Does Exposure to Static Magnetic Fields Generated by Magnetic Resonance Imaging Scanners Raise Safety Problems for Personnel?

Ghadimi-Moghadam A.1,2, Mortazavi S. M. J.2,3*, Hosseini-Moghadam A.4, Haghani M.2, Taeb S.2, Hosseini M. A.2, Rastegariyan N.5, Arian F.6, Sanipour L.6, Aghajari S.6, Mortazavi S. A. R.2, Soofi A.2, Dizavandi M. R.7

ABSTRACT

MRI workers are occupationally exposed to static and time-varying gradient magnetic fields. While the 24-hour time-averaged exposure to static magnetic fields is about a few mT, the maximum static field strength can be as high as 500 mT during patient setup. Over the past several years, our laboratory has performed extensive experiments on the health effects of exposure of animal models and humans to different sources of electromagnetic fields such as cellular phones, mobile base stations, mobile phone jammers, laptop computers, radars, dentistry cavitrons and MRI. This study is to investigate the adverse health effects in MRI workers and also to assess the effect of exposure of MRI workers to static magnetic fields on their cognitive functions. In the first phase of this study a questionnaire was designed to collect information from 120 MRI personnel. The collection of data about the adverse health effects was based on self-reporting by the participants. In the second phase, 47 volunteer university students were asked to continuously move around a 1.5 T MRI scanner. Visual reaction time and working memory tests were performed on all participants before and after the experiment. Forward digit span and backward digit span were used for assessing the working memory. Furthermore, participants were asked to report the symptoms they had experienced during the movement. The first phase of our study showed increased frequencies of adverse health effects in MRI workers. In this study the rates of self-reported symptoms such as a headache, sleep problems, myalgia, palpitation, fatigue, concentration problems, attention problems, nervousness and backpain were possibly affected by static magnetic field. Furthermore we found that reaction time and working memory could be influenced by the movements of the body around a MRI scanner. It can be concluded that movement through a high magnetic field can also lead to some adverse cognitive effects in MRI staff.

Keywords
Static Magnetic Fields (SMF), Electromagnetic Fields (EMFs), MRI, Health Effects, Cognitive Functions

Introduction

The interactions of static magnetic fields (SMFs) with the body are at molecular, cellular, tissue and organ level. Magnetic Resonance Imaging (MRI) is a widely used important diagnostic imaging method. Although MRI has been known as a safe diagnostic imaging procedure, adverse health effects such as a headache, vertigo, nausea, concentration problems, metallic taste, balance problems, bone health and seeing light flashes have been reported by MRI staff [1-4]. The number of MRI scanners worldwide is estimated to be 20,000–25,000.
and as usually about 5 personnel from different disciplines (MRI technologists, nurses, anesthetists, technicians, engineers, cleaners, etc.) are involved in each MRI scanner [5, 6], it is estimated that about 100,000 workers are being exposed to substantial electromagnetic fields generated by MRI scanners [7]. MRI workers are occupationally exposed to static and time-varying gradient magnetic fields. While the 24-hour time-averaged exposure to static magnetic fields is about a few mT, the maximum static field strength can be as high as 500 mT during patient setup [8].

It is worth mentioning that MRI workers are exposed to a static magnetic field during the whole working hours. As the static magnetic field of an MRI scanner is always on, MRI personnel moving around the scanner will be exposed to time-varying extremely low frequency magnetic fields which induce electric fields and currents in their bodies. Furthermore, MRI personnel are occupationally exposed to radiofrequency radiation and the switched gradient fields used for image encoding only during patients’ examinations.

Over the past several years, our laboratory at the Ionizing and Non-ionizing Radiation Protection Research Center (INIRPRC) has performed extensive experiments on the health effects of exposure of animal models and humans to different sources of electromagnetic fields such as cellular phones [9-16], mobile base stations [17], mobile phone jammers [18], laptop computers [19], radars [10], dentistry cavitrons [20] and MRI [21, 22]. The first goal of this study was to investigate the adverse health effects in MRI workers. The second goal of this study was to assess the effect of exposure of MRI workers to static magnetic fields on cognitive functions.

Results

A. MRI Workers

A statistically significant difference was found between the frequency of individuals who reported getting headaches in MRI workers and the control group (P=0.037). Moreover, a statistically significant difference was found between the frequency of individuals who reported sleep problems in MRI workers and the control group (P<0.001). Furthermore, frequencies of myalgia, palpitations, fatigue, concentration problems, attention problems, nervousness and back pain significantly affected MRI personnel compared to the control group.

B. Volunteer Students

The mean age of participants was 22.23 ± 1.99 years (ranged 20-32 years). As shown in Figure 1, the means of pre and post exposure reaction times were 635 ± 82 and 684 ± 126 msec, respectively (P=0.034). Furthermore, reverse digit span was found to be lower after exposure compared to that of pre-exposure (p>0.040). However, forward digit span, was not affected by exposure to static magnetic fields.

Materials and Methods

Questionnaire Study

A questionnaire was designed to collect information from MRI personnel from seven teaching hospitals affiliated to Shiraz University of Medical Sciences. The collection of data about the adverse health effects was based on self-reporting by the participants (120 personnel including technologists and nurses).
who performed an observational study on 361 employees of 14 clinical and research MRI facilities in the Netherlands. After analysing 633 diaries, they reported that in spite of the variations in their exposure categories, symptoms were reported during 16-39% of the MRI work shifts. Schaap et al. observed a positive association between the magnetic field strength of each scanner and reported symptoms (mainly vertigo and metallic taste) in staff working with closed-bore MRI scanners of 1.5 Tesla and higher [3]. These researchers suggested an exposure-response association between exposure to strong SMFs and transient health symptoms on the same day of exposure.

B. Volunteer Students

Altogether, these data suggest that in healthy individuals, reaction time and working memory can be influenced by the movements of the body around a MRI scanner. It can be hypothesized that the electric currents induced in the body during movements in the magnetic field may cause these cognitive effects. The increased reaction time observed in our study is in line with the findings of Bongers et al. who found a link between occupational exposure to SMFs of MRI scanners and an increased risk of accidents which caused injuries[25].

Acknowledgement

This study was supported by the Ionizing and Non-ionizing Radiation Protection Research Center (INIRPRC), Shiraz University of Medical Sciences (SUMS), Shiraz, Iran.

Conflict of interest

None declared.

References

1. Gungor HR, Ok N, Akkaya S, Akkaya N. Are there any adverse effects of static magnetic field from magnetic resonance imaging devices on bone health of workers?. Eklem Hastalik Cerrahisi. 2014;25:36-41. doi.org/10.5606/ehc.2014.08. PubMed PMID: 24650383.

2. Franco G, Mora E, Perduri R. Focusing ethical dilemmas of evidence-based practice in SMF-exposed MRI-workers: a qualitative analysis. Int Arch Occup Environ Health. 2010;83:417-21. doi.org/10.1007/s00420-009-
gamma rays after exposure to microwave radiation and oral intake of flaxseed oil. *Iranian Journal of Radiation Research.* 2011;9:9-14.

14. Mortazavi S, Habib A, Ganj-Karami A, Samimi-Doost R, Pour-Abedi B, Babaie A. Alterations in TSH and Thyroid Hormones following Mobile Phone Use. *Oman Med J.* 2009;24:274-8. doi.org/10.5001/omj.2009.56. PubMed PMID: 22216380. PubMed PMCID: 3243874.

15. Mortazavi SM, Daiee E, Yazdi A, Khiabani K, Kavousi A, Vazirinejad R, et al. Mercury release from dental amalgam restorations after magnetic resonance imaging and following mobile phone use. *Pak J Biol Sci.* 2008;11:1142-5. doi.org/10.3923/pjs.2008.1142.1146. PubMed PMID: 18819554.

16. Mortazavi SM, Ahmadi J, Shariati M. Prevalence of subjective poor health symptoms associated with exposure to electromagnetic fields among university students. *Bioelectromagnetics.* 2007;28:326-30. doi.org/10.1002/bem.20305. PubMed PMID: 17308051.

17. Mortazavi S. Safety issue of mobile phone base stations. *J Biomed Phys Eng.* 2013;3:1-2.

18. Mortazavi S, Parsanezhad M, Kazempour M, Ghahramani P, Mortazavi A, Davari M. Male reproductive health under threat: Short term exposure to radio-frequency radiations emitted by common mobile jammers. *J Hum Reprod Sci.* 2013;6(2):124-8. doi.10.4103/0974-1208-1208.117176. PubMed PMID: 24082653. PubMed Central PMCID: PMC3778601.

19. Mortazavi SM, Tavassoli A, Ranjbar F, Moammariea P. Effects of laptop computers’ electromagnetic field on sperm quality. *Journal of Reproduction & Infertility.* 2010;11:251-258.

20. Mortazavi SM, Vazife-Doost S, Yaghooti M, Mehdizadeh S, Rajaei-Far A. Occupational exposure of dentists to electromagnetic fields produced by magnetostriective cavitrons alters the serum cortisol level. *J Nat Sci Biol Med.* 2012;3:60-4. doi.org/10.4103/0976-9668.95958. PubMed PMID: 22690053. PubMed PMCID: 3361780.

21. Mortazavi SM, Daiee E, Yazdi A, Khiabani K, Kavousi A, Vazirinejad R, et al. Mercury release from dental amalgam restorations after magnetic resonance imaging and following mobile phone use. *Pak J Biol Sci.* 2008;11:1142-5. doi.org/10.3923/pjs.2008.1142.1146. PubMed PMID: 18819554.

22. Mortazavi SM, Neghab M, Anoosheh SM, Bahaeedini N, Mortazavi G, Neghab P, et al. High-field MRI and mercury release from dental amalgam fillings. *Int J Occup Environ Med.* 2014;5:101-5. PubMed PMID: 24748001.

23. Chakeres DW, de Vocht F. Static magnetic field effects on human subjects related to magnetic resonance imaging systems. *Prog Biomol Mol Biol.* 2005;87:255-65. doi.org/10.1016/j.pbiomolbio.2004.08.012. PubMed PMID: 15556664.

24. Guidelines on limits of exposure to static magnetic fields. International Commission on Non-Ionizing Radiation Protection. *Health Phys.* 1994;66:100-6. PubMed PMID: 8253572.

25. Bongers S, Slottje P, Portengen L, Kromhout H. Exposure to static magnetic fields and risk of accidents among a cohort of workers from a medical imaging device manufacturing facility. *Magn Reson Med.* 2015. doi.org/10.1002/mrm.25768. PubMed PMID: 26079378.