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To cite this article: Mohammad Hossein Bahreyni Toossi, Hamid Reza Sadeghnia, Maryam Mohammad Mahdizadeh Feyzabadi, Mahmoud Hosseini, Mahdijeh Hedayati, Razieh Mosallanejad, Farimah Beheshti & Zeynab Alizadeh Rahvar (2018) Exposure to mobile phone (900–1800 MHz) during pregnancy: tissue oxidative stress after childbirth, The Journal of Maternal-Fetal & Neonatal Medicine, 31:10, 1298-1303, DOI: [10.1080/14767058.2017.1315657](https://doi.org/10.1080/14767058.2017.1315657)

To link to this article: <https://doi.org/10.1080/14767058.2017.1315657>



Published online: 23 Apr 2017.



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ORIGINAL ARTICLE



Exposure to mobile phone (900–1800 MHz) during pregnancy: tissue oxidative stress after childbirth

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ABSTRACT

Background: The present study has investigated the effects of mobile phone (900–1800 MHz)-induced electromagnetic radiation on redox status in the heart, liver, kidney, cerebellum, and hippocampus of dams and the offspring mice.

Materials and methods: Pregnant Balb/C were divided into two groups including the control and the experimental group. The experimental group was exposed to mobile phone (900–1800 MHz), during pregnancy (2 h/d for 20 d). The dams and the offspring of both groups were sacrificed and tissues of interest were harvested immediately after delivery. Malondialdehyde (MDA) concentration, total thiol groups (TTG) content, superoxide dismutase (SOD), and catalase (CAT) activities were determined in the tissues.

Results: In the experimental groups, MDA levels were significantly increased, while TTG, SOD, and CAT were significantly decreased in the total tissues of dams and their offspring.

Conclusion: Exposure to mobile phone (900–1800 MHz) during pregnancy induced oxidative stress in tissues of dams and their offspring.

ARTICLE HISTORY

Received 26 December 2016
Accepted 1 April 2017

KEYWORDS

Exposure; mobile phone;
pregnancy; oxidative stress

Introduction

The widespread use of mobile phones has been led to worries about effects of mobile phone (900–1800 MHz)-induced electromagnetic radiation, on human health [1]. Global System for Mobile Communications (GSM) in Europe and Asia is the 900 MHz and 1800 MHz [2,3]. Exposure levels of the mobile phone range are usually described in terms of power density. Mobile phone waves are part of microwaves. Microwaves interactions with biological systems categorize into three groups: high (thermal), intermediate, low (non-thermal). Specific absorption rate (SAR) is the scale of thermal interactions of microwave with biological systems [4]. Thomas et al. [5] expressed that the threshold limit of power intensity for non-thermal effects of radio frequency (RF)/microwaves interactions with biological systems is 1000 ($\mu\text{W}/\text{m}^2$) and in longer time 100 ($\mu\text{W}/\text{m}^2$). Previous studies have reported that electromagnetic fields lead to oxidative stress in tissues [6]. Cellular damage at different levels (lipids, proteins, nucleic acids) lead to tissue injury

caused by excessive generation of free radicals/reactive oxygen species (ROS) and attenuation of the antioxidants, which is named as oxidative stress [7]. EMF can break the chemical bonds between compound atoms and produce ROS [8]. ROS damage to lipids lead to toxic aldehyde formation such as malondialdehyde (MDA) [9]. Lipid damage also induces disorder in cellular membrane functions [10]. Superoxide dismutase (SOD) and catalase (CAT) are low-molecular-weight antioxidants (LMWA) that directly defend the body against ROS [11]. Protein damage lead to reduction of total thiol groups (TTG). Aydin et al. [12] perceive that 900 MHz electromagnetic radiation leads to irretrievable oxidative damage in the lymphoid tissues of immature rats compared to adult rats. Electromagnetic radiation at 900 MHz during the prenatal period caused pathological changes in kidney tissues that owing to oxidative stress [13]. About 1800 MHz electromagnetic radiation caused morphological changes of lymphocytes [14]. Available information concerning prenatal exposure to mobile phones (900–1800 MHz) on tissue

oxidative stress of mother and their newborn immediately after delivery is limit. In the present study, the effects of EMF exposure of mobile phones (900–1800 MHz) in the prenatal period on oxidative stress biomarkers immediately after delivery in different tissues of dams and offspring mice was investigated.

Materials and methods

In this study, 64 Balb/c females and 32 Balb/c males were obtained from the Animal House of Faculty of Medicine of Mashhad University of Medical Sciences (MUMS), Mashhad, Iran. The mice were maintained at room temperature ($21 \pm 2^\circ\text{C}$) and humidity ($50\% \pm 10$), controlled (12/12 h) light/dark cycle, and in Plexiglas cages with two washes per week. Standard food and water was provided, *ad libitum*. When the mice reached to 5–6 weeks age and a weight 24–28 g, two female mice were left to mate with one male mouse in the same cage. Zero day of pregnancy was confirmed using vaginal smear. All animals were treated in accordance with the National Institutes of Health Guidance for the Care and Use of Laboratory Animals, and their use was approved by the Animal Ethics Committee of MUMS.

Pregnant mice were divided into control and experimental groups. No procedure was performed on the control group. The experimental group was exposed to mobile phone (900–1800 MHz)-induced electromagnetic radiation for 2 h/day on days 0–19 of pregnancy inside Plexiglas cages that were placed at a 2 m distance from the electromagnetic exposure system. The EMF exposure system was the 4-Band Jammer for Mobile Signal (version 1.1) (ELEKTROO Company, Shanghai, China, and Serial no. 080635). Every 4-Band was turned on with maximum power intensity. Mean power intensity measured by SPECTRAN HF-4060 (AARONIA AG, Strickscheid, Germany) that was 1 mw/m^2 . No procedure was performed on dams and offspring mice after birth. After delivery, the offspring mice obtained from both control and experimental groups ($n=5$ each) were euthanized using deep anesthesia and the tissues were removed for biochemical assessments. The tissues of the mothers of each group ($n=5$) were also extracted. SOD and CAT enzyme activities, total thiol content (TTG) and MDA values were determined in the tissues. SOD activity was measured according to the method described by Madesh and Balasubramanian [15] and expressed as $\text{mmol min}^{-1} \text{g}^{-1}$ of tissue. The method involves generation of superoxide radical by pyrogallol autoxidation and the inhibition of superoxide dependent reduction of the tetrazolium dye

MTT [3-(4,5-dimethyl-thiazol-2-yl) 2,5-diphenyl tetrazolium bromide] to its formazan, measured at 570 nm. CAT activity was measured based on the method described by Aebi. Decomposition of H_2O_2 in the presence of CAT was monitored at 240 nm, and CAT activity was expressed as $\text{mmol min}^{-1} \text{g}^{-1}$ of tissue [16]. Total thiol content was measured using DTNB (5,5'-dithiobis-(2-nitrobenzoic acid) as the reagent and expressed as nmol/g tissue. The reagent reacts with thiol groups to produce a yellow-colored complex that has peak absorbance at 412 nm [17]. MDA levels in the tissues were measured using the thiobarbituric acid (TBA) test and the pink-colored chromogenic formed during the reaction of TBA with lipid peroxides was measured spectrophotometrically at 535 nm and expressed as nmol/g tissue [17]. The data were expressed as mean $\pm$ SEM and analyzed using two-way analysis of variance (ANOVA). The statistical analysis was performed using GraphPad Software, Inc. (version 6.01, La Jolla, CA). The difference between the two groups was determined using independent *t*-test and the significance was considered at $p < .05$.

Results

Statistical analysis showed that the MDA level in all tissues including dams and offspring increased while TTG, SOD, and CAT decreased. The MDA levels in the heart, cerebellum, and hippocampus tissues of the experimental dams were significantly higher than those of the control group, with values of 92.4% ($p < .001$), 88.9% ($p < .001$), and 73.4% ($p < .001$), respectively (Figure 1). There was no significant difference between the MDA levels of kidney and liver tissues of experimental dams as compared with the

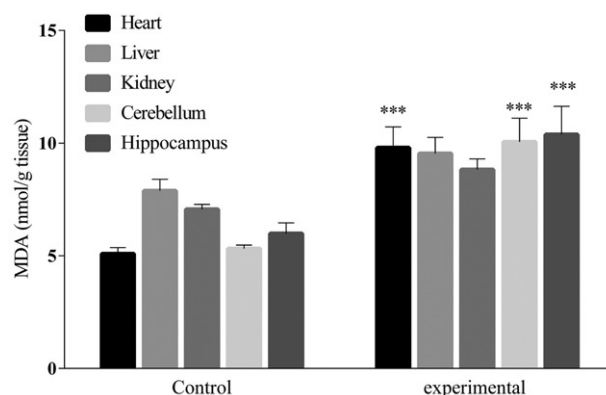


Figure 1. Malondialdehyde level in tissues of dams follow on mobile phone (900 and 1800 MHz)-induced electromagnetic radiation (mean power intensity = 1 mw/m^2) during pregnancy (2 h/d for 20 d), *** $p < .001$, compared with the control group.

control group ($p > .05$). Total thiol groups significantly decreased in the heart, liver, kidney, and cerebellum tissues of the experimental dams which were 31.2% ($p < .0001$), 21.0% ($p < .01$), 37.2% ($p < .001$), and 25.3% of the control value ($p < .001$). On the other hand, no significant changes on the total thiol content in the hippocampus of experimental dams were observed ($p > .05$) (Figure 2). MDA level increased in heart and liver tissues of the experimental offspring group compared with that of the control group in the following arrangement: 28.51% ($p < .01$) and 82.91% ($p < .001$) but kidney, cerebellum, and hippocampus tissues of the experimental offspring group was not significantly higher than that of the control group ($p > .05$) (Figure 3). Total thiol groups decreased in kidney tissues of the experimental offspring group compared with that of the control group 41.39% ($p < .001$) while decreasing in other investigated tissues of

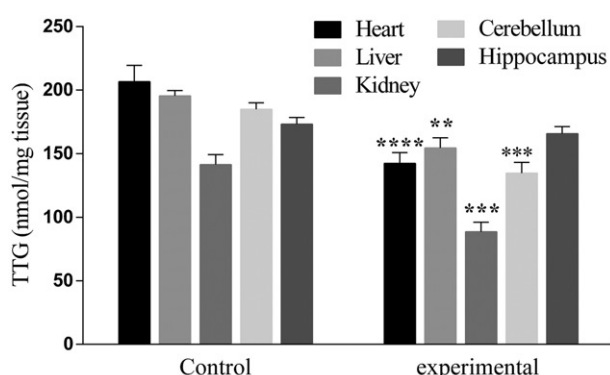


Figure 2. Total thiol groups content in tissues of dams follow on mobile phone (900 and 1800 MHz)-induced electromagnetic radiation (mean power intensity = 1 mw/m^2) during pregnancy (2 h/d for 20 d), *** $p < .001$, ** $p < .01$, compared with the control group.

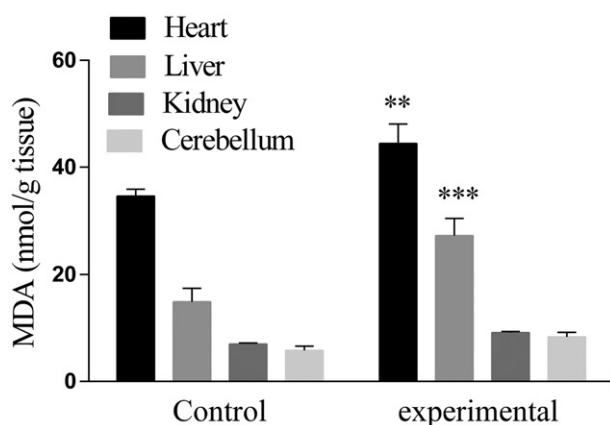


Figure 3. Malondialdehyde level in tissues of offspring follow on mobile phone (900 and 1800 MHz)-induced electromagnetic radiation (mean power intensity = 1 mw/m^2) during pregnancy (2 h/d for 20 d), *** $p < .001$ compared with the control group.

experimental offspring group compared with that of the control group was not significantly different ($p > .05$) (Figure 4). SOD activity significantly decreased in the cerebellum of experimental dams compared with the control group (72.3%, $p < .01$). Although, mean SOD activity in the heart, liver, kidney, and hippocampus of experimental dams was lower than control mice, but the decrease failed to reach statistical significance ($p > .05$) (Figure 5). In the same way, catalase activity in the kidney, cerebellum, and hippocampus of experimental dams was significantly lower than control group and decreased to 40.0% ($p < .01$), 41.2% ($p < .05$), and 54.9% ($p < .0001$) of control values, respectively. However, the decrease in catalase activity in the heart and liver of experimental dams did not reach to statistical significance ($p > .05$) (Figure 6).

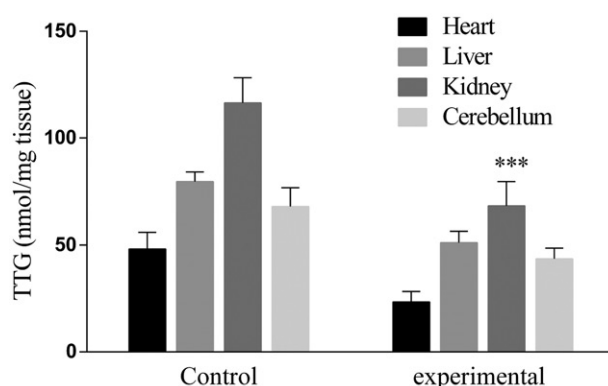


Figure 4. Total thiol groups content in tissues of offspring follow on mobile phone (900 and 1800 MHz)-induced electromagnetic radiation (mean power intensity = 1 mw/m^2) during pregnancy (2 h/d for 20 d), *** $p < .001$ compared with the control group.

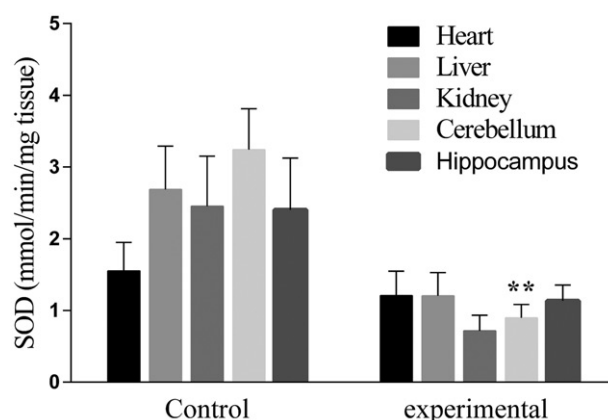


Figure 5. Superoxide dismutase (SOD) activity in tissues of dams follow on mobile phone (900 and 1800 MHz)-induced electromagnetic radiation (mean power intensity = 1 mw/m^2) during pregnancy (2 h/d for 20 d), ** $p < .01$, compared with the control group.

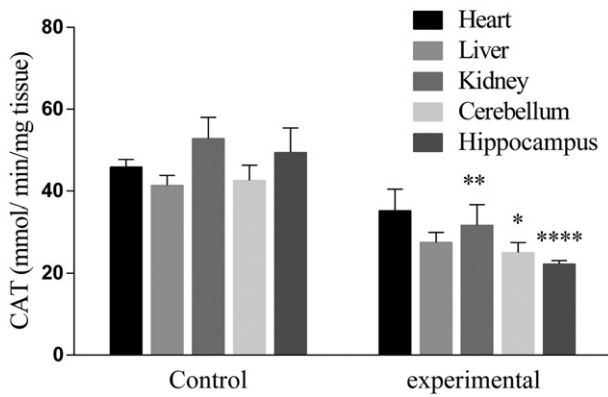


Figure 6. Catalase activity in tissues of dams follow on mobile phone (900 and 1800 MHz)-induced electromagnetic radiation (mean power intensity = 1 mw/m²) during pregnancy (2 h/d for 20 d), * $p < .05$, ** $p < .01$, *** $p < .001$, compared to the control group.

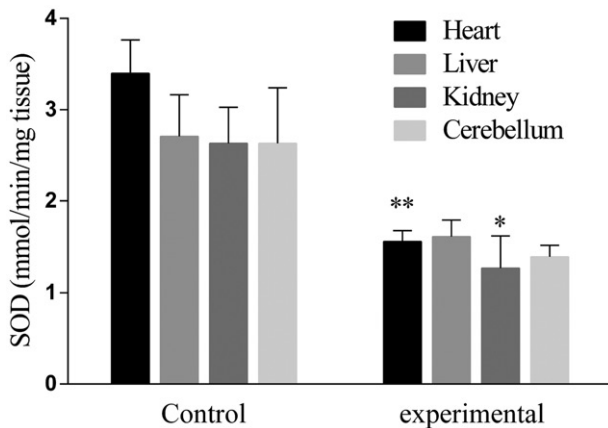


Figure 7. Superoxide dismutase (SOD) activity in tissues of offspring follow on mobile phone (900 and 1800 MHz)-induced electromagnetic radiation (mean power intensity = 1 mw/m²) during pregnancy (2 h/d for 20 d), ** $p < .01$, * $p < .05$ compared with the control group.

Superoxide dismutase decreased in heart and kidney tissues of the experimental offspring group compared with that of the control group in the following arrangement: 54.1% ($p < .01$) and 51.71% ($p < .05$) (Figure 7). Catalase decreased in heart, liver, kidney, and cerebellar of experimental offspring group compared with that of the control group ($p > .05$) (Figure 8).

Discussion

The results of present study showed that mobile phone-induced EMF exposure of pregnant rats caused oxidative stress in tissues of both the mothers and their offspring. This is first to report that the mobile phone EMF exposure during pregnancy induces oxidative damages in dams' tissues.

Nowadays more than half the world's population use the mobile phones [18]. Mobile phones emit

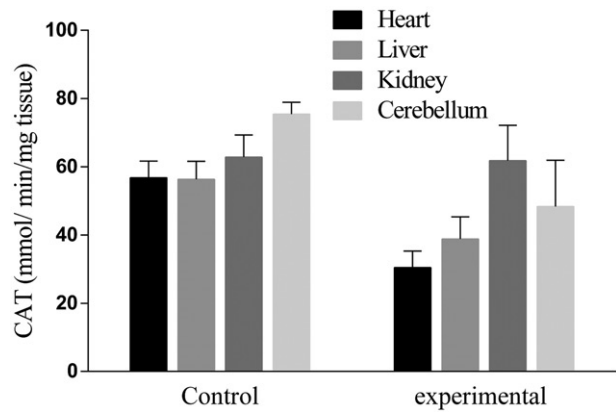


Figure 8. Catalase activity in tissues of offspring follow on mobile phone (900 and 1800 MHz)-induced electromagnetic radiation (mean power intensity = 1 mw/m²) during pregnancy (2 h/d for 20 d).

electromagnetic fields [19]. Electromagnetic fields can change the atomic energy level and the direction of electron spin, thereby increasing free radicals/reactive oxygen species (ROS) formations [8]. It has been well known that ROS induces oxidative damages to cellular macromolecules (lipids, proteins, DNA, etc.). In addition, reduction of antioxidants defense system can lead to cell death and tissue injury [6,18]. Global System Mobile Communication (GSM) Operator in Asia mostly applies a 900–1800 MHz band [20]. In the present study, to examine the effects of mobile phone, the 4-Band Jammer for Mobile Signal was used to provide an EMF with 900–1800 MHz band. On the other hand, effective level of electromagnetic fields on the tissues has been known to depend on different factors such as directly electrical conductivity of tissue. The body significantly absorbs water during pregnancy and whole-body electrical conductivity increases, therefore pregnant women and embryos are significantly more sensitive to electromagnetic fields induced by mobile phones compared with other people [21,22]. Considering this fact, the pregnant rats were exposed to mobile phone EMF in the current study. The results showed that mobile phone exposure increased MDA level of both the mother and offspring tissues while reduced thiol, SOD, and CAT. Consistently, previous studies have confirmed that exposure to EMF during pregnancy lead to childhood leukemia, brain tumor in adult, cardiovascular disease, and immune system disorders [23]. However, Turedi et al. have reported that exposure to mobile phone radiation for 1 h on days 13–21 of pregnancy increased CAT and SOD activities in the heart. The discrepancy might be due to stopping of the radiation after birth and examination of the heart tissue at the 21st post-natal day [23]. This procedure was different than that

of our study in which the experimental group was exposed to mobile phone induced electromagnetic radiation for 2 h on days 0–19 of pregnancy and biochemical estimations were performed immediately after delivery.

In contrast to our study, Turedi et al. showed that the SOD and CAT activities were increased in the hearts of 21-day-old offsprings. One possible explanation could be the fact that the offsprings were fed naturally with their mothers for 21 d, causing recover from oxidative stress [24,25].

Many studies have shown that the reduction of CAT and SOD activity could be considered as oxidative stress marker [26,27]. In the present study, we have shown that the heart of dams of the experimental group was very susceptible to oxidative stress ($p < .001$). The cycle of antioxidant enzyme activity of the heart is very short; therefore, the heart seems to have a low resistance against free radicals/ROS damages, compared with other tissues [23]. Hanci et al. [28] observed that 900 MHz electromagnetic radiation significantly increased MDA levels in the thymus and spleen, while SOD activity decreased in spleen tissue [28]. Narayanan et al. [29] also described exposure to mobile phone (900–1800 MHz) radiation in Wistar rats leading to memory damage and decreasing the acquisition of learned responses.

Radio frequency (RF)/microwaves interactions with biological systems categorize into three groups such as high (thermal), intermediate, and low (non-thermal). SAR is the scale of thermal RF/microwaves interactions with biological systems. The SAR scale directly depends on the increasing of tissue's temperature over a short period of time following the exposure. Specific heat capacity of tissue is approximately high; therefore, the SAR scale can be neglected in low power intensity and short durations of exposure [4]. Exposure level of mobile phone has been express by power intensity [4]. Haumann et al. [5] have expressed that threshold limit of power intensity for non-thermal effects of RF/microwaves interactions with biological systems is $1000 \mu\text{W}/\text{m}^2$ and at long time of exposure, that is $100 \mu\text{W}/\text{m}^2$. Power intensity are measured at a distance of 50 m from the Base Transceiver Station (BTS) is approximately 1000–2000 ($\mu\text{W}/\text{m}^2$) [30]. In our study, power intensity has been applied that was $1000 \mu\text{W}/\text{m}^2$. The biological effects of mobile phones do not depend solely on the external power density, they depend on the dielectric field inside the tissue or the body [4]. Effects of EMF in different tissues depend on the geometry and electrical properties of tissue [4]. Owing to the dams mostly absorbed the water in pre-natal period, increasing electrical conductivity can led

to oxidative stress in tissues of the dams and the off-spring mice. In conclusion, our result has showed that mobile phone (900–1800 MHz)-induced EMF during pregnancy cause oxidative stress in the tissues of the mothers and the offsprings.

Acknowledgements

The results described here were extracted from a M.Sc. student's thesis. The authors appreciate the Vice Chancellor for Research and Technology, Mashhad University of Medical Sciences for financial support (Grant No. 940160).

Disclosure statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

Funding

The author thank Mashhad University of Medical Sciences for financial support (Grant No. 940160).

References

- [1] Meo SA, Arif M, Rashied S, et al. Morphological changes induced by mobile phone radiation in liver and pancreas in wistar albino rats. *Eur J Anat.* 2010;14:105–109.
- [2] Maaroufi K, Had-Aissouni L, Melon C, et al. Spatial learning, monoamines and oxidative stress in rats exposed to 900 MHz electromagnetic field in combination with iron overload. *Behav Brain Res.* 2014;258:80–89.
- [3] Murphy J, Kaden D, Warren J, et al. International Commission for Protection Against Environmental Mutagens and Carcinogens. Power frequency electric and magnetic fields: a review of genetic toxicology. *Mutat Res.* 1993;296:221–240.
- [4] Stuchly MA, Stuchly SS. Experimental radio and microwave dosimetry. In: Polk C, Postow E, editors. *Handbook of biological effects of electromagnetic fields.* Boca Raton (FL): CRC Press; 1995; p. 295–336.
- [5] Haumann T, Münzenberg U, Maes W, editors. *HF-Radiation levels of GSM cellular phone towers in residential areas.* 2nd International Workshop on Biological effects of EMFS; 2002.
- [6] Özorak A, Nazıroğlu M, Çelik Ö, et al. Wi-Fi (2.45 GHz)- and mobile phone (900 and 1800 MHz)-induced risks on oxidative stress and elements in kidney and testis of rats during pregnancy and the development of off-spring. *Biol Trace Elem Res.* 2013;156:221–229.
- [7] Storz G, Imlayt JA. Oxidative stress. *Curr Opin Microbiol.* 1999;2:188–194.
- [8] Kiray A, Tayefi H, Kiray M, et al. The effects of exposure to electromagnetic field on rat myocardium. *Toxicol Ind Health.* 2013;29:418–425.
- [9] Hammer C, Braum E. Quantification of age pigments (lipofuscin). *Comp Biochem Physiol B.* 1988;90:7–17.

- [10] Halliwell B, Gutteridge JM. Free radicals in biology and medicine. Oxford: Oxford University Press; 1999.
- [11] Kohen R, Gati I. Skin low molecular weight antioxidants and their role in aging and in oxidative stress. *Toxicology*. 2000;148:149–157.
- [12] Aydin B, Akar A. Effects of a 900-MHz electromagnetic field on oxidative stress parameters in rat lymphoid organs, polymorphonuclear leukocytes and plasma. *Arch Med Res*. 2011;42:261–267.
- [13] Odaci E, Ünal D, Mercantepe T, et al. Pathological effects of prenatal exposure to a 900 MHz electromagnetic field on the 21-day-old male rat kidney. *Biotech Histochem*. 2015;90:93–101.
- [14] Esmekaya MA, Aytekin E, Ozgur E, et al. Mutagenic and morphologic impacts of 1.8 GHz radiofrequency radiation on human peripheral blood lymphocytes (hPBLs) and possible protective role of pre-treatment with Ginkgo biloba (EGb 761). *Sci Total Environ*. 2011;410:59–64.
- [15] Madesh M, Balasubramanian K. Microtiter plate assay for superoxide dismutase using MTT reduction by superoxide. *Indian J Biochem Biophys*. 1998;35: 184–188.
- [16] Dubey N, Raina R, Khan AM. Toxic effects of deltamethrin and fluoride on antioxidant parameters in rats. *Fluoride*. 2012;45:242–246.
- [17] Beheshti F, Hosseini M, Shafei MN, et al. The effects of Nigella sativa extract on hypothyroidism-associated learning and memory impairment during neonatal and juvenile growth in rats. *Nutr Neurosci*. 2017;20:49–59.
- [18] Khadrawy Y, Ahmed NA, Ezz HSA, et al. Effect of electromagnetic radiation from mobile phone on the levels of cortical amino acid neurotransmitters in adult and young rats. *Romanian J Biophys*. 2009;19: 295–305.
- [19] Topal Z, Hanci H, Mercantepe T, et al. The effects of prenatal long-duration exposure to 900-MHz electromagnetic field on the 21-day-old newborn male rat liver. *Turk J Med Sci*. 2015;45:1–7.
- [20] Calvente I, Fernandez M, Villalba J, et al. Exposure to electromagnetic fields (non-ionizing radiation) and its relationship with childhood leukemia: a systematic review. *Sci Total Environ*. 2010;408:3062–3069.
- [21] Durney CH, Massoudi H, Iskander MF. Radiofrequency radiation dosimetry handbook. DTIC Document; 1986.
- [22] Kismali G, Ozgur E, Guler G, et al. The influence of 1800 MHz GSM-like signals on blood chemistry and oxidative stress in non-pregnant and pregnant rabbits. *Int J Radiat Biol*. 2012;88:414–419.
- [23] Türedi S, Hanci H, Topal Z, et al. The effects of prenatal exposure to a 900-MHz electromagnetic field on the 21-day-old male rat heart. *Electromagn Biol Med*. 2015;34:390–397.
- [24] Aycicek A, Erel O, Kocyigit A, et al. Breast milk provides better antioxidant power than does formula. *Nutrition*. 2006;22:616–619.
- [25] Ezaki S, Ito T, Suzuki K, et al. Association between total antioxidant capacity in breast milk and postnatal age in days in premature infants. *J Clin Biochem Nutr*. 2008;42:133–137.
- [26] Melgarejo P, Artes F. Total lipid content and fatty acid composition of oilseed from lesser known sweet pomogranate clones. *J Sci Food Agric*. 2000;80:1452–1454.
- [27] O'shea M, Stanton C, Devery R. Antioxidant enzyme defence responses of human MCF-7 and SW480 cancer cells to conjugated linoleic acid. *Anticancer Res*. 1998;19:1953–1959.
- [28] Hanci H, Türedi S, Topal Z, et al. Can prenatal exposure to a 900 MHz electromagnetic field affect the morphology of the spleen and thymus, and alter biomarkers of oxidative damage in 21-day-old male rats? *Biotech Histochem*. 2015;90:535–543.
- [29] Narayanan SN, Kumar RS, Potu BK, et al. Spatial memory performance of Wistar rats exposed to mobile phone. *Clinics (Sao Paulo)*. 2009;64:231–234.
- [30] Akinyemi L, Makanjuola N, Shoewu O, et al. Comparative analysis of Base Transceiver Station (BTS) and power transmission lines effects on the human body in the Lagos Environs, Lagos State, Nigeria. *Afr J Comp ICT*. 2014;7:33–42.