Exposure to radiofrequency wave (RFW) generated by a base transceiver stations (BTS) antenna model affects learning and memory in female more than male rats

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► ***Short Report***

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ABSTRACT

Background: Exposure to electromagnetic radiation may impair memory. This study was conducted to evaluate the effect of radiofrequency wave (hereafter referred to as RFW) on passive avoidance learning and memory in healthy males and females. ***Materials and Methods:*** Ten adult male and ten female Sprague-Dawley rats (230±20 gr) were randomly divided into four groups including two control groups (one for males and one for females), and two experimental groups (exposed to 900 MHz radio frequency wave) each representing one gender. The exposure was performed for 30 consecutive days (4h/day). Evaluation of learning and memory of the rats started on the last day of exposure by shuttle box. Learning and memory of animals was recorded by the period of time they remained within the light area; this time was called the light time. ***Results:*** Results of the study showed that exposure to RFW significantly decreased the duration of light time in the rats within the experimental groups as compared to the control groups ($P<0.05$). Exposure to RFW significantly decreased the light time in females in comparison to males in the experimental group ($P<0.05$). Histological study of brain section did not show significant changes between groups. ***Conclusion:*** With regard to these findings, it was concluded that exposure to RFW causes disorder in memory retention of passive avoidance learning in rats. The extent of damage to the learning and memory in rats exposed to RFW was more for females than males.

Keywords: *RFW (radio frequency wave); learning and memory; BTS (base transceiver stations), rats.*

INTRODUCTION

Inhabitants living adjacent to base transceiver stations (BTSs) of mobile are at risk for developing neuropsychiatric problems such as headache, memory loss, nausea, dizziness, tremors, muscle spasms, numbness, tingling, altered reflexes, muscle and joint paint, leg/foot pain, depression, and sleep disturbance (1). Due to the extensive and growing usage of mobile communication, there is increasing concern about the interactions of electromagnetic radiation with the human organs and, in particular, with the brain (2). The evidence available on the potential health effects of BTS gives strong support to the notion that BTS may affect various facets of brain function, and behaviour (1). RFW generated by BTS station has been reported to produce oxidative stress on the central nervous system (3).

Exposure to RFW can influence neuronal functions, including regulation of synaptic plasticity, neurotransmitter release, neuronal survival, learning and memory (4). There is a physiologic difference in males and females in response to stress, and learning and memory. Sex differences are present not only in the hypothalamic–pituitary–adrenal axis control of the stress response but also in behavioural [5], morphological [6], and neurochemical [7] responses to stress.

RFW exposed at whole body specific absorption rate (SAR) of 1 W/kg in rats causes vacuolization of cytoplasm in the Purkinje cells of cerebellum [8].

Considering the importance of the reported deleterious effects of RFW, we investigated the effects of long-term exposure to RFW emitted from a BTS model (900 MHz) on passive avoidance behaviour in male and female rats and compared responses of both sexes.

MATERIALS AND METHODS

Animal experiments

Ten male and ten female Sprague-Dawley rats (230±20 g, age 5–8 weeks) colony-bred in the Animal House Centre, Shiraz, Iran, were housed (five rats per cage) in the animal room under controlled lighting (12-h light: 12-h darkness) and temperature (20±2 ˚C) conditions and had free access to pelleted food and tap water. All of the experimental procedures were carried out between 9 a.m. and 1 p.m. male and female rats were housed separately in plastic cages (diameter: 5.5 cm, length: 12 cm).

Radiofrequency signal generator

The signal generator for producing a 900MHz signal was made in the Department of Electrical Engineering, Shiraz University, and the output was monitored by a spectrum analyser (FSH6, from Rohde and Schwarz, Germany) to ensure the correct forward power from the custom-designed mobile base stations on the animals exposed. The power of the BTS antenna at minimum distance from their installation site to a citizen's residence (17 m) was measured via a probe connected to the spectrum analyzer. The power level reading was 75 db. Exposure at 900 MHz with the average power density of 86 mW/cm^2 (22.8-146.8 mW/cm2), with an average whole body and brain specific absorption rate (SAR) of 0.19-1.22 W/kg and 0/013 W/kg, were applied, respectively. Based on our calculation and evaluation, the signal generator could radiate the same power level at a 1m distance. Hence, the rats in the experimental groups were placed 1m from the signal generator.

Experimental design

The effect of RFW (900 MHz) (power density 0.6789 mW/cm2) on passive avoidance learning and memory in male (n=10) and female (n=10) rats was studied by dividing the animals into four groups, each group included five animals as follows:

Group 1, 2: The control groups (male and female rats)

Group 3, 4: The experimental groups (male and female rats); they were exposed to RFW of 900 MHz.

Groups 3 and 4 were exposed to the RFW 4 h/day (9 a.m. and 1 p.m.) during a period of 30 consecutive days. The control groups were placed in the same conditions without being exposed to the RFW. At the end of the thirtieth day, learning and memory tests were conducted by the shuttle box.

Passive avoidance apparatus

A two-way shuttle-box (manufactured by Aryoazma Co) with acrylic walls and steel floor bars was used. The box, 44×20×19 cm, was bisected by a vertical partition with an opening in the median that allowed the animals to move freely from one compartment to the next, including light and dark compartments. In the light compartment, the animal was secure while it was in the dark compartment and received a foot shock of 0.6 mA for one sec; with a latent period of one sec.

Procedure

Passive avoidance test was conducted by the method of Bures *et al.* (1983) [9], with modifications. On the first day, all animals were individually subjected to 2 minutes of conformity to the shuttle box, in which the rat could explore the light compartment and move about freely. At this stage, since the rat liked dark compartment, if the rat did not move to the dark compartment after 120 sec, it was eliminated from the study. This adaptation was repeated 30 minutes later. On the second day, the rats were placed in the light compartment and one sec after entering to the dark compartment received a 0.6 mA foot shock for one sec. On the third day, the procedure was analogous to the second day; the third day was considered as learning. On the fourth day, considered as memory consolidation, the procedure was similar to the learning days without foot shock. On the fifth day, regarded as memory retention, the procedure was the same as the fourth day. The rats were considered completely learned if they did not move to the dark compartment after 120 seconds during the third, fourth, and fifth meeting of experiments (9).

Histological examination

Histopathological examination of brain tissue was conducted on the last day of the experience. The brain was dissected and fixed in 10% neutral buffered formalin, embedded in paraffin, sectioned at 5 µm and stained with haematoxylin and eosin (H&E) for light microscopic examination.

Statistical analysis

The data obtained, presented as mean±SEM, was analysed by Statistical Package for Social Sciences (SPSS, version 16.0). In addition, it was analysed separately for each group with Kruskal -Wallis nonparametric test. In case of significant results by Kruskal-Wallis test, pairwise comparisons were made using Mann-Whitney test. A value of $P<0.05$ was considered statistically significant.

RESULTS

No change was observed in tissue sections of rats exposed to RFW and morphology of the pyramidal cells was normal in comparison with the control groups (figure 1).

The mean values (±SEM) of the passive avoidance learning and memory are presented in figure 2. On the learning session, memory consolidation, and retention evaluation, exposure to RFW significantly decreased the time spent in the light compartment in both of the experimental groups compared with the control groups ($p < 0.05$) and in females compared to the males in the experimental groups (figure 2).

These results showed that exposure to RFW impaired learning, memory consolidation, and memory retention.

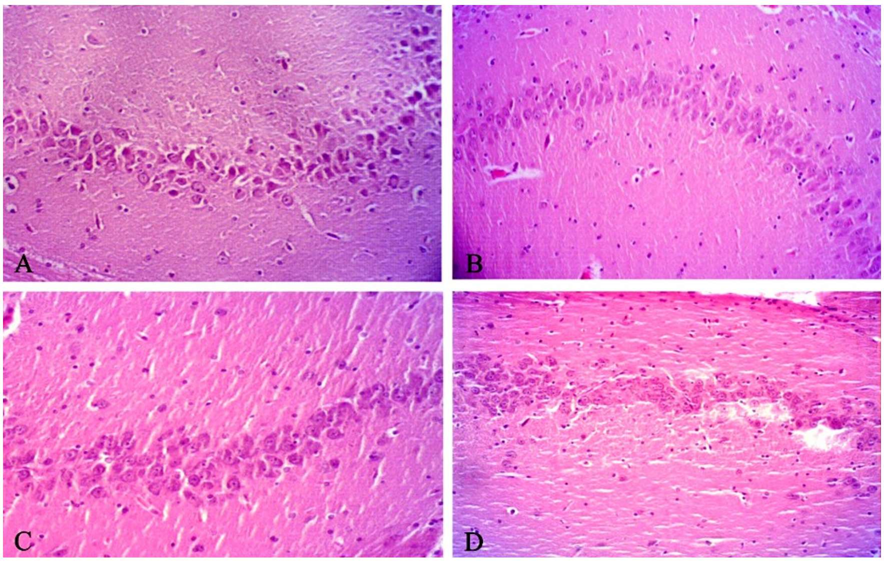

Figure 1. Learning and memory in females are more affected than males following exposure to radiofrequency wave (RFW) generated by a base transceiver stations (BTS) antenna model. Brain sections. **A.** Male control group; **B.** Female control group; **C.** Male exposed to RFW; **D.** Female exposed to RFW. Sections of all groups showed normal structure. H&E. ×100.

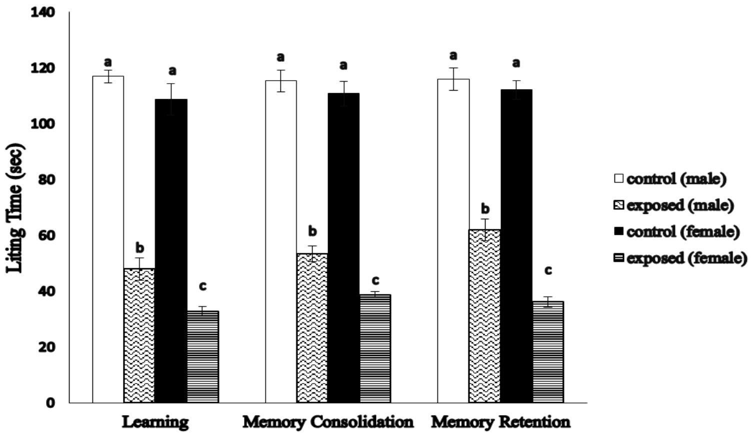

Figure 2. Learning and memory in females are more affected than males following exposure to radiofrequency wave (RFW) generated by a base transceiver stations (BTS) antenna model. Mean latencies (±SEM) in male and female groups and comparison of mean latencies (±SEM) between them during learning, memory consolidation and memory retention. Different alphabet letters indicate significant difference between groups

DISCUSSION

In the exposed groups, impaired learning, consolidation, and retention of memory was observed compared with the control groups in both sexses. Exposure to RFW may impair passive avoidance learning and memory through various mechanisms such as: 1) production of reactive oxygen species (ROS) (2), 2) decrease in the level of melatonin (10), 3) apoptosis (11), 4) changes in the release of neurotransmitters 5) increase in plasma level of corticosteroids (12) and 6) changes in the level of sex hormones in males and females (13).

It has been shown that exposure to 900 MHz RFW generated degenerative changes in hippocampal region possibly due to the oxidative stress (2). Exposure to RFW was reported to induce ROS formation in animal brain, cortical neurons, spleen, blood serum, and human semen (14). Exposure to 900 MHz RFW for 45 days (4 h/day) was reported to decrease antioxidant enzymes activity and increase MDAin the cerebellum and encephalon of the subjects in the experimental groups compared with the control groups (3).

In comparing male and female rats, RFW exerted a more deleterious effect on learning and memory in females than in males.

Sex hormones may also contribute to a differential development and functioning of brain structures that are important for learning and memory such as the hippocampus and the amygdala (15). For instance, it has been shown that males and females vary in hippocampal long -term potentiation (LTP) (long-lasting LTP in males, short-term potentiation in females) and these sex-dependent LTP differences influence contextual learning (16). Sex hormones are critically involved in these sex variations. For example, hippocampal LTP patterns differ across the estrous cycle (17) and estradiol enhances hippocampal LTP in males (18). Furthermore, estradiol has also been shown to influence (chronic) stress effects on spatial memory tasks (19).

Regarding stress effect of memory consolidation, there is some evidence that the phase of the menstrual cycle is critical for stress effects on memory (20).

Different responses of females and males to shock in shuttle-box could be due to the differences in hormonal states of both sexes. However, intact females acquire shuttle box avoidance behaviour more rapidly than males (21).

One possible mechanism which may explain the difference in males and females following exposure to RFW is different in their nervous system sensitivity to these waves due to the anatomical or structural diffecences.

CONCLUSION

The results of this study indicated that, in general, radio waves (mobile) impaired learning and memory. We also concluded that mobile phone radiation did not cause histopathological changes in the brain tissue in the rats exposed to RFW.

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Conflicts of interest: *Declared none.*

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