Iranian Journal of Medical Physics
Vol. 13, No. 1, March 2016, 58-64
Received: February02, 2016; Accepted: April30, 2016

Original Article

The Effect of Cellphone Radiation on Hematological Blood Cell Factors In BALB/C Mice

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Abstract

Introduction
The continuous and rapid growth of telecommunication industries, along with the common application of cell phones, hasraised debates on the associated risks for humanhealth due to exposure to radiofrequency fields, caused bycell phonesorother sources, and industrial and medical applications. Accordingly, in this study, we aimed to investigate the effects of cell phone radiation on BALB/c mice blood factors.

Materials and Methods
In this study, 48 BALB/c mice were divided into six groups, each consisting of eight animals. Fourexposure groups were exposed to radiation waves twice a day for 30 min, 1 h, 2 h, and 4 h, respectivelyover one month. On the other hand,one exposure group wasexposed to 900 and 1800 MHz radiations (2 W)for 4 h once a day. Afterwards, the blood samples were taken from the heart, and blood factors including white blood cell count, red blood cell count, platelet count, hemoglobin level, hematocrit level, MCH, MCHC,neutrophil count, and lymphocyte count weremeasured and analyzed by SPSS version 15.

Results
Based on the findings, MCHC in the exposure groupreceiving 0.5 h of radiation and MCH in the exposure groupsreceiving 0.5, 2, and 4 h of radiationwere significantlydifferentfromthe control group ($P<0.05$).

Conclusion
According to the results of the present study, it can be concluded that microwaves have significant effects on the blood of mice. Therefore, it is suggested that further studies be conducted in this area to confirm the findings.

Keywords: Electromagnetic Waves, BALB/C Mice, Cell Phone, Hematological Factors

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1. Introduction

The rapid growth of telecommunication industries, along withthe common application of cell phones, has raised debates on the incidence of medical complications in humans. Concerns about this issue stem from the fact that new technologies are often made available without providing the necessary background information about their nature for the public.Moreover, the possible harmful effects on human health are not adequately discussed in academic circles [1].

Considering the importance of this issue,in 1996,the World Health Organization (WHO) in collaboration with the International Commission on Non-Ionizing Radiation Protection (ICNIRP) started an international project on the effects of electromagnetic fields for assessing the potential risks of these waves for human health [1,2].

Most communication networks either work with the Global System for Mobile Communication (GSM) or Code Division Multiple Access (CDMA), which communicates with cell phones with a base transceiver station (BTS) via transmission of radiofrequency waves (RF)[1].Overall, the spectrum of the electromagnetic field is divided into two major categories: ionizing and non-ionizing. Radio frequencies are a subdivision of non-ionizing radiation. Moreover, microwaveradiations are a subdivision of radiofrequencies, while cell phone radiations a sub-type of microwaves [1, 2].

Use of cell phones is steadily growing in human communities, causing more concerns regarding thepossible adverse effects of electromagnetic waves radiated by cell phones for public health [3-6,10-11].In fourreview articles, studies focusing on the biological effects of radiowaves and microwaves on different phenomena (e.g., DNA structure, chromosomal deviations, blood-brain barrier, cancer, blood pressure, brain damage, genetics, and response to stress)were summarized and discussed in detail [7,12-14].

With this background in mind, the aim of the present study was to identify the effect of cellphone electromagnetic radiation on peripheral blood parameters in small laboratory mice.

2. Materials and Methods

In order to evaluate the effects of RF waves from cellphones, 48 male BALB/c mice were examined. The mice were housed in special cages (washed and sterilized twice a week) in an animal room at a temperature of 21±2°C and relative humidity of 65-70%with a natural light cycle. The animals had access to sufficient food and water in glass bottles ad libitum. They were exposed to radiation as they started to weigh 30-35 g and turned 7-8 weeks old (age of puberty).

2.1. Electromagnetic Radiation Exposure

A commercially available wireless cellphone jammer (MB06-Mobile Blocker) was used as the microwave generator base, which constantly emitted radiation at bandwidths of 930-960 and 1975-1980 MHz, respectively (very close to 900 MHz and 1800 MHz for CDMA and GSM, respectively). The cell phone jammer emitted waves with the same frequencies as those of cell phones and all the bands in the cell phone network. The maximum power of the device was applied at a distance of 2 m.

In this study, the mice were randomly divided into six groups(one control and five exposure groups), each consisting of eight animals. The characteristics and radiation mode applied in each group are presented in Table 1. Each group was maintained in a separate non-metal cage. The horizontal polarization was similar;therefore,cages in the exposure groups were located at a 2 m distance from the device. Five cages were radiated twice a day at 12 h intervals, while one cage was radiated once a day.

As presented in Table 1, radiation took place once in the morning from 4:00 to 8:00a.m.and once in the evening from 16:00 to 20:00 p.m. for 30 consecutive days. At each stage of radiation, the cages of the exposure groups were removed from the electromagnetic field,as shown in Table 1.

Table 1. Characteristics of the study groups and duration of radiation over one month

Groups	Duration of radiation (h)	Frequency of radiation within 24 h	Time of radiation in the morning	Time of radiation in the evening
Control (0 h)	-	-	-	-
0.5 h of radiation twice a day (0.5×2h)	0.5	twice	4:00-4:30	16:00-16:30
1 h of radiation twice a day (1×2 h)	1	twice	4:00-5:00	16:00-17:00
2 h of radiation twice a day (2×2 h)	2	twice	4:00-6:00	16:00-18:00
4 h of radiation once a day (4×1 h)	4	once	4:00-8:00	-
4 h of radiation twice a day (4×2 h)	4	twice	4:00-8:00	16:00-20:00

Table 2.Mean values (mean±SD) of blood factors in the control and exposure groups after 30 days of cell phone wave irradiation

Groups / Blood factors	Control	0.5 h of radiation twice a day (0.5×2 h)	1 h of radiation twice a day (1×2 h)	2 h of radiation twice a day (2×2h)	4 h of radiation once a day (4 h)	4 h of radiation twice a day (4×2 h)
White blood cell count (WBC) (10^3 cell/µL)	3.70±3.17	6.70±3.24	5.00±2.41	4.30±1.62	4.80±1.77	5.10±1.40
Red blood cell count (RBC)(10^3 cell/µL)	6.80±1.86	7.20±1.32	7.50±0.48	7.10±1.30	7.10±1.14	6.80±1.13
Hemoglobin level (HGB)(g/dL)	9.60±3.03	11.90±1.93	11.70±0.78	11.10±2.12	10.90±1.56	11.00±1.57
Hematocrit level (HCT)	32.00±8.80	35.90±6.36	37.70±2.42	36.00±6.82	35.10±5.51	35.00±5.57
Mean corpuscular volume (MCV)(fL)	49.00±2.11	50.00±1.56	50.10±1.40	50.90±2.71	49.30±1.60	51.30±2.70
Polymorphonuclearneutrophil(PMN)	25.50±8.82	28.30±15.33	30.10±14.00	39.40±14.00	36.60±16.83	35.50±12.28
Mononuclear lymphocyte (MN)	74.50±8.82	71.40±15.00	70.10±13.80	60.60±13.70	63.40±16.84	64.50±12.30
Platelet count (PLT) ($X10^3$/µL)	221.00±165.80	375.00±309.23	491.30±444.35	530.40±385.06	280.00±217.73	591.40±575.81
Mean corpuscular Hemoglobin (MCH)(pg)	14.10±2.00	16.60±1.30 *	15.50±0.43	15.70±0.85 *	15.30±0.53	16.20±0.89*
mean corpuscular hemoglobin concentration (MCHC)(g/dL)	28.90±4.70	33.20±2.30 *	31.00±1.16	30.90±0.41	31.10±1.11	31.50±1.10

*Significant difference between the data at P<0.05

After the cell phone jammer was turned on and enough radiation was exposed, the animals were returned to their safe normal place of living. Environmental conditions of the experiment room resembled those of the animal room.

By the end of irradiation, all BALB/c mice were anesthetized with ether and the required blood for hematology was prepared by taking blood directly from the heart. Then, eight blood factors, including white blood cell count (WBC), red blood cell count (RBC), platelet count (PLT), hemoglobin (HGB) level,

hematocrit (HCT) level, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) were assessed, using a CBC(complete blood count) device at GhaemHospital, Mashhad, Iran.

By using the prepared peripheral blood slides, neutrophil count and lymphocyte count were determined with a microscope by the expertsat Ghaem Hospitalhematology laboratory. The collected data were analyzed, using SPSS version 15. Normal distribution of blood factors was quantitatively confirmed by Kolmogorov-Smirnov test. Therefore, one-way analysis of variance and Tukey's test were used to compare the groups.

3. Results

Among 10 evaluated blood factors, the results showed that only MCHC in the exposure group receiving 0.5 h of radiation and MCH in exposure groups receiving 0.5, 2, and 4 h of radiation weresignificantly differentfrom the control group ($P<0.05$). In other words, a significant difference was observed in MCH and MCHC levels between the control group and some radiation exposure groups (Table 2).

4. Discussion

The present study aimed to investigate the effects of cell phone waves on different blood factors. In this study, 10 blood factors in male adult BALB/c mice were assessed after a month of exposure to cell phone electromagnetic waves. After the exposure, a significant difference was observed in MCH and MCHC, compared to the control group. MCH in exposure groups receiving radiation for 0.5, 2, and 4 h and MCHC in the exposure group receiving radiation for 0.5 h significantly increased in comparison with the control group.

Some previous studies have also investigated the possible effects of cellphone electromagnetic waves on blood factors. In this regard, similar to the present study, Abdel-Aziz (2010) investigated the use of vitamin C and E for reducing the potential effect of a 900 MHz electromagnetic wave (for 8 h over two weeks) on 10 blood factors in rats.Rats which had not used any vitamins (vitamin C and E)experienced no significant change in MCH, MCHC, or PLT. The discrepancy between the findings could be attributed tothe irradiation method or type of the assessed animals [15].

In a study by Baharara et al. (2009), the effect of cell phone waves on the hematopoietic system of immature BALB/c mice was studied. The results showed that cell phone electromagnetic radiation to the hematopoietic system of immature male mice (one month old) over 15 days (30 min daily) had no effects on blood factors. However, histological studies of the liver, spleen, and bone marrow indicated a significant impact, which was in agreement with the results of the presents study in terms of most blood factors.Overall, the discrepancy between the reported results could be attributed to the use of mature mice [16].

The results of a previous study on blood factors in immaturerats under microwaves indicated significant changes, which were more pronounced in immature rats, compared to mature ones [17]. Moreover, Singh et al.evaluated the harmful effect of electromagnetic radiation emitted from video display units on RBC of Swiss albino mice up to 56 days. The results showed blood smear, morphology, scanning electron micrograph of RBC, RBC count, and hemoglobin concentration were reduced up to day 42 after exposure[18].

In contrast with the results of the present research, in a study in 2011 in Iran, the effect of 950 MHz cellphone electromagnetic wave (power of 3-6 W for 2 h per day for a period of two weeks)on blood factors was investigated in twogroups of rabbits. The results showed a significant decline in lymphocyte count in both groups, compared to the control group. PLT count in the test group receiving 3 Wradiations reduced, while the count increased in the group receiving6 W waves. These results were inconsistent with the findings of the present study (1 h of radiation twice a day). Such a difference could be due to the type of

evaluated samples, differences in intensity, and radiation methods [19].

In a study in 2012, the effect of electromagnetic radiation from a GSM communication network for one month on seven blood factors was investigated in four generations of rats. The findings showed that in allfourgenerations,MCV, MCH, and MCHC did not significantly change, compared to the control group. However, in terms offour factors including RBC, PCV, PLT, and WBC, there was a significant increase in some ratgenerations. In the first generation of rats, blood factors including packed cell volume (PVC), RBC, and WBC increased. These results were in conflict with the present findings, which might be due to the variation in the duration of irradiation [20].

In a previousstudy, rats in two test groups were placed under 900 and 1800 MHz electromagnetic radiation for 12 weeks (7 h daily), respectively. Measurement of blood factors between the fourth andtwelfth weeks showed that irradiation did not significantly affect the blood factors between the fourth and the sixth weeks; these findings were in agreement with the present results. However, after longer irradiation between the sixth and twelfth weeks, a significant difference was observed in the two test groups regardingMCV, HGB, WBC, and MCH, which is incompatible with the results of the present study due to the difference in irradiation duration [21].

In a previous study, electromagnetic radiation from GSM cell phoneswithin90 and 180 days showed a significant increase in RBC, WBC, PLC, and MVC, whereas no change was observed in MCH or MCHC after three months of irradiation. However, after six months of irradiation, a significant decline was observed in these factors. Changes in MCH and MCHC depend on the duration of irradiation and are in line with MCH and MCHC changes in the present study in some durations of irradiation [22].

Since the human body is incessantly exposed to radiation from various sources, further research is required in this area. The present results did not provide strong evidence on the presence of a meaningful difference between constant and interrupted (fragmentized) radiations by cell phones for 4 h. This could imply that cellular compensatory mechanism does not act effectually to compensate for the destruction caused by interrupted cellphone waves. In comparisons made between constant and interrupted radiations, in spite of adequate time, the compensatory mechanisms did not strongly treat damaged cells when radiation was interrupted.

Previous studies and observations reveal that cell phone electromagnetic waves are dependent on physical (frequency, power, rate, and duration of irradiation) and biological conditions (tissue, cell, age, and site of blood sampling) [23]. These waves can produce various biological effects. However, it seems that no consensus has been reached on the safety or possible harms of RF irradiation due to cell phones, while occurrence of biological reactions following RF irradiation could indicate that these waves might be hazardous. Therefore, unnecessary and indiscriminate use of cellphones cannot be entirely risk-free; accordingly, enhanced public awareness is highly recommended.

In the present study, whole body exposure of adultBALB/cmice to electromagnetic irradiation from antennas and cellphone sets (cellphone electromagnetic waves are designed according to physical conditions) could slightly though adversely affect blood factors, depending on the duration of irradiation.

The installed power of background radiation depends on the number of BTS antennas and the distance from them. According to the literature, the power of background radiation ranges from 0.1 $\mu W/m^2$ to 9 W/m^2 [24]. Since the human body is constantly under the exposure of radiation by station antennas 24 h a day, further research is recommended to probe into longer durations of irradiation while considering different physical and biological conditions.

5. Conclusion

According to the results of the present study, it can be concluded that microwaves have significant effects on the blood of mice. Therefore, it is suggested that further studies be conducted in this area to confirm the findings.

Acknowledgment

We would like to thank the research deputy of the Mashhad University of Medical Sciences and the staff of Ghaem Hospital histology laboratory. Also,we extend our gratitude to the members of Medical Physics Research Center of Mashhad Buali Research Institute for their valuable assistance during different stages of the study.

References

1. International Commission on Non-Ionizing Radiation Protection. Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). Health Phys. 1998;74(4):494-522.
2. Grandolfo M. Worldwide standards on exposure to electromagnetic fields: an overview. The Environmentalist. 2009 july 1;29(2):109-17.
3. McNamee JP, Chauhan V. Radiofrequency radiation and gene/protein expression: A review. Radiation research. 2009 Sep;172(3):265-87.
4. Remondini D, Nylund R, Reivinen J, De Gannes F, Veyret B, Lagroye I, Haro E, Trillo M, Capri M, Franceschi C, Schlatterer K. Gene expression changes in human cells after exposure to mobile phone microwaves. Proteomics. 2006 Sep 1;6(17):4745-54.
5. Zhao R, Zhang S, Xu Z, Ju L, Lu D, Yao G. Studying gene expression profile of rat neuron exposed to 1800 MHz radiofrequency electromagnetic fields with cDNA microassay. Toxicology. 2007 jun 25;235(3):167-75.
6. Paparini A, Rossi P, Gianfranceschi G, Brugaletta V, Falsaperla R, De Luca P, Romano Spica V. No evidence of major transcriptional changes in the brain of mice exposed to 1800 MHz GSM signal. Bioelectromagnetics. 2008 May 1; 29(4):312-23.
7. Zhu Y, Gao F, Yang X, Shen H, Liu W, Chen H, Jiang X. The effect of microwave emmision from mobile phones on neuron survival in rat central nervous system. Progress In Electromagnetics Research. 2008;82(2): 87-98.
8. Vanderstraeten J, Verschaeve L. Gene and protein expression following exposure to radiofrequency fields from mobile phones. Environmental health perspectives. 2008 Sep;116(9):1131.
9. Zhao T, Zou S, Knapp P. Exposure to cell phone radiation up-regulates apoptosis genes in primary cultures of neurons and astrocytes. Neuroscience letters. 2007 jan 22;412(1):34-8.
10. Qutob SS, Chauhan V, Bellier PV, Yauk CL, Douglas GR, Berndt L, Qutob SS, Chauhan V, Bellier PV, Yauk CL, Douglas GR, Berndt L, Williams A, Gajda GB, Lemay E, Thansandote A, McNamee JP. Microarray gene expression profiling of a human glioblastoma cell line exposed in vitro to a 1.9 GHz pulse-modulated radiofrequency field. Radiat Res. 2006 Jun;165(6):636-44.
11. Tohidi FZ, Toosi MH, Azimian H, Khademi S, Fardid R, Sarab GA. The gene expression level of p53 and p21 in mouse brain exposed to radiofrequency field. IJRR. 2015 Oct 1; 13 (4) :337-343.
12. Gurisik E, Warton K, Martin DK, Valenzuela SM. An in vitro study of the effects of exposure to a GSM signal in two human cell lines: monocytic U937 and neuroblastoma SK-N-SH. Cell Biol Int. 2006 Oct;30(10):793-799.
13. Sage C. An overview of radiofrequency/microwave radiation studies relevant to wireless communications and data. InProceedings of "International Conference on Cell Tower Siting–Lingking Science & Public Health, 7th–8th June 2000 Jun (Vol. 200).
14. Makker K, Varghese A, Desai NR, Mouradi R, Agarwal A. Cell phones: modern man's nemesis? Reproductive Biomedicine Online. 2009 Dec 31;18(1):148-57.
15. Abdel-Aziz I, El-Khozondar HJ, Shabat M, Elwasife K, Mohamed-Osman A. Effect of electromagnetic field on body weight and blood indices albino rats and theraputic action of vitamin C or E. Romanian J.Biophys.2010; 20(3): 235–44.

16. Baharara J, Parivar K, Ashraf A, Azizi M. The effect of cell phone waves on hematopoietic system of immature BALB/c mice. KAUMS Journal (FEYZ). 2009 jan 1; 13 (2) :75-81.
17. Jelodar G, Zare Y, Ansari M, Nazifi S. Effect of Radiation Leakage of Microwave Oven on Hematological Parameters of Rat at Pre and Post Pubertal Stage.Zahedan Journal of research in Medical Sciences. 2008 Dec 1; 10 (4) :265-271.
18. Singh H, Kumar C, Bagai U. Effect of Electromagnetic Field on Red Blood Cells of Adult Male, Swiss albino Mice. International Journal of Theoretical & Applied Sciences. 2013; 5(1): 175-182.
19. Sarookhani MR, Safari A, Zahedpanah M, Rezaei MA, Zaroushani V. Effects of 950 MHz mobile phone electromagnetic fields on the peripheral blood cells of male rabbits. African Journal of Pharmacy and Pharmacology. 2012 Feb 8;6(5):300-304.
20. Otitoloju AA, Osunkalu VO, Oduware R, Obe IA, Adewale AO. Haematological effects of radiofrequency radiation from GSM base stations on four successive generations (F1–F4) of albino mice, Mus Musculus. Journal of Environmental and Occupational Science. 2012;1(1):17-22.
21. Usman AD, Ahmad WW, Ab Kadir MZ, Mokhtar M, Ariffin R. Effect of radiofrequency electromagnetic field exposure on hematological parameters of mice. World ApplSci J. 2012;16(5):656-64.
22. Otitoloju AA, Osunkalu VO, Akogun MM, Obe IA, Adewale OA, Akinde OR. Stimulation of haemopoetic activity in bone marrow and deformation of red blood cells in albino mice, Mus musculus exposed to radiations from GSM base stations. Sierra Leone Journal of Biomedical Research. 2010;2(2).
23. Nemzek JA, Bolgos GL, Williams BA, Remick DG. Differences in normal values for murine white blood cell counts and other hematological parameters based on sampling site. Inflammation research. 2001 Oct 1;50(10):523-7.
24. Felix OK, Gabriel AU, Emmanuel AC. Investigation and Analysis on Electromagnetic Radiation from Cellular Base Station Transmitters and the Implications to Human Body. Journal of Environment and Ecology. 2014 Jan 1;5(1):46.