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ÖZGÜN ARAŞTIRMA / ORIGINAL ARTICLE

The effects of electromagnetic field exposure at short and long term of 900 mhz frequency emitted from mobile phones on rat bone tissue

Cep telefonlarından yayılan 900 mhz frekans elektromanyetik alana kısa ve uzun dönem maruziyetin sıçanların kemik dokusu üzerine etkisi

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ABSTRACT

Objectives: There are increasing number of evidence that exposure to the radiofrequency fields from mobile phones could affect human health. An electromagnetic field (EMF) has some biological effects on the behavior of the cell population of bone. The aim of this study was to investigate the effects of 900 MHz EMF emitted by mobile phones on the bone mineral density (BMD) of rat bone tissue.

Materials and methods: This study was done in Süleyman Demirel University, Turkey in 2006 . A total of 30 male rats were divided in three groups. EMF with 1±04 mW/cm^2 power and 900 MHz frequency: Group I (n=10) was exposed to short term (ST) 900 MHz EMF for 30 min/day, fıve day per week during 4 weeks, group II (n=10) was exposed to long term (LT) 900 MHz EMF for 30 min/day fıve day per week during 8 weeks and group III (n=10) was non-irradiated as control group and was held in the same environmental conditions for the same time except EMF application. At the end of the experiment, BMD of all rats was measured by scanning with Dual Energy X-ray Absorptiometry.

Results: Both lumbar spine and femur diaphysis BMD values were found to be lower in the exposed to ST or LT 900 MHz groups compared with the control group. However, the differences did not reach to a significant level (P>0.05).

Conclusions: It can be said that exposure to ST or LT 900 MHz EMF acquired from cellular phones and/or similar sources with an average power intensity of 1.04 mW/cm^2 and a SAR value of 0.008 W/kg has not significant effects on rats bone tissue BMD

Key words: Mobile phone, bone mineral density, electromagnetic fields, 900 MHz

ÖZET

Amaç: Cep telefonlarından yayılan radyofrekans dalgaların insan sağlığına etkisiyle ilgili artan sayıda kanıt vardır. Elektromanyetik alanın (EMA) kemik hücreleri üzerine bazı biyolojik etkileri olduğu bildirilmiştir. Çalışmamızda, cep telefonlarından yayılan 900 MHz frekansındaki EMA'nın rat kemik dokusundaki kemik mineral yoğunluğu (KMY) üzerine etkilerini araştırmak amaçlanmıştır.

Gereç ve yöntem: Bu çalışma Süleyman Demirel Üniversitesinde 2006 yılında yapıldı. Otuz erkek sıçan üç gruba ayrıldı. 1.gruptaki ratlar; kısa dönem, dört hafta boyunca haftada beş gün ve günde 30 dakika 1 ± 04 mW/cm^2 gücünde ve 900 MHz frekansında EMA'a maruz bırakıldı. 2.gruptaki ratlar ise; aynı güçte uzun dönem, sekiz hafta boyunca haftada beş gün ve günde 30 dakika 900 MHz frekansında EMA'a maruz bırakıldı. 3.gruptaki ratlar EMA uygulanan ratlarla aynı gün, süre ve çevresel şartlarda tutuldu ancak EMA uygulanmadı ve kontrol grubu olarak kabul edildi. Çalışma sonunda tüm sıçanların KMY değerleri "Dual Energy X-ray Absorptiometry" cihazı ile taranarak ölçüldü.

Bulgular: Kısa ya da uzun dönem EMA maruziyetine bırakılan her iki grupta; kontrol grubuna göre lomber ve femur KMY değerlerinde minimal azalma vardı. Ancak aradaki fark istatistiksel olarak anlamlı düzeye ulaşmadı (p>0.05).

Sonuç: Cep telefonu ve benzer kaynaklardan yayılan 1.04 mW/cm^2 gücünde ve of 0.008 W/kg SAR değerinde EMA'a kısa ya da uzun dönem maruziyetin, sıçanların kemik dokusu KMY üzerine anlamlı etkisi olmadı.

Anahtar kelimeler: Cep telefonu, kemik mineral yoğunluğu, elektromanyetik alan, 900 MHz

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INTRODUCTION

Several authors have reported that electromagnetic fields (EMF) may have several adverse biological effects. There are increase number of evidence that exposure to the radiofrequency fields from mobile telephones or their base station could affect human health.[1-7] The bone is a potential route for the absorption of hazardous materials in the environment.[8,9] The low-frequency electromagnetic fields (LFEMF) have some biological effects on the behavior of the cell populations of bone.[10-14]

On the other hand, there are very few studies[8,15-17] regarding the effect of high frequency EMF on bone tissues. Although some papers have focused on the general effects of high frequency EFM on various organs and tissues, there is still no comprehensive study targeting to reveal the underlying mechanisms of the effects of high frequency EMF on bone tissue. In this study, we aimed to investigate the effects of short and long term of 900 MHz EMF on bone mineral density (BMD).

MATERIALS AND METHODS

Study Protocol

Prior to this study, the protocol was reviewed and approved by the Süleyman Demirel University (SDU), Isparta / Turkey Ethics Commitee (11/2005) and the study was done in SDU animal research laboratory in three months (from January to March) at 2006. Approximately 5-month-old and weighing 230–250 g thirty Wistar-albino adult male rats were used in the experiments. The adult rat is a suitable experimental model for human bone mass variations, in addition there is no study will affect factors such as menstruation and menopause in male rat.[18] Animals were obtained from the breeding unit of SDU, School of Medicine. The study was approved by the Institutional Review for Animal Research Board and conducted in accordance with the institutional guidelines. The experiment was designed to obtain reliable data with minimum number of animals. Animals were maintained at a temperature of 23 ±3°C and a relative humidity of 50±10%, with a 12:12 h light-dark cycle and access to standard chow and water ad libitum. During the study, animals were not given a special diet. In addition to they were shielded against extra EMF and no restrictions were made on animal movements. The study was designed in three groups. Group I (n=10) was exposed to short term (ST) 900 MHz EMF 30 min/day for 4 weeks, group II (n=10) was exposed to long term (LT) 900 MHz EMF 30 min/day for 8 weeks and group III (n=10) was non-irradiated as control group and was held in the same environmental conditions for the same time except EMF application.

Experimental Setup and Radiofrequency Exposure

An electromagnetic energy generator (Set Elec.Co. 900/1800 Lab.Test Transmitter, Model GHZ2005X, Istanbul / Turkey) (Figure 1) has been used. Setup was tested at the electromagnetic compatibility laboratory of Department of Electronics and Communication Engineering of SDU. Generator emission was checked and verified by the satellite level meter (Promax, MC-877C, Spain). All the exposure measurements were carried out by Portable RF Survey System, Holaday, HI-4417 (MN, USA) with its standard probe. Theoretical analysis of local or whole body specific absorption rate (SAR) are from the study of Gajsek at al.[19,20] The SAR values were between 0.008 and 4.2 W/kg; 0.13–1.4 W/kg (average). During exposure, each rat was put in a special plastic holder (PVC restrainer). A dipole antenna of exposure system was placed under the plastic holder (Figure 2). The quality of the transmitted signal was checked by using spectrum analyzer, Promax, AE-566 (Barcelona/Spain) with its appropriate near-field probes. The power density measurements were made by using EMF survey meter (Holaday Industry Inc., UK). The whole body of the rat was positioned in close contact above the dipole antenna, and the tube was ventilated from head to tail in order to decrease the stress of the rat while in the tube. Rats were exposed to 30 min/day 900 MHz throughout 4 weeks (group I) and 900 MHz (group II) EMF for 5 days/week throughout 8 weeks. The unexposed control group (group III) was kept in the same laboratory conditions. The experimental setup is shown figure 3.

BMD Assessment

At the end of 4 and 8 weeks, BMD was measured in all animals under sevofluorane anesthesia and then decapitated. The total body images of the animals were obtained with DEXA scanner (Norland XR-46 bone densitometer, Norland Corp., Fort Atkinson, WI) using a small animal scan software (available

from Norland). The scan resolution was 0.5 x 0.5 mm, and scan speed was 60 mm/sec. Analysis of the different subareas were carried out on the image of the animal on the screen using a region of interest (ROI) for the lumbar spine (L2-4) as trabecular bone and the proximal femoral diaphysis as cortical bone. The lumbar spine and femoral diaphysis BMDs (grams per g/cm^2) were measured (Figure 4). To minimize the interobserver variations the same technician carried out all analyses. Measuring one rat repeated three times assessed the reproducibility of the measurement system. The coefficient of variation (cv) was 1.4% for lumbar spine and 1% for femur diaphysis.

Statistical analysis

Data were analyzed using the statistical package SPSS 11.0 for Windows (SPSS Inc., Chicago, IL). Results were expressed as mean ±SD. The groups were compared using one-way ANOVA followed by the Least Significant Differences method. Statistical significance was set at the 0.05 levels.

Table 1. The results of the BMD measurements of both spine and femur

	Group 3 (n=10) (control)	Group 2 (n=10) (ST 900 MHz)	Group 1 (n=10) (LT 900 MHz)	p value
Lomber vertebraes BMD	0,176 ± 0,012	0,175 ± 0,018	0,173 ± 0,007	0,861
Femur BMD	0,186 ± 0176	0,183 ± 0,111	0,181 ± 0,008	0,982

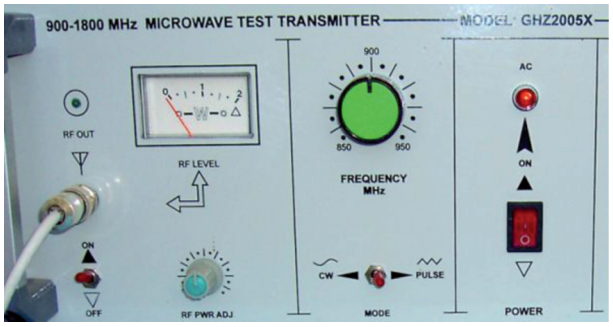

Figure 1. Electromagnetic energy generator which produced 900 MHz EMF like mobile phone frequency (Set Elec.Co. Istanbul / Turkey)

Figure 2. The rats are in the round plastic tube cage over the dipole antenna

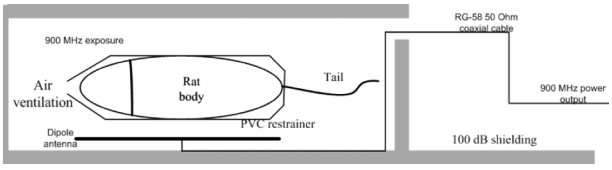

Figure 3. 900 MHz EMF Exposure system

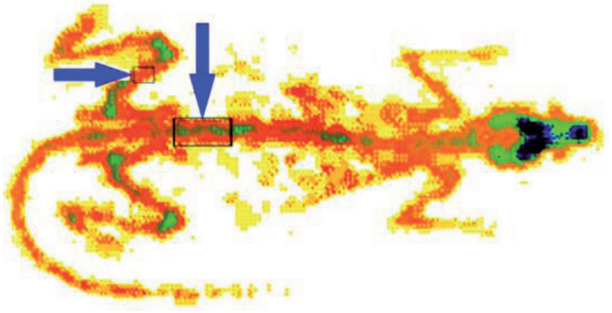

Figure 4. DEXA scanner: the screen using a ROI for the lumbar spine (L2-4) as trabecular bone and the proximal femoral diaphysis as cortical bone. (Norland XR-46 bone densitometer)

RESULTS

The mean BMD values of effect of lumbar spine and femoral diaphysis of ST 900 MHz and LT 900 MHz GSM-like EMF exposure rats are shown in table1.

BMD of both lumbar spines that were exposed to ST and LT 900 MHz are lower than the control

group. However, these differences were not found to be significant (p=0.861, table-1). BMD of both femur diaphysis, which were exposed to ST and LT 900 MHz, are lower than the control group. But these differences were not found to be significant (p=0.982, table-1). Both lumbar spine and femur diafiz BMD are lowest in the exposure to LT 900 MH group, should be noted.

DISCUSSION

As cellular phone usage gets more widespread, electromagnetic radiation has become an important health problem, which was also reported by the previous studies suggesting the harmful effects of radiofrequency waves on human health.[1-10] So far, there has been a controversy whether EMF has a negative effect on health or not. Previous studies have shown that high frequency EMF emitted from mobile phone mostly interacts with the auditory, endocrine and nervous systems.[21] For instance, the incidence of several malignancy types and tumors of central nervous system was suggested to increase as a result of consequences of changes in biochemical markers after EMF exposure.[3] Various negative effects of EMF such as physical and nervous asthenia, sleep disorders, headache, myalgia and dysesthesia of the extremities have also been published.[5-7,22] In addition to there are some studies have deal with effects on reproduction and development.[3,4,23] However, not only the potential side effects for these are of interest, but also potential side effects to the other systems are of importance. It is supposed that mechanisms involved in this process are related with heat at high frequency and chemical changes at low frequency.[5,7,15] The bone is a potential route for the absorption of hazardous materials in the environment.[8,9]

The low-frequency electromagnetic fields (LFEMF) have some biological effects on the behavior of the cell populations of bone. It increases the maturation of bone trabecula, bone volume, and bone formation.[10,11,24] Morever The low-frequency puls electromagnetic fields (LFPEMF) accelerate bone repair.[25] However, İt does not observe any effects LFEMF on bone tissue [12,13] or leads to loss of bone.[14] İn addition to LFPEMF does not any effects LFEMF on bone tissue.[26] In the scientific literature, most of the studies have been design on the interactions between LFEMF and bone tissue. Yet the effects of associated with mobile phone high frequency electromagnetic fields (EMF) have not been clearly exposed to bone tıssue.

We did not find plenty of studies regarding the effects of EMF on BMD. In our study, we have applied EMF at 900 MHz high frequencies in which we investigate the BMD variations via the DEXA method after exposure to EMF with a power intensity of 1.04 mW/cm^2 and 0.008 W/kg SAR values acquired from 900 MHz cellular phones and/or similar sources 30 minutes daily for 4 and 8 weeks.

Results of this study showed that BMD of both lumbar spines which were exposed to ST and LT 900 MHz are lower than the control group. However, these differences were not found to be significant (p=0.861, Table 1). BMD of both femur diaphysis which were exposed to ST and LT 900 MHz are lower than the control group. But these differences were not found to be significant (p=0.982, Table 1).

When the experimental studies carried out with rats that examine the effects of the high frequency and high energy EMF emitted from cellular phones and/or similar resources over the bone mineral tissue in literature is searched, the methodology of this study was found as similar to previous studies;[8,15,16] and in these experimental studies are mentioned that EMF provided by cellular phones and/or similar sources has an effect to some extent over the bone mineral density. Yıldız et al.[8] Expressed in their study that both femur and vertebral bone densities of the rats exposed to 900 and 1800 MHz radiation are found to be lower than the control group but this difference does not reach to the level of statistical significance. Atay et al.[15] founded that there is a minimal increase in lumbar bone mineral density whereas there is a minimal decrease in femur bone mineral density in the 1800 MHz EMF exposed rat group in comparison to the control group but expressed that these differences were not to carry statistical significance. Çiçek et al.[16] expressed that the bones of the rats exposed to 1800 MHz EMR have decreased breaking power, bending resistance and total breaking energy. On the other hand: In a clinical study accomplished on humans about the effects of high frequency EMF (900-1800 MHz) emitted from cellular phones over BMD, it is expressed that people using mobile phones in the mobile phone carrying values of bone mineral density is reduced

in men who carry their cellular phones on their belts.[17]

Results of our study are compatible with the results of these studies indicated. But while in the mentioned studies above the exposure length to EMF were 4 weeks, unlikely in our study also exposure to EMF was 8 weeks which could be counted as a long term exposure. And in long term the negative effects of EMF exposure duration appears to be increasing because both lumbar spine and femur diaphysis BMD are lowest in the exposure to LT 900 MH group, should be noted (Table 1). Though our results are not statistically significant it can be concluded that our study supports the results of the above study with our findings of decreased BMD's of rat lumbar and femurs exposed to ST-LT 900 MHZ EMF. However, here it may be beneficial to express that: No scientific explanation has been put forward neither in the mentioned studies [8,15-17] above nor in our study how these alterations occurred in the bone tissue acquired by EMF emitted from the cellular phones, and furthermore how different effects are obtained from high frequency 900 MHz EMFs. Besides, we could not find a statistically significant effect of ST-LT 900 MHz EMF to the bone tissue, but also we cannot explanation that it is minimal change decreased BMD's of rat lumbar and femurs exposed to ST-LT 900 MHZ EMF.

These minimal negative changes can be explained that as reported in previous studies: The effect of electromagnetic radiation emitting cellular phones and base stations on human health may vary according to the frequency, tıme exposure and power of the EMF.[5,15,26,27] Moreover electromagnetic waves have dual effect on tissues: thermal and chemical. As electromagnetic fields with high frequency can be hazardous in terms of thermal changes, extended time exposure to electromagnetic waves can lead to some unexpected biochemical changes in the body.[1,5,15,28] Perhaps our results may have emerged by chance. Anyway, as we did not conduct any histopathological examination and analysis in this context, this constituted a limitation for the detailed evaluation of the structural and cellular aspects. in this study we did not investigate any objective parameters (biochemical, scintigraphical and early histopathological or temperature changes in rats) that may explain the mechanism of the 900 MHz EMF effects. If we had done so then we might have assertively commented on these results.

As a result, It can be said that exposure to ST or LT 900 MHz EMF acquired from cellular phones and/or similar sources with an average power intensity of 1.04 mW/cm2 and a SAR value of 0.008 W/kg has insignificant effects on BMD. We share the idea that similar or different methodologies (frequency, time, SAR, power and etc. of EMF) and objective parameters (biochemical, scintigraphical, histopathological, temperature and etc) supported further studies in this subject are needed.

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