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Effects of Acute Exposure to Extremely Low Frequency (50 Hz) Electromagnetic Fields on Information Acquisition in Male and Female Mice

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***Abstract*—The aim of this experimental study was to investigate the effect of extremely low frequency (50 Hz) electromagnetic fields(ELF EMF) on the acquisition of information in mice and compare this effect in adult male and female mice. A sinusoidal electromagnetic field was created using a round coil electromagnet and laboratory animals were placed in the round coil for 30 minutes to exposure to a 8mT, 50Hz. Then information acquistion was evaluated with passive avoidance learning in a standard wooden box that despite his natural tendency, mice learns to stay on a small platform to avoidant electric shock. The results showed that exposure to a 50 Hz, 8mT electromagnetic field for 30 minutes before the animal's avoidance learning has devastating effects on information acquisition and learning in male ($p < .005$) and female ($p < .037$) mice.**

Keywords- electromagnetic field; extremely low frequency; Information Acquisition;mice

I. INTRODUCTION

In recent years, achieving new technologies, the human has created different intensities electromagnetic fields, communication services and various electrical devices. But alongside the benefits of technologies, there are worries about influences of electromagnetic fields on the metabolism and biological processes and molecular mechanisms and cellular organisms. The first report in 1979 about possible damaging effects of exposure to electric and magnetic fields by Whertteimer and Leeper was related to electrical fields and cancer in children [1].

In 1980 researchers investigated an increased risk of leukemia and brain tumors in people who were faced to exteremly low frequency electromagnetic fields (ELF EMF). Such evidence was led to increased attention to the risk of EMF [2]. Further research was focused on the risk of central nervous system disorders including Alzheimer and Parkinson diseases in people who were exposure to occupational electromagnetic fields and electric shock [3]. It was also found that occupational exposure to the same fields increases the risk of heart disorders, Cardial Arrhythmia-Related Conditions and Acute Myocardial Infraction [4]. Animal models and human designs have shown that ELF EMF can change peripheral and central nervous system activity. These changes include the increased activity of hypothalamic nuclei and intracerebral nuclei [6], neurotransmitter synthesis in synapses and Ganglya [7], changes in the activity of neuronal receptors including dopamine receptor and 5-HT (1B) [8] and such changes ultimately affect the learning and memory functions [9].

Behavioral and psychological studies have shown that exposure to ELF can affect human cognitive functions and behaviors of animals[10,11, 12 , 13]. For example exposed rats to 25 or 50 Hz fields in the short term (7 days) or long term (25 days) were examined in the Y form maze. The results indicated that neither short-term, nor long term exposure did not make a change in motor activity, but 50 Hz field exposure will decrease recognition of new arm of the maze[13]. In another experimental study Jadidi and his colleagues (2007) confirmed that 20 min exposure to 8 mT, 50 Hz field can impair spatial memory consolidation but such impaires can not created by a 2 mTesla field[14]. The researchers believe that ELF EMF can make changes in calcium ion homeostasis in neuronal tissues. Hippocampal regions of mouse brain which has exposed to 50 Hz field for 90 days (50 and 100 mT) were isolated and compared with the control group. it was found that exposure to ELF EMF increased Ca ions levels in cells [1].

In the other hand some researchers have reported that ELF fields have positive effects on cognitive functions. Liu et al (2008) examined spatial learning and memory changes using Morris water maze after 4 weeks exposure to ELF EMF (4hours daily with a 50 Hz, 2mT ELF). they reported that such exposure leads to reduced long-term delay in finding the hidden platform, and improved long-term memory, without effect on short term memory or motor activity [15]. Kavaliers et. al have observed behavioral improvement in mice water maze responses that is associated with biological opioid system [16].

Considering the above findings, it is not absolutely correct confirmed that the ELF fields can improve learning and memory or impair cognitive functions. This study investigated the effect of ELF EMF (50 Hz) on information acquisition (learning) in male and female mice.

II. METHOD

A. Sbjects and Experimental Groups

Adult male and female mice (25 - 30 g) were separately housed five per cage in a room with natural light cycle and constant temperature (24 ± 2 C). Food and water were available ad libitum. All procedures were conducted in agreement with the National Institutes of Health Guide for care and use of laboratory animals. Four groups were used: male sham-exposed, male exposed to 8 mT , female sham-exposed, female exposed to 8 mT.

B. Behavioral Training

This experimental study was aimed to examined one of the most stable kinds of learnings that named as avoidance learning. In this type of learning, animal not only does not receive reinforcement, but also receives a kind of stimuli or situations that may threat the survival of it. Since such irritating situations are a serious threat, generally only once experimental effort makes a long remain stable learning. In this study, to measure learning or acquisition of information, laboratory animals (mice) were evaluated with inhibitory (passive) avoidance task. Passive avoidance learning box is a wooden box with dimensions 30 * 30 * 40 cm and the floor of the 29 steel bars, the diameter of 0.3 cm. Bars are away from each other 1 cm. A wooden platform(4 x 4 x 4cm) is placed in the middle floor of the box. By an electric shock (1 Hz, 0.5 seconds, and 50 V, DC) can be controlled irritating situation (Grass S44-Quincy, Massachusetts.USA). In the learning stage, the animal was gently placed on the small wooden platform in the middle of box. Animal's natural tendency to coming down from the platform, make it to move in space of larger wooden box immediately. A 15 seconds electric shock was given as soon as animal came down from the platform and placed on the floor of the box.

So despite his natural tendency, mice learns to stay on platform. After 24 hours and in test session, avoidance learning with step-down latency was calculated[17].

C. The Electromagnetic Field Exposure System

Electromagnetic field was applied in a room adjacent to that used for behavioral experiments. A sinusoidal magnetic field was created using a round coil electromagnet made from a 1000 turned copper wire (0.50 mm). The electromagnet was supplied with a sinusoidal waveform signal generator (GFG-8019G, Good Will instrument Co.). Then amplifier output droved to coil, producing a ELF of 8 mT at the center of the coil. The desired intensity ELF (8 mT) calibrated using a Gauss meters (K72106-9-WALKER, USA) at the center of the coil. The heat generated by coil dissipated due to good ventilation in exposure area. The electrical apparatuses and exposure system adjusted on the laboratory non-metallic table.

30 min before training in the inhibitory avoidance learning apparatus, mice were exposed to electromagnetic field (in the center of round coil).

III. RESULTS

Because of significant differences in behavioral learning of animals, non-parametric statistical methods were used for data analysis.

In the first step, the two gender differences in learning session groups were compared. Using SPSS software and non-parametric test Mann – Whitney, male mice group and female mice group were compared and results showed that there has not any significant difference between the two groups (20 male and 20 female mice) in the learning session (U Mann-Whitney = 188.50, $p < .736$).

Compared the male control group and experimental group (10 mice in each group) in the learning session was not significant (U Mann-Whitney = 45.00, $p < .684$). Similar result in female groups was obtained (U Mann-Whitney = 39.00, $p < .358$). See fig 1.

The analysis of test session(information acquisition) data showed that the step-down latency in groups which mice exposed to electromagnetic Tesla 8 mT (50 Hz) were significantly lower than control groups. Comparison of experimental and control mice indicated significant differences between two control ane experimental male groups (U Mann-Whitney = 12.500, $p < .005$) and also significant differences between control and experimental in female mice too(U Mann-Whitney = 22.500, $p < .037$). See fig 2.

IV. DISCUSSION

Based on the results, it can be concluded that exposure to 8 mT, 50 Hz electromagnetic field before animals experience an avoidance learning position, impairs the acquisition information. So information acquisition and animal's learning will not be used and animal's step-down latency and avoiding the shock reduces. It is well-known that the differences between step-down latency on the platform in learning and test sessions is an index of the rate of information acquisition in inhibitory (passive) avoidance task. Staying on the platform in test session in male and female mice control indicated that information acquisition was remain, while two experimental groups performed significantly less than control groups. Therefore it can be stated that exposure to electromagnetic field even in short duration 30 minutes, can impair information acquisition and cognition in mice. These findings are in agreement with the results showing the impairing effects of ELF on cognitive functions[14, 9, 10, 11].

Previous studies mainly focused on cognitive functions specially the memory and learning in different tasks and duration of expusure, so inconsistent results are predictable.

Jadidi et al. (2007) provide evidence that exposure to a 50 Hz, 8 mT magnetic field for 20 min impaired consolidation spatial memory using a water maze but, not retrieval of learned information. Further, no effect was found in 2 mT magnetic field [14]. McKay and Persinger (2000) also found 60 min exposure to 200–500 nT ELF before training phase impaired spatial memory in the radial maze whereas exposure before testing phase decreased responding time of rats in this task [18]. Lai et al. (1998) showed that 60 min exposure to a 60 Hz, 1 mT ELF before training impaired spatial memory in a water maze[12]. Decreased perception, memory and cognition functions were found in 60 min exposure to 50 Hz, 1 mT magnetic field in a human study [9]. However, there are evidence which show no significant effects or a positive effect of ELF on learning and memory[19]. For instance, Kurokawa, Nitta, Imai, and Kabuto(2003) found no significant effects of a 50 Hz, 50 lT magnetic field on human brain[20]. Also there was not any harmfull effects of 45 min exposure to a magnetic field at 0.75 mT on memory in mice[21]. This inconsistency may be due to differences in protocols (such as type of task, intensity of the applied ELF and exposure duration, etc.) among different studies.

The mechanisms underlying the harmful effects of magnetic field on learning and memory are not known. The brain cholinergic system plays a crucial role in learning and memory[22,23]. It has shown that exposure to ELF decreased activities of cholinergic system in the frontal cortex and hippocampus, both regions are involved inmemory processing[11]. Thus, one possibility is that the impairment of cognition proccessing can result from decrement in transmission of cholinergic system. Also exposure to ELF can change calcium ion[1], and EEG, GABA, and calcium ions in the brain and these changes may effect on cognition[24].

In summary, findings indicate that 30 min exposure to a 50 Hz 8 mT, electromagnetic fields can impair information acquisition in a passive avoidance learning. In agreement with others our data indicates that exposure to ELF has impairment effect on learning and memory functions. Therefore, further studies are required to find out the underlying mechanisms.

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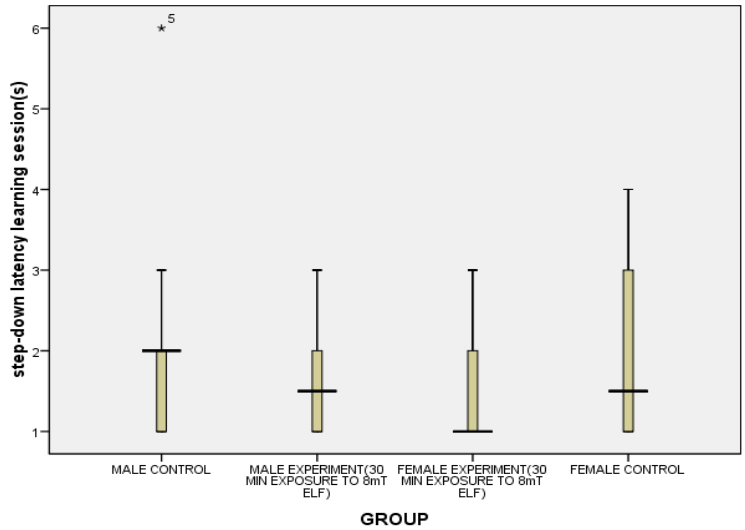

Fig 1. Step-down latency in learning session

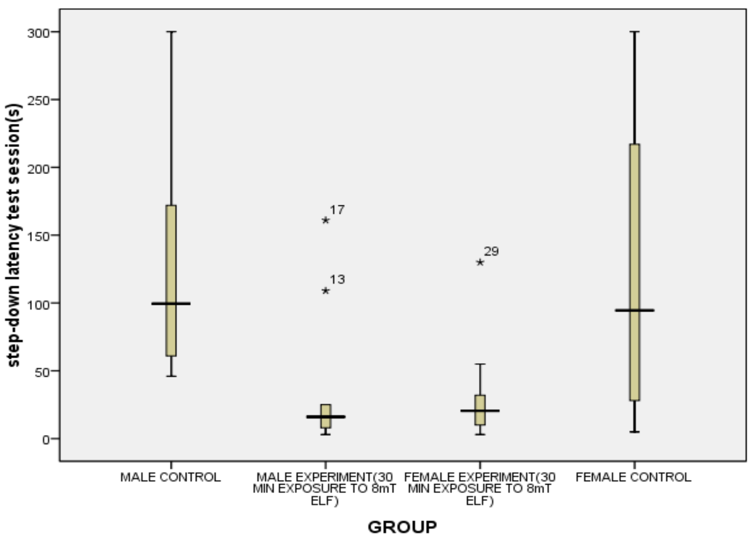

Fig 2. Step-down latency in test session(information Acquisition)