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

[1]Pediatric Infectious Ward, Yasuj University of Medical Sciences, Yasuj, Iran
[2]Ionizing and Non-ionizing Radiation Protection Research Center (INIRPRC), Shiraz University of Medical Sciences, Shiraz, Iran
[3]Medical Physics and Medical Engineering Department, School of Medicine, Shiraz University of Medical Sciences, Shiraz, Iran
[4]Student Research Committee, Shiraz University of Medical Sciences, Shiraz, Iran
[5]Speech and Language Pathology Department, School of Rehabilitation, Shiraz University of Medical Sciences, Shiraz, Iran
[6]M.Sc Student in Radiobiology and Protection, Paramedical School, Shiraz University of Medical Sciences, Shiraz, Iran
[7]MRI Department, Shahid Faghihi Hospital, Shiraz University of Medical Sciences, Shiraz, Iran

*Corresponding author: S. M. J. Mortazavi, Ph.D Professor of Medical Physics Ionizing and Non-ionizing Radiation Protection Research Center (INIRPRC), and Fox Chase Cancer Center, 333 Cottman Avenue, Philadelphia, PA 19111, USA
E-mail: S.M.Javad.Mortazavi@fccc.edu

Received: 28 June 2015
Accepted: 8 November 2015

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 set up [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.

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).

Cognitive Functions

In this part of the study, 47 volunteer university students (18 males and 29 females) were asked to continuously move around a 1.5 T MRI scanner (Siemens Medical Solutions, Erlangen, Germany) for 15 minutes. 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 to measure the working memory. Furthermore, participants were asked to report the symptoms they had experienced during the movement.

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 backpain 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.

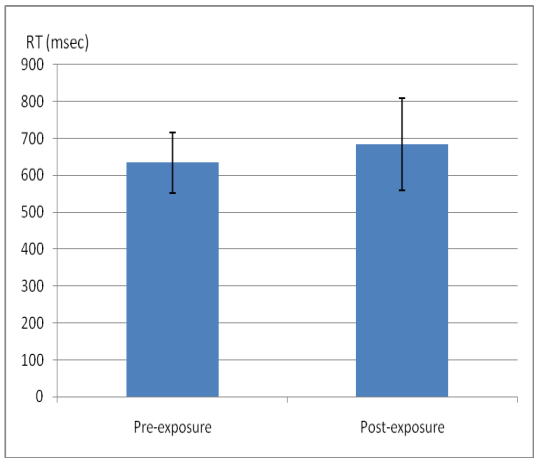

Figure 1: The means (±SD) of pre and post exposure reaction times

Discussion

A. MRI Workers

In a general view, our results showed increased frequencies of adverse health effects in MRI workers. In our study the rates of self-reported symptoms such as headache, sleep problems, myalgia, palpitations, fatigue, concentration problems, attention problems, nervousness and backaches were possibly affected by exposure to static magnetic field. Altogether these findings are in line with this well documented point that movement in a static magnetic field, depending on the basic factors such as magnetic flux density, the speed of movement and the magnitude of induced currents in the tissues, may result in physiologically significant sensory perception disorders such as vertigo, nausea, the perception of flickering light in the visual field, and a metallic taste in the mouth due to the changes of the magnetic flux penetrating the body [23, 24]. These findings are in line with several studies which reported temporary and dose-correlated vertigo and nausea in workers and patients exposed to static magnetic fields. Further studies are needed to explore these bioeffects as well as their magnitudes and possible mechanisms. Our findings are generally in line with reports submitted by Schaap et al. 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-

0476-8. PubMed PMID: 19888595.

3. Schaap K, Christopher-de Vries Y, Mason CK, de Vocht F, Portengen L, Kromhout H. Occupational exposure of healthcare and research staff to static magnetic stray fields from 1.5-7 Tesla MRI scanners is associated with reporting of transient symptoms. *Occup Environ Med*. 2014;**71**:423-9. doi.org/10.1136/oemed-2013-101890. PubMed PMID: 24714654. PubMed PMCID: 4033112
4. de Vocht F, van Drooge H, Engels H, Kromhout H. Exposure, health complaints and cognitive performance among employees of an MRI scanners manufacturing department. *J Magn Reson Imaging*. 2006;**23**:197-204. doi.org/10.1002/jmri.20485. PubMed PMID: 16374876.
5. Moore EA, Scurr ED. British Association of MR Radiographers (BAMRR) safety survey 2005: potential impact of European Union (EU) Physical Agents Directive (PAD) on electromagnetic fields (EMF). *J Magn Reson Imaging*. 2007;**26**:1303-7. doi.org/10.1002/jmri.21154. PubMed PMID: 17969163.
6. Wilen J, Hauksson J, Mild KH. Modification of pulse sequences reduces occupational exposure from MRI switched gradient fields: Preliminary results. *Bioelectromagnetics*. 2010;**31**:85-7. PubMed PMID: 19753611.
7. Hansson Mild K, Hand J, Hietanen M, Gowland P, Karpowicz J, Keevil S, et al. Exposure classification of MRI workers in epidemiological studies. *Bioelectromagnetics*. 2013;**34**:81-4. doi.org/10.1002/bem.21728. PubMed PMID: 22532229.
8. Bradley JK, Nyekiova M, Price DL, Lopez LD, Crawley T. Occupational exposure to static and time-varying gradient magnetic fields in MR units. *J Magn Reson Imaging*. 2007;**26**:1204-9. doi.org/10.1002/jmri.21152. PubMed PMID: 17969141.
9. Mortazavi SM, Motamedifar M, Namdari G, Taheri M, Mortazavi AR, Shokrpour N. Non-linear adaptive phenomena which decrease the risk of infection after pre-exposure to radiofrequency radiation. *Dose Response*. 2014;**12**:233-45. doi.org/10.2203/dose-response.12-055.Mortazavi. PubMed PMID: 24910582. PubMed PMCID: 4036396.
10. Mortazavi SMJ, Motamedifar M, Namdari G, Taheri M, Mortazavi AR. Counterbalancing immunosuppression-induced infections during long-term stay of humans in space. *Journal of Medical Hypotheses and Ideas*. 2013;**7**(1):8-10. doi:10.1016/j.jmhi.2012.12.001.
11. Mortazavi SM, Rouintan MS, Taeb S, Dehghan N, Ghaffarpanah AA, Sadeghi Z, et al. Human short-term exposure to electromagnetic fields emitted by mobile phones decreases computer-assisted visual reaction time. *Acta Neurol Belg*. 2012;**112**:171-5. doi.org/10.1007/s13760-012-0044-y. PubMed PMID: 22426673.
12. Mortazavi S, Mosleh-Shirazi M, Tavassoli A, Taheri M, Mehdizadeh A, Namazi S, et al. Increased Radioresistance to Lethal Doses of Gamma Rays in Mice and Rats after Exposure to Microwave Radiation Emitted by a GSM Mobile Phone Simulator. *Dose Response*. 2013;**11**:281-92. doi.org/10.2203/dose-response.12-010.Mortazavi. PubMed PMID: 23930107. PubMed PMCID: 3682203.
13. Mortazavi S, Mosleh-Shirazi M, Tavassoli A, Taheri M, Bagheri Z, Ghalandari R, et al. A comparative study on the increased radioresistance to lethal doses of gamma rays after exposure to microwave radiation and oral intake of flaxseed oil. *Iranian Journal of Radiation Research*. 2011;**9**:9-14.
14. Mortavazi S, Habib A, Ganj-Karami A, Samimi-Doost R, Pour-Abedi A, 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**:1142-6. doi.org/10.3923/pjbs.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: 17330851.
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 radiofrequency radiations emitted by common mobile jammers. *J Hum Reprod Sci*. 2013;**6**(2):124-8. doi: 10.4103/0974-1208.117178. PubMed PMID: 24082653; PubMed Central PMCID: PMC3778601.
19. Mortazavi SMJ, Tavassoli A, Ranjbari F, Moammaiee 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, Rajaie-Far A. Occupational exposure of dentists to electromagnetic fields produced by magnetostrictive 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**:1142-6. doi.org/10.3923/pjbs.2008.1142.1146. PubMed PMID: 18819554.
22. Mortazavi SM, Neghab M, Anoosheh SM, Bahaeddini 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 Biophys 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.