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Original Article

Effects of short and long term electromagnetic fields exposure on the human hippocampus

Omur Gulsum Deniz[a,*], Suleyman Kaplan[a], Mustafa Bekir Selçuk[b], Murat Terzi[c], Gamze Altun[a], Kıymet Kübra Yurt[a], Kerim Aslan[b], Devra Davis[d,e]

[a] Department of Histology and Embryology, Medical School of Ondokuz Mayıs University, Samsun, Turkey
[b] Department of Radiology, Medical School of Ondokuz Mayıs University, Samsun, Turkey
[c] Department of Neurology, Medical School of Ondokuz Mayıs University, Samsun, Turkey
[d] Department of Medicine and Public Health, The Hebrew University, Jerusalem, Israel
[e] Environmental Health Trust, Teton Village, WY, USA

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ABSTRACT

The increasing use of mobile phones may have a number of physiological and psychological effects on human health. Many animal and human studies have reported various effects on the central nervous system and cognitive performance from of exposure to electromagnetic fields (EMF) emitted by mobile phones. The aim of the present study was to evaluate the effects of mobile phones on the morphology of the human brain and on cognitive performance using stereological and spectroscopic methods and neurocognitive tests.

Sixty healthy female medical school students aged 18–25 years were divided into a low exposure group (30 subjects, <30 min daily use by the head) and high exposure group (30 subjects, >90 min daily use by the head). Magnetic resonance images (MRI) of the brain analysed on OsiriX 3.2.1 workstation. Neuropsychological tests were performed for each subject. In addition, three dominant specific metabolites were analysed, choline at 3.21 ppm, creatine at 3.04 ppm and *N*-acetyl aspartate at 2.02 ppm. Analysis of the spectroscopic results revealed no significant difference in specific metabolites between the groups ($p > 0.05$). There was also no significant difference in terms of hippocampal volume between the groups ($p > 0.05$). In contrast, the results of the stroop and digit span (backward) neurocognitive tests of high exposure group for evaluating attention were significantly poorer from low exposure group ($p < 0.05$). Based on these results, we conclude that a lack of attention and concentration may occur in subjects who talk on mobile phones for longer times, compared to those who use phones relatively less.

1. Introduction

Mobile phones, which operate at frequencies of 1.8–2.2 gigahertz (GHz) for digital systems and 400–900 MHz for analogue systems, are currently very widely used, especially among adolescents. Intensive use of mobile phones among adolescents is leading to concern regarding common physical and emotional problems, ranging from insomnia to problems with concentration [1,2]. During mobile phone use, the human brain can be exposed to a high specific absorption rate (SAR) because of its close proximity to sources of radiofrequency electromagnetic fields (RF-EMF) source. Exposure to mobile phones is generally associated with the emitted RF power. Various parameters, including the properties of the absorbing tissue, the antenna position and the magnetic field frequency, must be considered in evaluating the side-effects of RF-EMF exposure on human health [3–5]. In that context, Hardell et al. suggested that long-term exposure to RF-EMF emitted by mobile phones may increase the risk of brain tumours, such as glioma and neuroma [6].

The morphological and biochemical alterations caused by RF-EMF exposures have been investigated in animal studies. At this point, prenatal exposure results in smaller litter size, lower birth weight and offspring with significant impairment of the hippocampus, pyramidal cell and glial cells [7–9]. Neuronal damage in the central nervous system has been reported due to both prenatal or early adult exposures to electromagnetic radiation [3,10]. Effects of EMF have also been reported at the cellular level, including alter-

* Corresponding author at: Department of Histology and Embryology, Medical Faculty, Ondokuz Mayıs University, 55139, Samsun, Turkey.
E-mail address: omur.denizomu@gmail.com (O.G. Deniz).

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ations in intracellular signalling pathways such as ionic distribution and changes in calcium (Ca^{+2}) ion permeability [11,12]. Several *in vivo* studies have also reported effects of RF-EMF on behaviour, neurotransmitters and blood–brain barrier permeability [13,14]. In addition to the cellular effects of electromagnetic radiation, the potential carcinogenic effects of EMF emitted by mobile phones has been investigated in various previous studies [15–20].

The prenatal effects of EMF exposure can include cell death and inhibition of the differentiation of neural stem cells. EMF exposure can also affect neurogenesis in both the developing and adult brain [10]. Bas et al. suggested that EMF exposure can affect the new formation of cells in the cornu ammonis (CA) of the hippocampus during the embryonic development. This may result in deterioration of behavioural and cognitive functions involving learning tasks and short-term memory [7]. Although many *in vitro* and *in vivo* experimental studies have been performed, the potential effects of EMF exposure on the central nervous system are still unclear [21,22].

This study was designed to evaluate the effects of EMF emitted by mobile phones on the hippocampus using stereological, neurological and spectroscopic methods that have previously been validated. At this point; we considered two groups with relatively lower and higher reported use of mobile phones. Furthermore; for the better understand of the effects of EMF on the brain tissue, there is a need for further studies at the cellular and molecular level.

2. Materials and methods

This cross-sectional study was performed following approval by the Medical Research Ethics Committee of Ondokuz Mayıs University (2014/547). Informed consent was obtained from all subjects prior to the study.

2.1. Study group

In the present study; the medical students were given volunteer forms in accordance with our study criteria. At this point; the related students were recruited from the sixty healthy female medical students (volunteer) who are between 18 and 25 years of age and have been using mobile phones <30 min daily use by the head and >90 min daily use by the head for 5 years. Then; magnetic resonance imaging (MRI) examination of medical students' hippocampus was performed on a 1.5 T scanner (Magnetom Symphony, Siemens, Germany) between September and November 2014, at the Ondokuz Mayıs University hospital. These were divided into two groups depending on the duration of time they reported having talked on their cell phones. Because mobile phone use is ubiquitous, it was not possible to find a unexposed control group. So, the low exposure group consisted of 30 subjects who had spoken on their cell phones for <30 min daily use by the head in the previous five years. The high exposure group consisted of 30 subjects speaking on mobile phones for >90 min daily use by the head in the previous five years. Because people tend to hold phones next to the side of the head that corresponds to their dominant hand, the right-side hippocampus was evaluated on images from right-handed medical students, and the left hippocampus on images from left-handed medical students.

2.2. Magnetic resonance imaging protocol

MR images were taken using a 1.5 T MR unit (Magnetom Symphony, Siemens, Germany) with a six-channel coil. Data were analysed from T1-weighted sequences (T1-fl3d-cor-iso) with the parameters Repetition Time/Echo Time (TR/TE): 13.0/4.76 ms; FOV read: 200; FOV phase: 100; section thickness, 2.0 mm with an intersection gap of 0,2 mm; flip angle: 25°; average: 2, distance factor: 20; bandwidth: 160 and phase end: R > > L.

2.3. Magnetic resonance spectroscopy analysis

In addition to MRI, spectroscopy was also performed at the Ondokuz Mayıs University hospital using a 1.5 T system (Magnetom Symphony, Siemens, Germany) with a six-channel head coil. Magnetic resonance spectroscopy (MRS) permits examination of the brain by detecting the levels of some metabolites related to neuronal and glial conditions [23]. Also, MRS can explore aging at the molecular level. Multivoxel MRS was performed using a point-resolved spectroscopy sequence (CSI-Se-135-PRESS). The scanning parameters were Repetition Time/Echo Time (TR/TE): 1500/135 ms; average: 4; flip angle: 90°; water suppression BW:

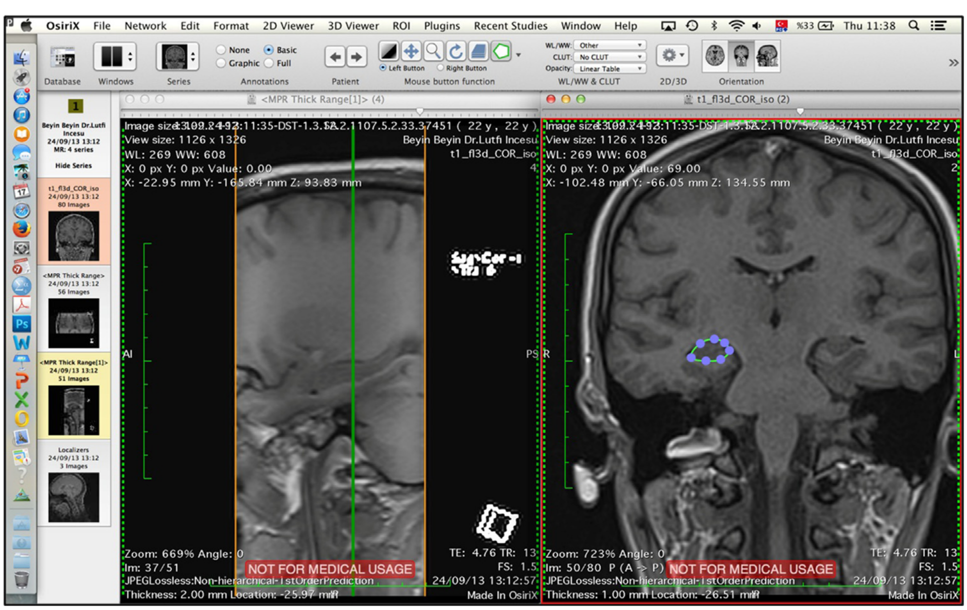

Fig. 1. MR images from one subject showing the hippocampus. Images were analysed on the software OsiriX 3.2.1 workstation. Hippocampal volumes were estimated using the output data from this process.

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