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Effects of 1800 MHz Electromagnetic Field Emitted from Cellular Phones on Bone Tissue

Cep Telefonlarından Kaynaklanan 1800 MHz Elektromanyetik Alanın Kemik Doku Üzerine Etkileri

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Objectives: An electromagnetic field (EMF) has biological effects on the behavior of the cell populations. The purpose of this study was to investigate the effects of 1800 MHz EMF which is similar to the cellular phones on the bone mineral density (BMD) of rat bone tissue.

Materials and Methods: A total of 30 male rats were divided into two groups as EMF and controls. EMF with 1±04 mW/cm^2 power and 1800 MHz frequency has been applied on rats for four weeks, five days per week and 30 minutes each day. Control group was held in the same environmental conditions for the same time except EMF application. At the end, BMD of all rats was measured by scanning with Dual Energy X-ray Absorptiometry.

Results: Although a small increase in lumbar BMD and a decrease in BMD of the femur was determined in the group affected by 1800 MHz EMF, a significant difference was not found (p>0.05).

Conclusion: Our results suggest that high frequency EMF has no effect on bone tissue with regard to osteoporosis. As serious diseases like cancer has been speculated as an outcome of exposure to frequencies used in mobile phones, further studies are warranted to reveal its effects on human health.

Key words: Cellular phone; electromagnetic field; 1800 MHz; bone mineral density.

Amaç: Elektromanyetik alanın (EMA) kemik hücreleri üzerine bazı biyolojik etkileri olduğu bildirilmiştir. Çalışmamızda, cep telefonlarından yayılan 1800 MHz frekansındaki EMA'nın rat kemik dokusundaki kemik mineral yoğunluğu üzerine etkilerini araştırmak amaçlanmıştır.

Gereçler ve Yöntemler: Otuz erkek Wistar-albino sıçan kontrol ve EMA olmak üzere iki gruba ayrıldı. EMA grubundaki ratlar, dört hafta boyunca haftada beş gün ve günde 30 dakika 1±04 mW/cm^2 gücünde 1800 MHz frekansında EMA'ya maruz bırakıldı. Kontrol grubu, aynı gün ve sürede EMA uygulanmaksızın aynı çevresel şartlarda tutuldu. Çalışma sonunda tüm sıçanların kemik mineral yoğunluğu değerleri "Dual Energy X-ray Absorptiometry" cihazı ile taranarak ölçüldü.

Bulgular: EMA grubunda kontrol grubuna göre lomber kemik mineral yoğunluğunda minimal artma, femur kemik mineral yoğunluğunda ise minimal azalma saptandı. Ancak, istatistiksel olarak anlamlı fark saptanmadı (p>0.05).

Sonuç: Osteoporoz açısından bakıldığı zaman yüksek frekanslı EMA'nın kemik dokusu üzerinde etkisi saptanmamıştır. Cep telefonları frekanslarına maruz kalmanın etkileri arasında kanser gibi ciddi hastalıkların olması nedeniyle insan sağlığı üzerindeki etkilerini araştırmak amacıyla daha ileri çalışmalara gereksinim olduğu kanaatindeyiz.

Anahtar sözcükler: Cep telefonu; elektromanyetik alan; 1800 MHz; kemik mineral yoğunluğu.

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With the extensive use of mobile phones in daily life, more attention have aroused on electromagnetic field (EMF) emitted from phones and base stations. The vast majority of mobile phones use 900 MHz or 1800 MHz frequency bands. In addition, some have dual band function. There is a controversy that EMFs have harmful effects on human health. There are published reports on the effects of mobile phone use for the auditory and the central nervous system.[1] However, not only the potential side effects for nervous system 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.[2]

Many studies have been performed on low-frequency EMF. The low-frequency EMF has biological effects on the behavior of bone cell populations. It increases the maturation of bone trabeculae, volume and formation.[3,4] However, there are also contradictory reports mentioning no observation for effects of low-frequency EMF on bone tissue.[5,6] Moreover, McElhaney et al.[7] have reported that low-frequency EMF may lead to loss in bone tissue. The controversy about potential effects associated with the exposure to EMF has recently been increased by the common use of mobile telecommunication devices.[8] On the other hand, there are very few studies 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 1800 MHz EMF on bone mineral density (BMD).

MATERIALS AND METHODS

A total of thirty Wistar-albino male rats (20 weeks old and 256±20 gr) were used in this study. Animals were obtained from the breeding unit of the School of Medicine where investigation was performed and all of the guiding principles in the care and use of laboratory animals were strictly adhered throughout the study. Standard rat chow and tap water were provided ad libitum. Experimental period was four weeks. The study was designed in two groups. Group I (n=15) was non-irradiated as control whereas group II (n=15) was irradiated with 1800 MHz, 30 min/day for four weeks and five days per week. During the study, all animals were shielded against extra EMF. At the end of four weeks, BMD was measured in all animals that were anesthetized with sevoflurane (Sevorane®, Abbott, USA). Prior to this study, the protocol was reviewed and approved by the University Ethics Committee where experiments were performed.

Experimental Setup and Radiofrequency Irradiation

The EMF setting used in this study was explained in detail by previous studies by Yıldız et al.[8] and Koyu et al.[2] We used an electromagnetic energy generator which produced 1800 MHz EMF similar to the mobile phone frequency [CW=Continuous Wave and GSM pulsed wave signal (CDMA 217 Hz pulse)] (SET ELEC.CO. 900/1800 Lab. Test Transmitter, Model 8050 GX, İstanbul, Turkey). An 1800 MHz continuous wave electromagnetic energy generator [peak specific absorption rate (SAR) was 2 W/kg, average power density 1.04 mW/cm^2] produced at the electromagnetic compatibility laboratory of the University where experiment has been performed, was used in the study. The power density measurements were made using an EMF meter which was developed at Sakarya University, Department of Science Education (Holaday Industry Inc., Adapazarı, Turkey). Electric field density was adjusted to 28 V/m.

The experiment setting was as follows: a round plastic tube cage (width: 5.5 cm, length: 12 cm) and a dipole antenna (Fig. 1). 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 in group II were exposed for 30 min/day for five days/week for four weeks to 1800 MHz EMF. The control group which was non-irradiated stayed in the same laboratory conditions.

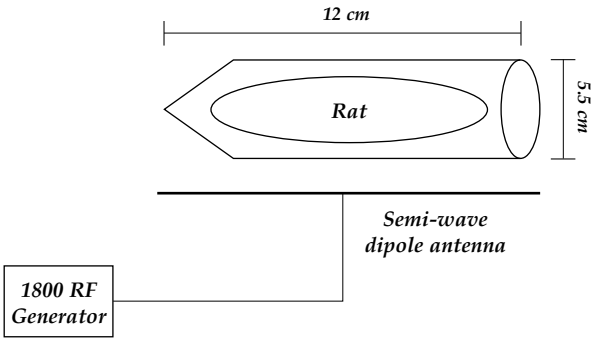

Fig. 1. *Experimental setup as illustrated.*

BMD Assessment

At the end of four weeks, BMD was measured from bone tissues of the rats. Total body images of the animals were obtained with DEXA scanner (Norland XR-46 bone densitometer, Norland Corp., Fort Atkinson, WI, USA) using a small animal scan software (Fig. 2). The scan resolution was 0.5x0.5 mm with a scan speed of 60 mm/sec. Analysis of different subareas were carried out on the image of the animals on the screen using a region of interest for the lumbar spine (L2-4) for trabecular bone and the proximal femoral diaphysis for cortical bone.[7] The lumbar spine and femoral diaphysis BMDs (g/cm^2) were measured (Fig. 3). In order to minimize the interobserver variations, same technician carried out all analyses. Measurement process was repeated three times for each rat in order to assess the efficiency of the measurement method. The coefficient of variation was 1.4% for lumbar spine and 1% for femur diaphysis.

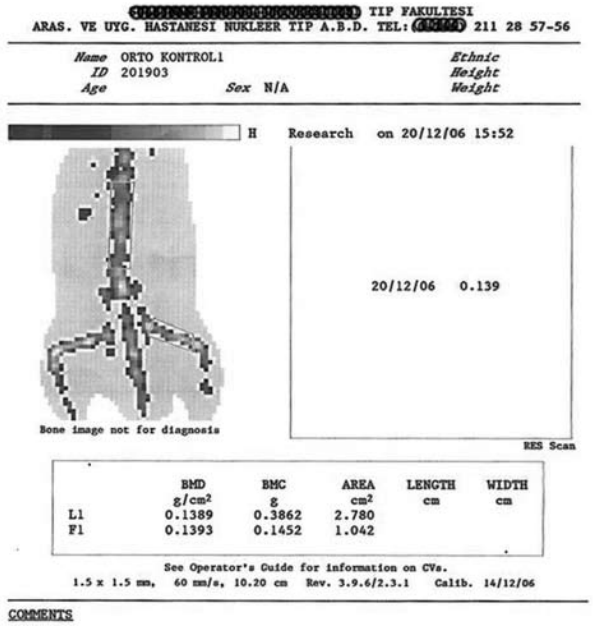

Fig. 3. *Lumbar spine and femoral diaphysis BMD measurement sample.*

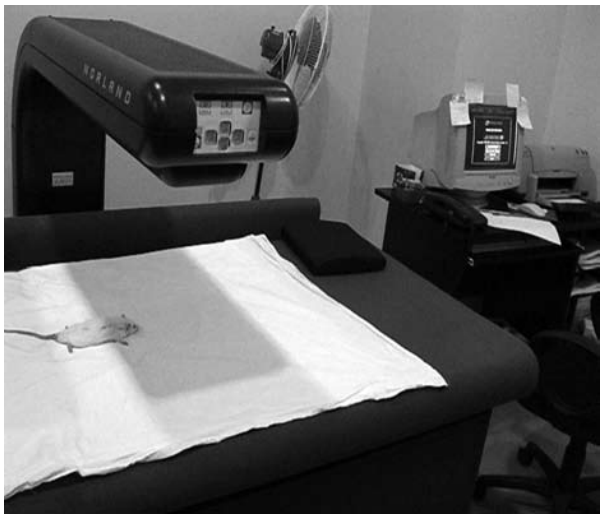

Fig. 2. *Scanning technique with the DEXA scanner.*

Statistical Analysis

SPSS 15.0 for Windows was used for statistical analysis of the established data. One sample Kolmogorov-Smirnov Test was performed for the normal distribution test. Mann Whitney U test was performed for group comparisons and p values less than 0.05 were considered as significant. In order to determine whether the sample size is suitable for the current study, power analysis was performed with two significance and sample size values.

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

Groups		Median	Range	*p*	Power analysis
Lumbar	Controls (n=15)	0,138	0,05	0.447	0,83
	1800 Mhz (n=15)	0,140	0,08		
Femoral	Controls (n=15)	0,183	0,10	0.725	0,44
	1800 Mhz (n=15)	0,167	0,13		

RESULTS

Mean BMD values for lumbar spine and femoral diaphysis were given in Table 1. A slight increase on lumbar spine BMD and decrease on femoral BMD were determined in the group exposed to 1800 MHz EMF, when compared with the controls. However, these differences were not statistically significant ($p>0.05$).

DISCUSSION

Radiofrequency waves emitting from cellular phones and base stations has emerged as a fact which affect increasing number of people by the time. 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.[1,2,9,10] So far, there has been a controversy whether EMF has a negative effect on health or not. Animal studies have shown that high frequency EMF mostly interacts with endocrine and nervous systems. 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.[9,10] Various negative effects of EMF such as physical and nervous asthenia, sleep disorders, headache, myalgia and dysesthesia of the extremities have also been published.[11]

Electromagnetic waves have dual effect on tissues: thermal and chemical. As electromagnetic fields with high frequency can be hazardous in terms of thermal changes, long time exposure to low frequency electromagnetic waves can lead to some unexpected biochemical changes in the body.[12] The effect of electromagnetic radiation emitting from cellular phones and base stations on human health is due to their frequency and power. As the frequency interval of analogue phones is between 800 and 900 MHz, digital phones work between 1850 and 1990 MHz frequencies.[13] In this study, we used a radio frequency energy source, which have produced signal at 1800 MHz frequency, identical to those of the cellular phones. As the rats included in this study were 20 weeks old, there was an ongoing bone growth and development which may make the bony tissue more susceptible to EMF. The experiment can also be planned according to an adult bone model. After one month of exposure, we did not detect any differences in bone mineral density when compared with controls. However, 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 addition, as the sample sizes of the groups were found relatively small in power analysis for the femoral BMD measurements, this should also be accepted as another restriction for the current study.

There are several studies regarding whether therapeutic utilization of pulsed EMF has beneficial effect, however, there is no consensus about the standardization of the magnetic field used. In most studies, pulse with 150-300 microsecond intervals have been used.[11] The optimal application duration for EMF has also not been determined. Indeed, this period may vary according to the frequency and power of the magnetic field. All of the previous studies were on fracture healing and conducted via using electromagnetic field with low energy.[14,15] Ijiri et al.[16] have used pulsed EMF for 10 hours in their study. Whereas, Matsumoto et al.[17] have made two different applications, four or eight hours, and they have reported that there was no difference between the two groups and four hours of pulsed EMF application was found as sufficient.[17] We did not find many studies regarding the effects of high frequency EMF on bone mineral tissue. We have applied EMF at 1800 MHz with high frequency. We have referred to the studies conducted by Yıldız et al.[8] and Koyu et al.,[2,13] in which EMF with 1±04 mW/cm^2 power and 0.008 W/kg of SAR value has been applied to the rats 30 minutes daily for five days a week for four weeks which was in accordance with the approval of ICNIRP (International Commission on Non-Ionizing Radiation Protection).[18]

There are not many studies focusing on the effects of EMF with high frequency, as in the cellular phones, on bone mineral tissues. In our

study, mean bone mineral densities of rat femurs exposed to 1800 MHz of EMF were lower and rat lumbar vertebrae bones exposed to 1800 MHz of EMF were higher than the controls. However, these differences were not statistically significant. Our results suggest that high frequency EMF may have no effect on bone tissue with regard to osteoporosis. Cancer has been suggested as an outcome of exposure to mobile phones, therefore one of the major drawbacks of our study is the lack of pathological examinations. As a result, further studies are warranted to reveal the effects of cellular phone use on human health.

REFERENCES

1. Kaprana AE, Karatzanis AD, Prokopakis EP, Panagiotaki IE, Vardiambasis IO, Adamidis G, et al. Studying the effects of mobile phone use on the auditory system and the central nervous system: a review of the literature and future directions. Eur Arch Otorhinolaryngol 2008;265:1011-9.
2. Koyu A, Gökalp O, Özgüner F, Cesur G, Mollaoğlu H, Özer MK, et al. Subkronik 1800 MHz elektromanyetik alan uygulamasının TSH, T3, T4, kortizol ve testosteron hormon düzeylerine etkileri. Genel Tıp Derg 2005;15:101-5.
3. Tabrah FL, Ross P, Hoffmeier M, Gilbert F Jr. Clinical report on long-term bone density after short-term EMF application. Bioelectromagnetics 1998;19:75-8.
4. Sert C, Mustafa D, Düz MZ, Akşen F, Kaya A. The preventive effect on bone loss of 50-Hz, 1-mT electromagnetic field in ovariectomized rats. J Bone Miner Metab 2002;20:345-9.
5. Yamada S, Guenther HL, Fleisch H. The effect of pulsed electromagnetic fields on bone cell metabolism and calvaria resorption in vitro, and on calcium metabolism in the live rat. Int Orthop 1985;9:129-34.
6. Giavaresi G, Fini M, Gnudi S, Martini L, Mongiorgi R, Aldini NN, et al. Effect of pulsed electromagnetic fields on ovariectomized rats. Electro Magnetobiol 1999;18:119-31.
7. McElhaney JH, Stalnaker R, Bullard R. Electric fields and bone loss of disuse. J Biomech 1968;1:47-52.
8. Yildiz M, Cicek E, Cerci SS, Cerci C, Oral B, Koyu A. Influence of electromagnetic fields and protective effect of CAPE on bone mineral density in rats. Arch Med Res 2006;37:818-21.
9. Dinçer S, Kanan B, Ömeroğlu S, Gönül B. Düşük frekanslı elektromanyetik alana maruz kalan farelerde doku lipid peroksidasyonu, askorbik asit ve glutatyon düzeylerindeki değişiklikler. Türkiye Tıp Dergisi 1998;5:173-6.
10. Okudan N, Çiçekçibaşı AE, Büyükmumcu M, Çelik İ, Gökbel H, Salbacak A, et al. Çok düşük (50 Hz) frekanslı manyetik alanın farelerin serum kortizol ve testosteron düzeyleri ile testis histolojisi üzerindeki etkilerinin belirlenmesi. Selçuk Tıp Derg 2006;22:1-7.
11. Leisner S, Shahar R, Aizenberg I, Lichovsky D, Levin-Harrus T. The effect of short-duration, high-intensity electromagnetic pulses on fresh ulnar fractures in rats. J Vet Med 2002;49:33-7.
12. Rothman KJ. Epidemiological evidence on health risks of cellular telephones. Lancet 2000;356:1837-40.
13. Koyu A, Cesur G, Özgüner F, Elmas O. Cep telefonlarından yayılan 900 MHz elektromanyetik alanın serum kortizol ve testosteron hormonu üzerine etkisi. SDÜ Tıp Fak Derg 2005;12:52-6.
14. Basset CAL. Pulsating electromagnetic fields: a new method to modify cell behavior in calcified and non-calcified tissues. Calcif Tissue Int 1982;34:1-8.
15. Matsunaga S, Sakou T, Ijiri K. Osteogenesis by pulsing electromagnetic fields (PEMFs): optimum stimulation setting. In Vivo 1996;10:351-6.
16. Ijiri K, Matsunaga S, Fukuyama K, Maeda S, Sakou T, Kitano M, et al. The effect of pulsing electromagnetic field on bone ingrowth into a porous coated implant. Anticancer Res 1996;16:2853-6.
17. Matsumoto H, Ochi M, Abiko Y, Hirose Y, Kaku T, Sakaguchi K. Pulsed electromagnetic fields promote bone formation around dental implants inserted into the femur of rabbits. Clin Oral Implants Res 2000;11:354-60.
18. Shupak NM. Therapeutic uses of pulsed magnetic-field exposure: a review. The Radio Science Bulletin 2003;307:9-32.