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EXPOSURE TO ELECTROMAGNETIC FIELD BY USING MOBILE TELEPHONES AND ITS INFLUENCE ON THE BRAIN FUNCTIONS

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Abstract. *The widespread use of cellular telephones in recent years inevitably raises the question of the effects on brain function of the electromagnetic fields (EMF) emitted by such telephones.*

The aim of this work was to investigate the changes in the experimental behaviour of the animalsr under the conditions of long-term mobile phones electromagnetic field exposition.

We used 4 weeks old, 20 BALB/c mice, divided into two groups: experimental - consisting of 4 female and 4 male animals and control consisting of 8 female and 4 male animals. The experimental group was for two months continually exposed to 900 MHz EMF to mobile phones. In addition to stand-by exposure every-day in different time 30 minutes of telephone using was simulated. The individual, collective behavior and body mass was observed. The experimental group was exposed to EMF during 2 months and observed for another month.

The animals in experimental group exposed to EMF showed less weight gain ($p<0.05$), after two months, meanwhile the amount of used food was similar in both groups. The most important observations were changing of basic behavior models and collective defence reflexes as well as aggressive behavior. The experimental animals exposed to EMF did not show spatial organization of their living space onto clutch and feeding places. After removing the source of EMF, this change in behavior disappears after few weeks.

The currently available results suggest that some aspects of cognitive function and some direct measures of brain and body physiology may be affected by exposure to electromagnetic fields of the type emitted by mobile telephones.

Key Words: *Brain Functions, Behavior, Microwave Radiation, Mobile Telephones*

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1. INTRODUCTION

Our knowledge about mobile telephones and its effects on human health as well as on natural environment is still insufficient because modern technology is developing and spreading quite fast. Now, there are 700 millions of mobile phone users and it is assumed that in 2005 there will be about 1,4 billion users. The dangers from electromagnetic field (EMF) exposure by using cellular phones are huge because its effects on human health and environment are not visible in a short-time period. For them to become evident it takes a long exposure time [1]. In that way the extensive use of mobile phones has given rise to a public debate about possible adverse effects on human health. A recent report of the Independent Expert Group on Mobile Phones established by the British government summarized the relevant studies on the biological effects of EMF. They proposed that a precautionary approach (limited daily duration of talking, dislocation of cellular and radio towers from urban environment, limited use for children etc.) be adopted until more robust scientific information becomes available [2].

One of the first observations about negative effects on EMF on human health is appearance of different non-specific symptoms: irritability**,** neurovegetative distony and insomnia in workers with radar equipment and radio towers. It was noticed that mice exposed to relatively a low level of microwave radiation have disturbance of long term memory. Exposure to pulse EMF with specific absorption rate (SAR) of $1.2\left[W/kg\right]$ induces slower finding of the platform with food and impaired spatial orientation in the water maze [3]. These effects of EMF were similar both for low (50-60 Hz) and high (2450 MHz) frequency [4, 5]. It is well accepted that exposure to the electromagnetic fields in the microwave region imposes stresses on the living cells when (SAR) is beyond a level sufficient to cause any significant rise of the the temperature of the cells and tissues. In this case there is a clear mechanism, namely a heat stress that causes effects.

A considerable body of experimental work with EMF from mobile phones has revealed that effects can occur under conditions in which the macroscopic temperature does not exceed normal levels. It is proposed that these nonthermal effects appeared under oscillatory compatibility among electromagnetic waves and their relays in living organism. Exposure to EMF can cause changes in the conformation of biologically active macromolecules, which can result in significant effects on the biological function [6].

Two studies published by Kovisto and colleagues showed that people's exposure to 902 MHz EMF, typical of mobile telephones, decreased response times in simple reaction and vigilance tasks and the time needed to perform a mental arithmetic task as well as the response times on a working memory task [7].

2. EXPERIMENTAL

Aim

The aim of this work was to investigate the effects on the behaviour of an experimental group of animals subject to a long-term exposure to mobile phone electromagnetic field.

Material and Methods

In this experiment we used BALB/c mice from the same clutch. The mice were 4 weeks old at the beginning of experiment and they were divided into two groups: I-experimental group, consisting of 4 female and 4 male animals, II-control group, consisting of 8 female and 4 male animals.

All experimental animals were situated in the same room with daylight and without near sources of EMF, in the cages $30 \times 40 \times 40$ cm ($W \times L \times H$). The experimental group was continually exposed to 900 MHz EMF from mobile phones. In addition to stand-by exposure every day at different time we simulated 30 minutes of telephone using. The experimental exposure to EMF was 2 months long. The mobile telephone was situated in the center of cage, while the distance of EMF generator from the floor corners was 3 cm and maximal distance from the floor corners was 28.2 cm. The amount of the food was not limited and the animals were fed *libidum*.

The individual and collective behavior of the experimental animals was observed and compared with the control one. The body weight and quantity of used food were also registered at the beginning and at the end of experiment. The experimental group was exposed to EMF during 2 months, after that the source of EMF was removed and animals were observed for another month.

3. RESULTS AND DISCUSSION

Results

The average body weight of experimental animal was 10.2±1.1 g at the start of experiment. There was not any statistical difference in body weight between sex (10.3±1.3 g for females; 9.7±1.7 g for males) and between the experimental and the control groups.

Fig. 1. Experimental group of animals exposed to EMF

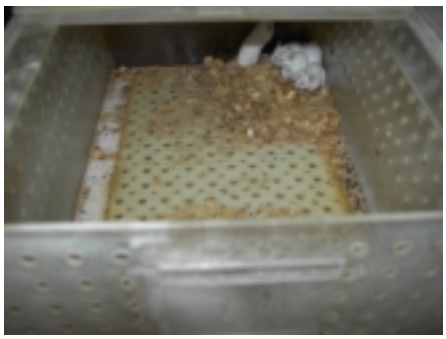

Fig. 2. Control group of animals

The animals in the experimental group exposed to EMF showed less weight gain in comparision to the control one (14.2±1.4 g vs. 15.8±1.7 g; $p<0.05$), after two months. Meanwhile the amount of used food was similar in both groups.

Besides visible lower body weight and irritable behavior of the animals in the experimental group, the most important observations were the changes of the basic behavior models and collective defense reflexes. The mice in control group as well as all animals caged in little. By the rule space showed clear polarization of their living space onto clutch and feeding places these two departments are at the opposite sides of floor diagonal. Instead of this, the experimental animals exposed to EMF did not show this spatial organization of their living space. It is very indicative that localization of the clutch was always under an antenna of the mobile phone, even to the feeding places (Fig.1).

Collective defense behavior was different in the experimental group in comparision to the control. The mice expressed visible individual panic reaction, disorientation and a greater degree of decomposure (Fig. 1). In the control group these deviations of behavior were not registered and all the animals show compact collective defense reaction (Fig. 2).

It is worth noticing that after removal of the source of EMF, this change in behavior disappears after few weeks.

In the second phase of experiment, one month after removing mobile phones, animals in the experimental group increased their body weight similar to those from the control group. As in the first phase the quantity of used food was similar between groups.

4. DISCUSSION

The widespread use of mobile phones in recent years inevitably raises the questions of the effect on brain function of the EMF emitted by such telephones. A number of reports have now appeared indicating that the high-frequency electromagnetic fields emitted by mobile phones do influence cognitive function and brain electrical activity. It is demonstrated that 30min human exposure to EMF during sleep reduced waking after sleep onset and affected the EEG in non rapid eye movement (non-REM sleep phase) [8].

The study published by Huber R. and colleagues showed more prominent disturbances of EEG in healthy, young male subjects exposed for 30 min to EMF (900 MHz; spatial peak specific absorption rate 1 [W/kg]) during the waking period preceding sleep. Compared with the control condition with sham exposure, spectral power of EEG in non-rapid eye movement phase of sleep was increased. The change in EEG power was similar for both hemisphere and no asymmetry was detected. The increase of power in the first 30 min of non-REM sleeping was no longer present at the end of the 3h sleep episode. This shows that the effect of EMF is transitory and restricted to the initial part of sleep. This is one of the possible reasons for increased irritability and slower weight gain of experimental mice [9].

The changing of behavior in experimental animals in the way of losing collective defense reaction and appearance of individual panic reaction could not be explained only by disturbance of cognitive functions but also as a result of deep subcortical structures disorders. In that way it is interesting that unilateral EMF exposure does not induce lateralisation of EEG disorders, but parallel involved both hemispheres. One of the possible explanations related to this phenomena is that subcortical regions may contain the most sensitive structures to EMF influence, and their bilateral cortical projection may explain the absence of hemisphere EEG asymmetry.

Since the thalamus is centrally involved in the generation of sleep spindles, it represents a prime candidate for an EMF sensitive subcortical structure. It is most likely that fine functional changes in hypothalamus have a limited effect on EEG disturbances, which is normalized within 3 hours after exposition to EMF. But the effect of EMF on thalamus seems a much stronger attack on the thalamic functions in the domain of reflex and instinctive behavior. In that way disorders of instinct and instinctive behavior in experimental animals were more stable and prolonged during a whole day.

It is important to note that, in this study disorder of brain function and behavior of the animals normalized less than two weeks after removing sources of EMF, as well as body weight after one month. This is a longer period compared to that observed by Borberly. and Huber [8, 9].

It is obvious that a longer exposure has longer lasting effects, but it is still unknown if these effects are a result of a slight increase in the temperature of the underlying brain tissue or structural-conformational changing of biomolecules.

5. Conclusion

The currently available results suggest that some aspects of cognitive function and some direct measures of brain and body physiology may be affected by exposure to electromagnetic fields of the type emitted by mobile telephones.

It remains to be seen whether repeated exposure to electromagnetic fields could have long lasting effects on brain physiology and cognitive function.

References

1. S. Radic, B. Djindjic., D. Sokolovic, D. Krstic, D. Petkovic, V. Markovic: *Mobilna telefonija-opasnost ili "tek" pretnja za ljudsko zdravlje*,Verba Medica, 2002.
2. IEGMP-Mobile Phones and Health. National Radiological Protection Board, Didcot Oxon London, 2000.
3. H. Lai, A. Horita, A.W.Guy : *Microwave irradiation affects radial-arm maze performance in the rat,* Bioelectromagnetics ,15, 2 (1994).
4. B.Wang, H. Lai: *Acute exposure to pulsed 2450-MHz microwaves affects water-maze performance of rats,* Bioelectromagnetics, 21, 1 (2000).
5. H. Lai, M. A. Carino, I. Ushijima: *Acute exposure to a 60 Hz magnetic field affects rats' water-maze performance,* Bioelectromagnetics, 19, 2 (1998).
6. A. J. Laurence, W. P. French, A. R. Linder, R. D. McKenzie: *Biological effects of electromagnetic fields-mechanism for the effects of pulsed microwave radiation on protein conformation,* J Theor Biol, 206, 2000.
7. M. Kovisto, C. M. Krause, A. Revonsuo: *Effect of electromagnetic field emitted by cellular phones on the EEG during a memory task*, NeuroReport, 11, 2000.
8. A.A. Borberly, R. Huber, T. Graft: *Pulsed high frequency electromagnetic field affect human sleep and sleep electroencephalogram,* Neurotics Let, 275, (1999).
9. R. Huber, T. Graf, A. Kimberly, L.Wittman, E. Gallmann, D. Matter, et al.: *Exposure to pulsed high-frequency electromagnetic field during waking affects human sleep EEG,* NeuroReport, 11, 15 (2000).

UTICAJ ELEKTROMAGNETNOG POLJA MOBILNIH TELEFONA NA MOŽDANE FUNKCIJE

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Masovna upotreba mobilnih telefona poslednjih godina nametnula je pitanje njihovog štetnog delovanja na ljudsko zdravlje sa posebnim osvrtom na njihovo delovanje na moždane funkcije.

Cilj ovog rada je ispitivanje promena ponašanja eksperimentalnih životinja u uslovima dugotrajne ekspozicije elektromagnetnom polju karakteristika kao kod mobilne telefonije.

Za eksperiment su korišćeni BALB/c miševi, stari 4 nedelje. Oni su podeljeni u dve grupe: eksperimentalnu (4 ženke i 4 mužjaka) i kontrolnu grupu (8 ženki i 4 mužjaka). Eksperimentalna grupa je dva meseca kontinuirano bila izložena elektromagnetnom polju (EMP) od 900 MHz poreklom od mobilnog telefona. Pored bazične ekspozicije svakodnevno je simulirano 30 minuta upotrebe mobilnog telefona. Posmatrane su promene ponašanja kako individualnog tako i kolektivnog ponašanja, kao i promene telesne težine. Eksperimentalna grupa je bila eksponirana EMP tokom 2 meseca, a zatim praćena sledećih mesec dana.

Životinje iz eksperimentalne grupe izložene dejstvu EMP pokazuju slabiji prirast u telesnoj masi ($p<0.05$), iako je količina upotrebljene hrane bila ista u obe grupe. Najvažnija opservacija je promena osnovnih modela ponašanja i kolektivnog odbrambenog refleksa uz prisutnu povećanu agresivnost. Eksperimentalne životinje izložene EMP nisu pokazivale prostornu organizaciju životnog prostora na leglo i mesto za hranjenje. Sve ove promene su tokom nekoliko nedelja nestale nakon uklanjanja izvora EMP.

Navedeni rezultati ukazuju da neke kognitivne i moždane funkcije kao i fiziološki procesi u organizmu mogu biti poremećeni usled ekspozicije EMP karakteristika sličnih onima koji se koriste u mobilnoj telefoniji.

Ključne reči: *funkcije mozga, ponašanje, mikrotalasno elektromagnetno zračenje, mobilni telefoni*