirement and the results cannot be obtained directly in mmHg and require an additional evaluation (29).

After the rats were anesthetized using intramuscular injection of ketamine (50 mg/kg) and xylazine (5 mg/kg), they were placed supine position on a stainless steel platform and gently immobilized using head and tail holders. The measuring part of the tonometer was placed on the eyeball and the values shown on the tonometer were recorded. Each measurement was made two times and the average of the two measurement was calculated and taken as the final result. All measurements were made by the same person and in accordance with the manufacturer's instructions for use.

Statistical Analysis: The results were statistically analyzed using "SPSS (ver.23. Armonk, NY: IBM Corp)". To check normality of variables, "Shapiro Wilk test" was used. Statistically comparisons of "Sham and Experimental groups" were evaluated by using "Independent T Test". Within-group temperature changes were analysed with the paired t-test. Data were expressed as "Mean±Standard Deviation". Statistical significance levels were considered as 5%.

Results

Whole Body Electric Field and SAR Distributions: The average electric field value calculated from the electric field values measured with the portable electric field probe in different parts of the application chamber was found to be 6.0 V/m. Figure 2 shows the electric field obtained by computer simulation on the rat and the SAR distributions calculated for 10 g tissue mass using this electric field. As can be seen, the maximum electric field value was calculated as 5.0 V/m (Figure 2A) and the maximum SAR value for 10 g tissue mass was calculated as 0.006 W/kg (Figure 2B).

Skin Temperature: Figure 3 and Figure 4 show examples of the thermal camera images recorded before and after the application from the sham group and experimental group, respectively.

Figure 5 shows the temperature distribution before and after the application for both groups. The mean skin temperature in the eye area before the application was 34.53±0.25 ^{o}C in the sham group and 34.33±0.057 ^{o}C in the experimental group, while it was 34.17±0.14 ^{o}C in the sham group and 34.18±0.086 ^{o}C in the experimental group after the application. There was no significant difference between the pre- and post-application temperature values in the skin temperature, within the sham group ($p=0.186$) and experimental group ($p=0.226$). There was no significant difference between the sham group and experimental group in the pre- and post-application temperature ($p=0.251$, $p=0.949$, respectively).

Intraocular Pressure: While the mean intraocular pressure was 17.03±5.16 mmHg in the sham group. This mean value is similar to that previously reported (30). It was determined as 9.65±4.40 mmHg in the experimental group. As seen in Figure 6, it was observed that the intraocular pressure decreased by approximately 43% in the experimental group compared to the sham group, and this decrease was statistically significant ($p<0.001$).

Discussion

In this study conducted on rats, the effect of mobile phones with 4.5 G technology on intraocular pressure was investigated, and it was determined that standing in front of a mobile phone screen for 2 hours a day for 45 days led to a decrease in intraocular pressure by approximately 43%.

Dosimetry is an important factor in determining the effects of mobile phones [1]. In this study, the FIT technique was used to calculate the SAR value and the

Fig. 1. 4.5G RF Radiation Experiment Chamber

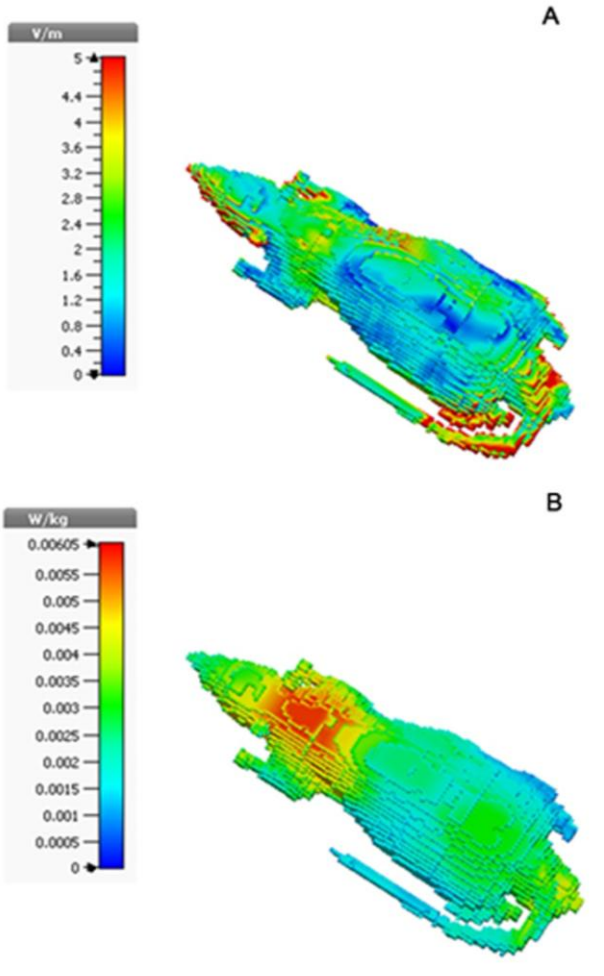

Fig. 2. Electric Field Distributions (A) and SAR Distributions (B) of Rats

average body SAR value for 10 g of tissue was calculated as 0.006 W/kg. One of the two most widely used standards for the SAR value all over the world is the Federal Communications Commission (FCC), and the other is the United States and International Commission on Non-Ionizing Radiation Protection (ICNIRP). Near field SAR upper limit is

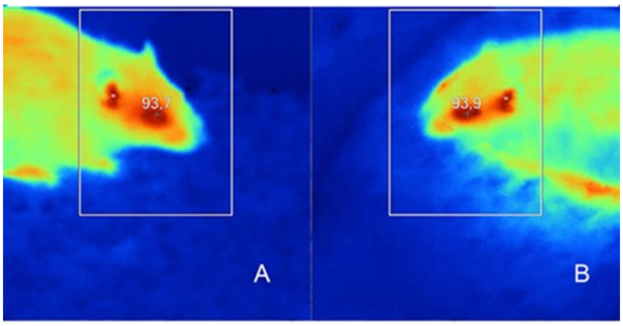

Fig. 3. Thermal Camera Recordings Taken Before (A) and after (B) Application To Measure Skin Temperature In The Sham Group. Values Are Given In Degrees Fahrenheit (F) As Taken From The Device

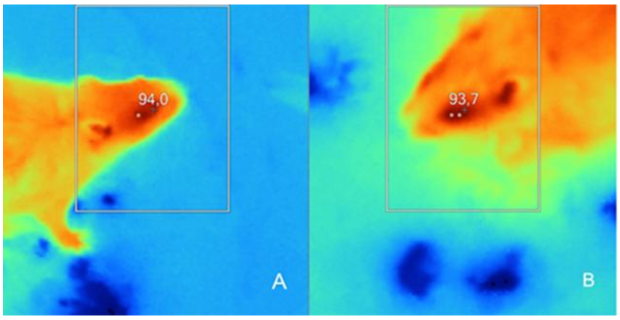

Fig. 4. Thermal Camera Recordings Taken Before (A) and After (B) Application To Measure Skin Temperature In The Experimental Group. Values Are Given In Degrees Fahrenheit (F) as Taken From The Device

determined as 2 W/kg (for 10 g tissue; 10-10000 MHz) according to ICNIRP and as 1.6 W/kg (for 1 g tissue; 0.1-6000 MHz) according to FCC. The SAR value calculated as 0.006 W/kg in our study is well below these limits. However, these limits were redefined in the bioinitiative report published by international independent researchers in 2012. These limits are hundreds of times lower than the limits set by the FCC and ICNIRP (31). There are many studies in the literature related the damage caused by low-intensity RF exposure. In one of these studies, impaired learning performance in animals has been reported at SAR values of $5,953\times10^{-4}$ W/kg, $5,835\times10^{-4}$ W/kg and $6,672\times10^{-4}$ W/kg, (32). In another study, in which RF energy with a maximum SAR value of 0.001 W/kg was used, it was reported that there was a change in brain tissue miRNA expression (33). This and similar studies (34)supports that health problems may occur at exposures far below the limits specified by ICNIRP and FCC. Although the maximum SAR value was 0.006 W/kg in our study, ocular hypotonia occurred in rats.

The number of studies examining the effect of mobile phones on intraocular pressure is very limited. Shokoohi-Rad et al. used a mobile phone with a communication frequency of 900-1800 MHz and a SAR value of 0.79 W/kg in their study on 41 subjects with normal eyes and 42 subjects with glaucoma (25).

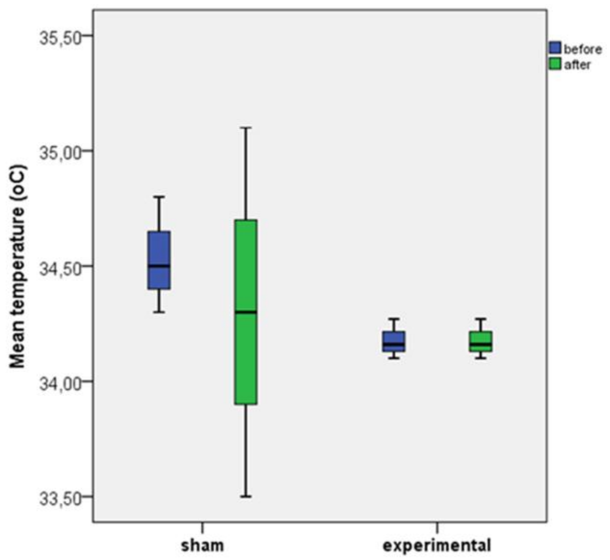

Fig. 5. Average Skin Temperature Values Around The Eyes Before And After The Application In Sham And Experimental Groups

Intraocular pressures of all subjects were measured with a tonometer before talking on cell phone and these were accepted as control values. Then, the subjects talked on cell phone for 5 minutes and their intraocular pressure was measured once more 20 minutes after the conversation. As a result of the experiment, there was no significant change in intraocular pressure in normal individuals, but it was reported that intraocular pressure increased significantly in patients with glaucoma after cell phone conversations (25). In the study by Lee and Kim (26), participants with 127 glaucoma and 31 healthy pairs of eyes, performed a continuous fixation task consisting of watching a movie on a smartphone screen for 30 minutes at a viewing distance of 30 cm. In all participants, a small but statistically significant increase in intraocular pressure was observed depending on the time of the measurements made 5, 10 and 30 minutes after the application. In the presented study, a mobile phone with a SAR value of 0.384 W/kg and operating in the 800-2600 MHz frequency band was used, and the SAR value inside the rats was calculated as a maximum of 0.006 W/kg for 10 g tissue mass. Our study did not include animals with glaucoma. For this reason, we made our comparisons with previous studies according to control values including healthy individuals. While Shokoohi-Rad et al. did not observe a difference before and after the application in the control values, Lee and Kim observed a significant increase in intraocular pressure. Unlike previous studies, in the present study, it was observed that RF field exposure for 2 hours/day for 45 days resulted in a significant reduction in intraocular pressure of rats with normal eyes. As can be seen, the results regarding the effect

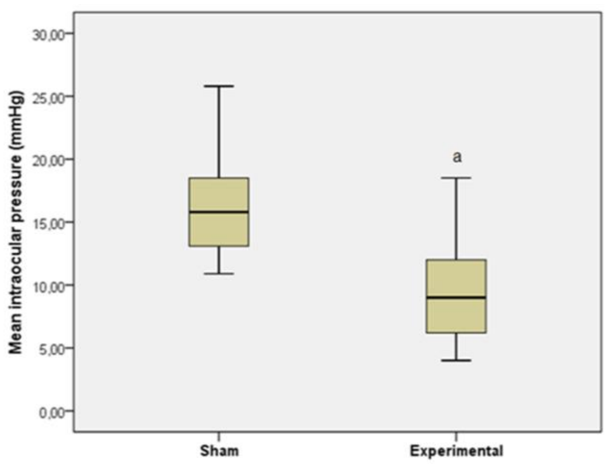

Fig. 6. Mean Intraocular Pressure Changes In Sham And Experimental Groups. [a]Means That The Difference Between The Sham And The Experimental Group Is Statistically Significant

of smartphone use on intraocular pressure differ from each other. This difference may be due to the difference between the methods used. The most important difference between the three studies is the RF field exposure time. While Shokoohi-Rad et al. had subjects make a phone call for only 5 minutes and examine the effect, this time was 30 minutes in total in Li and Kim's study. On the other hand, rats were exposed to the RF field for a total of 5400 minutes (45 days x 120 minutes) due to the video call made via Skype in our study.

Intraocular pressure must be kept at a certain level in order to provide nutritional support to the tissues of the eye that do not contain blood vessels and to maintain the ocular shape. This is achieved by the balance between the production, circulation and outflow of aqueous humor, which is a clear liquid that fills the anterior and posterior chambers of the eye (36). This balance can be disturbed by various reasons. These causes include inflammation, hormonal factors, anemia and ocular ischemia, and various physical and chemical agents (37). The main ocular structures involved in aqueous humor dynamics are the ciliary body, trabecular meshwork, and uveoscleral tract. The ciliary body is the production site of aqueous humor, the trabecular meshwork and the uveoscleral tract are the outflow sites (38). The balance between the production and output of aqueous humor is crucial for maintaining a stable IOP. Low IOP is caused by excessive output and/or insufficient aqueous fluid production (37). Low IOP in the present study may be related to decreased production of aqueous humor or increased outflow. An important limitation of this study is that no parameters related to the aqueous humor dynamics such as aqueous flow and uveoscleral outflow were measured in the study.

As a result, in this study conducted in rats, it was observed that being in front of a 4.5 G compatible smartphone screen for 2 hours a day for 45 days caused a decrease in intraocular pressure. Decreased intraocular pressure may pose a significant risk to vision. In order to explain the mechanism of low intraocular pressure caused by RF radiation, a detailed examination of the mechanics and dynamics of aqueous humor is needed.

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