www.ajbrui.org

Afr. J. Biomed. Res. Vol. 23 (January, 2020); 57- 63

Research Article

Some Health Effects of Exposure to Static Magnetic Fields and Radiofrequency Energy among MRI Staff Working with 1.5 and 3.0 Tesla Scanners In South Africa

***Rathebe P.[1], Weyers C.[2] and Raphela F.[3]**

[1]*University of Johannesburg, Department of Environmental Health, Doornfontein Campus, Johannesburg*
[2]*Central University of Technology, Free State, Department of Life Sciences, Bloemfontein*
[3]*Central University of Technology, Free State, Department of Clinical Sciences, Bloemfontein*

ABSTRACT

Occupational exposure to magnetic resonance imaging (MRI)-related electromagnetic fields is associated with the development of adverse and transient health effects. The aim of this study was to assess the health effects associated with exposure to Static Magnetic Fields (SMFs) and radiofrequency (RF) energy amongst MRI staff in 1.5 and 3.0 T MRI units. Data were collected through questionnaires completed by 42 MRI staff members working in Hospital A (57.89%) and Hospital B (42.11%) in the Mangaung metropolitan region. Of the participating staff, four did not indicate the facilities in which they worked. Twenty-four of the participants were female and eighteen were male, and their mean age was 37 years (range of 20 to 61). The questionnaire was categorized in terms of the participants' biographical, work, and health-related information. Radiographers (35.71%), student radiographers (11.9%), nurses (9.52%), medical physicists (4.76%), maintenance engineers (4.76%), radiologists (9.52%), and cleaners (23.81%) working in both hospitals participated in the study. The data was analysed to determine the percentages and frequencies for the categorical data. Of the 42 participants, 30.95% reported hypertension, 11.9% reported hypotension, 2.38% reported cataracts, 16.67% reported depression, and 16.67% reported increased heart rates as a priori-unrelated health effects. Regarding priori-related health effects, 26.19% of the participants reported a metallic taste, 40.48% reported vertigo, 21.43% reported nausea, 7.14% reported hypothermia, 2.38% reported hyperthermia, 19.05% reported concentration difficulties, 21.43% reported blurred vision, and 19.05% reported vitamin deficiencies. Vertigo was reported to be the most common SMF exposure-related effect. Of the 61.9% of MRI staff who wore PPE, 30.77% were found to wear MRI-related PPE when working in the MRI units. The results reported in this study were found to be consistent with the exposure-related effects of MRI units investigated in many other studies. The results also suggest future studies that could determine the association between exposure and the development of depression and cataracts in a larger study population of MRI workers.

Keywords: Health effects; MRI scanners; exposure assessment; questionnaires; 1.5 and 3 T scanners

*Author for correspondence: *E-mail*: *prathebe@uj.ac.za*

Received: January 2019; Accepted: July, 2019

Abstracted by:
Bioline International, African Journals online (AJOL), Index Copernicus, African Index Medicus (WHO), Excerpta medica (EMBASE), CAB Abstracts, SCOPUS, Global Health Abstracts, Asian Science Index, Index Veterinarius

INTRODUCTION

Magnetic resonance imaging (MRI) staff provides routine care to patients undergoing MRI procedures, and the implications for these patients are well-known and have been addressed in many studies. However, literature is scarce on the occupational hazards and risks associated with the exposure of MRI staff to the magnetic fields emitted by MRI scanners (Gorlin *et al*., 2015). Several studies have indicated that staff who work with MRI scanners commonly develop transient symptoms such as nausea, dizziness, a metallic taste, magnetophosphenes, severe headaches, tinnitus, and concentration problems in severe cases (De Vocht *et al*., 2015). These symptoms are ascribed to exposure scenarios that include static magnetic fields (SMFs) and time-varying and radiofrequency (RF) energy (Schaap *et al*., 2014). According to Karpowicz *et al*. (2007), exposure to RF energy typically is associated with thermal effects and electro-sensitive tissue excitations, whereas possible adverse and transient health effects are associated with SMFs,

especially in cases of chronic exposure to high fields (7 Tesla or more).

Exposure of MRI staff to SMFs is a pressing concern, since fields always are turned on, even when patients are not being scanned. Karpowicz and Gryz (2006) indicated that the most significant exposure occurs in the proximity of the magnet housing. Exposure to RF energy is also possible during patient examinations; however, this happens only in special cases, such as when staff assists patients with severe medical conditions, patients with claustrophobia, and children (Karpowicz and Gryz, 2006). Due to the minimal attention that has been paid to exposure of MRI staff to electromagnetic fields (EMFs) in health care settings, Vijayalaxmi *et al.* (2015) highlighted the need to investigate the long-term effects of different exposure levels encountered by health care workers in MRI areas. In 2015, the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) expressed the same view regarding the need for epidemiological studies on exposure to RF energy and SMFs, which also were deemed important by the 2013 European Union directive. The study reported here investigated the health effects of MRI staff exposed to SMFs and RF energy from 1.5 and 3 T MRI scanners in public hospitals in the Mangaung metropolitan region of South Africa.

MATERIALS AND METHODS

Study design: A descriptive, cross-sectional study was conducted to investigate the health effects associated with the exposure of MRI staff to SMF and RF energy. The study was conducted in November 2018 in two South African public hospitals located within the Mangaung metropolitan municipality. Self-administered questionnaires were used to collect data about SMFs and RF energy exposure-related symptoms experienced by the study participants. Prior to the commencement of the study, ethical clearance was obtained from the Health Sciences Research Ethics Committee of the University of the Free State (reference number: UFSHSD2018/0438). Approval to conduct the study at the hospitals was obtained from the Free State Department of Health (reference number: FS201805 020) and the hospital managers.

Participants: The study population consisted of workers of different races who were employed full-time and were assigned to work in the MRI units. Control group was not included in this study as every personnel who work in the MRI department is exposed to MRI-related electromagnetic fields. Twenty-two full-time MRI staff members employed in Hospital A, and sixteen full-time MRI staff members employed in Hospital B participated in the study. Two maintenance engineers and two medical physicists were not able to indicate their respective resident hospitals, as they rotated between Hospitals A and B. Thus, forty-two participants from two hospitals, namely radiographers (15), student radiographers (5), medical physicists (2), cleaners (10), nurses (4), radiologists (4) and maintenance engineers (2) participated in the study. Both male and female participants aged between 20 and 61 years participated in the study.

Ethical considerations: The participants agreed to enrol voluntarily - no remuneration was offered to them, and they were not required to pay participation costs. All efforts were made to keep their personal information confidential and to ensure anonymity in their participation. Each participant spent approximately 15 minutes completing the questionnaire, and they were given the option to withdraw from the study if they felt uncomfortable at any point. An information letter containing the study details was issued to each participant. Informed written consent (signed by both particpants and the researchers) was obtained from the participants.

Pilot study: The self-administered questionnaires consisting of closed and open-ended questions were piloted amongst two community service nurses, two radiographers and two student medical physicists in both hospitals. The community service nurses and radiographers did not form part of the main study as they were employed by the department of health on a temporary contract.

Sample size determination: An NCSS 2019 was used to calculate the sample size. A sample size of 38 participants was required to achieve 95% confidence interval with marginal error of 5%. Due to small sample size obtained from sample size calculation, all 42 MRI staff were approached and consent was obtained.

Data collection: The self-administered questionnaires were used to obtain information about exposure symptoms amongst MRI workers. Transient health effects that have been investigated in previous studies (De Vocht *et al*., 2015; Schaap *et al*., 2016; Zanotti *et al*., 2016) and found to be associated with exposure to MRI fields were included. The questionnaire consisted of three sections, collecting biographical, work and health-related information. The biographical information of the participants gathered included their age, gender and level of education. The work-related items gathered information about their working experience, health and safety training, job titles, and utilisation of personal protective equipment. The third sectioncomprised questions that gathered data on exposure and health-related symptoms; all the questions were asked to obtain categorical data. All participants in this study were exposed to SMFs and RF energy from 1.5 and 3.0 T MRI scanners during their eight-hour work shifts.

At the time of data collection, November 2018, there were 30 healthcare workers who rotated in shifts in the MRI unit of hospital A and 20 in hospital B. Of the 50 workers from both hospitals assigned to work in the MRI facilities, 42 were selected to participate in the study using a simple random sampling technique and were divided according to their job titles within the MRI facilities. Once consent was attained, the questionnaires were handed to the participants to complete.

Data analysis: The data from the questionnaires were captured electronically by the researcher in Microsoft Excel (2016). Further analysis was done using SAS version 9.2 where descriptive statistics, namely frequencies and percentages were calculated for categorical data. The Fischer extract test also was performed to compare the mean values. A significance (α) of 0.05 was used.

RESULTS

The categorical data are presented in the form of frequencies and percentages and discussed as biographical descriptions, work-related and health-related information. The results on health-related information included a priori symptoms which were associated with exposure to SMF and RF energy in several studies.

Biographical descriptions: The biographical information on the participants is presented in terms of frequencies and percentages. Figures 1 and 2 indicate the distribution of the participants' highest qualifications and gender respectively. As can be seen in Figure 1 the highest qualification most frequently indicated was diploma (40.47%), followed by a grade 12/N4 (35.74%), degree (19.04%), honours (4.76%) and master's (4.76%) respectively. Of the 42 participants, 41 disclosed their age. The mean age of the participants was 37.4 years with a standard deviation of 11.3 and a range of 20 to 61 years of age.

The majority (57.14%) of the participants in the MRI units of the two hospitals were females, thus 42.86% were male.

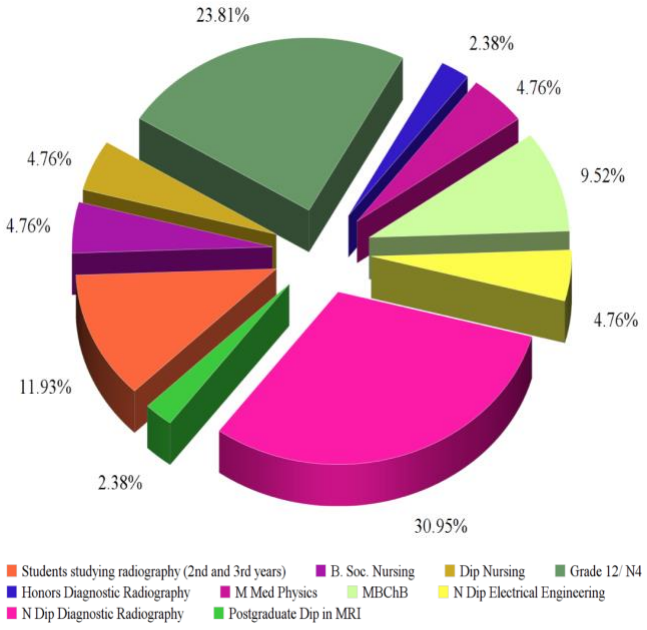

Figure 1:
The distribution of the highest qualifications of the participants

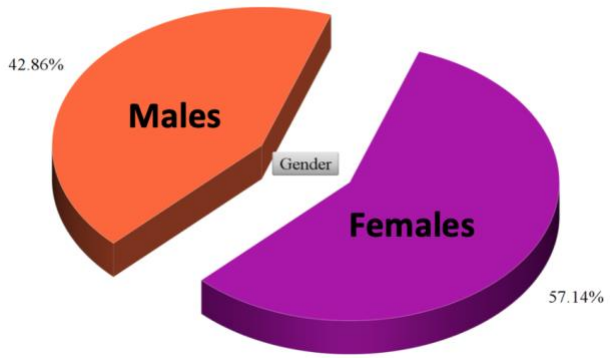

Figure 2:
The gender distribution of the participants

Work-related information

The results depicted in Figure 3 show the distribution of participants' job titles and years of experience. Of the 42 participants in this study, 57.89% (n=22) worked at hospital A, while 42.11% (n=16) worked at hospital B, and four participants did not indicate their working facility. The majority of participants were radiographers (35.71%), followed by cleaners (23.81%), student radiographers (11.9%), nurses (9.52%), radiologists (9.52%), medical physicists (4.76%) and maintenance engineers (4.76%). The average work experience of the participants was 12.8 years with a standard deviation of 11.7 and the work experience ranged from 7.2 months to 43 years. The nurses had an average work experience of 32 years (range: 20 to 43 years) in their respective hospitals, followed by radiographers (20.1 years, range: 3 to 35 years), medical physicists (11.5 years, range: 11 to 12 years), radiologists (3.8 years, range: 3 to 5 years), cleaners (6.2 years, range: 2 to 15 years), maintenance engineers (4.5 years, range: 0.6 to 12 years) and student radiographers (3 years, range 1 to 3 years).

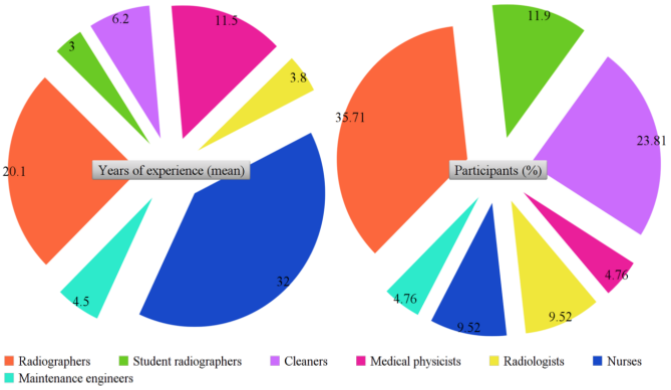

Figure 3
Number of participants (according to profession) and years of experience

With regard to training in the use of MRI scanners, 61.90% (n=26) of participants received training, while 38.10% (n=16) never received training. Furthermore, 64.29% (n=27) received training on the safety of MRI units and 35.71% (n=15) of participants did not receive such training. In the MRI facility, 61.90% (n=26) of MRI staff members wore personal protective equipment (PPE), while 38.10% (n=16) did not wear PPE at work. Of the 61.90% of workers who wore PPE, 30.77% (n=8) wore PPE when working with MRI scanners, whereas 65.38% (n=17) of participants did not wear PPE when working with MRI scanners. One participant (3.85%) did not respond to this question.

The results in Figure 4 show the utilization of PPE by the participants. Regarding the type of PPE used, the responses varied: 50% of the participants used a radiation badge or dosimeter, while thyroid shields and radiation aprons were used by 38.26% of the participants. Twenty-three percent of participants wore safety boots and aprons, while radiation safety glasses, lead gloves and ear muffs were used by 19.23%, 7.69% and 3.85% of participants respectively. The results also indicate that 3.85% of the participants made use of thermal protective gloves and face shield. Of the 26

participants who used PPE when working in the MRI units, 53.85% (n=14) indicated that they always wore PPE, 34.62% (n=9) indicated sometimes, and 11.54% indicated that they never wore such equipment. Some participants (15.38%) reported that their PPE was maintained once a year, 3.85% reported twice a year, 7.69% reported that their PPE was not maintained at all, 34.62% reported that they did not know whether the PPE was maintained or not, with 11.54% who reported monthly maintenance, and 26.92% could not specify how regularly equipment maintenance took place. Of the 42 participants, six (14.29%) reported that a PPE maintenance record was in place, 9.52% (n=4) indicated that there was no existing PPE maintenance records in place, while 59.52% (n=25) indicated that they did not know, and 16.67% (n=7) indicated wearing PPE as not applicable to their work.

With regard to medical examinations of MRI staff, 28.57% (n=12) of the participants underwent a medical examination a year before this study, 2.38% (n=1) had been examined one year and six months earlier, 11.9% (n=5) had not been examined for two years, 2.38% (n=1) had not been examined for three years, 2.38% (n=1) were examined six months earlier, and 35.71% (n=15) never underwent medical examinations. Some respondents, 7.14% (n=3) had undergone a medical examination only once since they were employed as MRI staff, 2.38% (n=1) underwent a medical examination once every year, while 7.14% (n=3) reported to have undergone medical examinations once every five years. Of the 42 respondents, 33.33% (n=14) received training on the health effects of exposure to SMFs and RF energy from MRI units, while 66.67% (n=28) never received training. Of the 33.33% (n=14) of participants who received training, 7.14% (n=1) received the training 15 years ago, 7.14% (n=1) received training 12 years ago, 7.14% (n=1) seven years ago, 14.29% (n=2) three years ago, 14.29% (n=2) two years ago, 14.29% (n=2) a year ago, and 21.43% (n=3) received training in January 2018. One participant (7.14 %) reported to have received training on continuous basis, while one respondent (7.14%) did not respond.

The participants selected a variety of responses to the question regarding control measures to minimise the harmful effects of SMFs and RF energy. Thirty-four participants (80.95%) indicated that control measures were in place to reduce the effects of SMFs and RF energy, while 16.67% (n=7) of participants reported that no control measures were in place. One participant (2.38%) was unsure whether any control measures were in place to minimise the effects of SMFs and RF energy. Of the 42 participants who provided information on the type of control measures in place, 82.35% indicated a faraday cage, 41.18% indicated education and training, 20.59% indicated rotation of workers, while 17.65% indicated limited exposure time, and 2.94% indicated the use of PPE

Health-related information: Table 1 below depicts the self-reported health effects that participants reported to have been diagnosed with while working in the MRI units.

Table 1 indicates the prevalence of health effects per job title. A statistical significant difference was observed when the prevalence of increased heart rate ($p< 0.0068$), metallic taste in the mouth ($p< 0.0001$) and vertigo ($p< 0.0080$) were compared among participants. Of the 42 participants, 97.62% (n=41) reported not to have experienced a warmth sensation on the skin while working with MRI scanners, leaving 2.38% (n=1) who reported to have experienced a warm sensation while working with the MRI scanners. All the respondents (n=42) reported that they did not experience any warm sensation after working with the MRI scanners. One participant (2.38%) was suffering from irritated eyes after working with MRI scanners on a weekly basis.

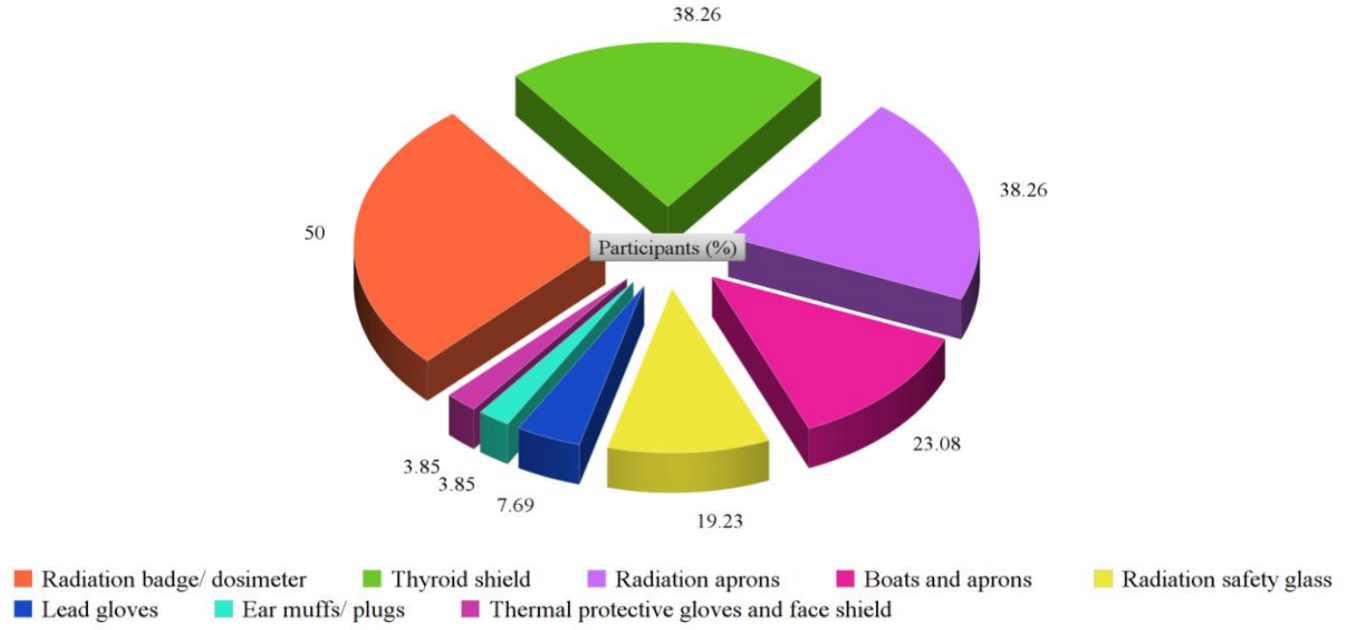

Figure 4:
Types of PPE used by MRI staff

Table 1:
Health-related effects of working in the MRI unit

Health effects	**Radiographers**	**Nurses**	**Cleaners**	**Maintenance engineers**	**Radiologists**	**Student radiographers**	**Medical physicists**	***P*- value**
Hypertension	0% (0)	0% (0)	10% (1)	0% (0)	0% (0)	0% (0)	0% (0)	$p< 0.6429$
Depression	20% (3)	25% (1)	10% (1)	0% (0)	0% (0)	20% (1)	0% (0)	$p< 0.9135$
Increased heart rate	6.67% (1)	0% (0)	50% (5)	0% (0)	0% (0)	20% (1)	0% (0)	$*p< 0.0068$
Metallic taste	6.67% (1)	0% (0)	100% (10)	0 % (0)	0% (0)	20% (1)	100% (2)	$*p< 0.0001$
Vertigo	20% (3)	50% (2)	100% (10)	100% (2)	0% (0)	40% (2)	50% (1)	$*p< 0.0080$
Nausea	0% (0)	50% (2)	30% (3)	50% (1)	0% (0)	20% (1)	50% (1)	$p< 0.0169$
Numbness of extremities	6.67% (1)	25% (1)	0% (0)	0% (0)	0% (0)	20% (1)	0% (0)	$p< 0.7304$
Hypothermia	13.33% (2)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)	$p< 1.0000$
Hyperthermia	0% (0)	0% (0)	10% (1)	0% (0)	0% (0)	0% (0)	0% (0)	$p< 0.6429$
Concentration difficulties	13.33% (2)	0% (0)	40% (4)	0% (0)	0% (0)	20% (1)	0% (0)	$p< 0.0906$
Blurred vision	25% (1)	0% (0)	40% (4)	0% (0)	0% (0)	40% (2)	0% (0)	$p< 0.1647$
Vitamin deficiencies	13.33% (2)	0% (0)	30% (3)	0% (0)	0% (0)	20% (1)	50% (1)	$p< 0.2209$
Warm sensation on the skin	0% (0)	0% (0)	0% (0)	50% (1)	0% (0)	0% (0)	0% (0)	$p< 0.1667$
Irritated eyes	6.67% (1)	0% (0)	10% (1)	0% (0)	0% (0)	0% (0)	0% (0)	$p< 0.9604$
Headache	26.67% (4)	0% (0)	30% (3)	50% (1)	0% (0)	20% (1)	0% (0)	$p< 0.5937$
Fatigue	20% (3)	25% (1)	0% (0)	0% (0)	0% (0)	20% (1)	0% (0)	$p< 0.7828$

*Fischer extract test

Another participant (2.38%) experienced irritated eyes while working with MRI scanners, with 4.76% (2) participants who did not indicate whether they experienced irritated eyes or not. Thirty-nine (92.86%) participants did not experience irritated eyes while working with MRI scanners. Only male participants (n=18) were required to indicate whether they experienced pain in their testes while and after working with the MRI scanner. All the male (n=18) participants indicated that they did not experience pain in their testes while and after working with MRI scanners.

Nine (21.43%) participants indicated that they had experienced a headache while working with MRI scanners, whereas 76.19% did not have similar experiences. One participant (2.38%) could not specify whether he/she experienced a headache while working with MRI scanners. Of 42 participants, 15 (35.71%) experienced a headache after working with MRI scanners, one participant (6.67%) reported to experience headaches on an hourly basis, 6.67% (n=1) on a daily basis, 46.67% (n=7) on a weekly basis, and 40% (n=6) reported to have experienced headaches on a monthly basis. One participant (6.67%) could not indicate how frequently he/she experienced headaches. Twenty-six (61.90%) did not suffer from a headache after working with the MRI scanners. With regard to fatigue, 11.9% (n=5) experienced fatigue while working with the MRI scanners, 85.71% (n=36) did not experience fatigue while working with MRI scanners, while one (2.38%) participant could not specify whether he/she experienced fatigue or not. Fifteen (35.71%) participants suffered from fatigue after working with MRI scanners, leaving 59.2% who did not suffer from fatigue after having worked with the scanners, while two (4.76%) participants did not indicate whether they experienced fatigue or not. Of the 15 participants who suffered from fatigue after working with MRI scanners, 40% experienced fatigue daily, 26.67% experienced fatigue on a weekly basis and 13.33% experienced fatigue on a monthly basis. Twenty percent of the participants did not indicate how often they experienced fatigue.

Two participants (4.76%) reported to experience insomnia on a weekly basis since being on the MRI staff. Thirty-six (85.71%) participants reported not experiencing insomnia, and four (9.52%) participants could not specify whether they experienced insomnia or not. Five (20.83%) of 24 female participants reported to have worked with MRI scanners while they were pregnant and 79.17% (n=19) never worked with MRI scanners while pregnant. Of 20.83% (n=5) female participants, 80% (n=4) worked with MRI scanners during the first trimester while pregnant, and all five (100%) of them reported to have worked with MRI scanners during the second and third trimesters. Of the 42 participants, 30.95% (n=13) had been diagnosed with hypertension since working with MRI units. Five (11.90%) participants reported hypotension, while 2.38% (n=1) had been diagnosed with cataracts. Of 42 participants, 16.67% (n=7) had been diagnosed with depression, and 16.67% (n=7) reported to have an increased heart rate since working in MRI units.

Twenty-six percent of participants experienced a metallic taste in their mouths and 40.48% suffered from vertigo while working in the MRI units. Nine (21.43%) experienced nausea while working in the MRI units, while 7.14% had numbness in their extremities. No spontaneous abortion was reported amongst female participants, however, 4.76% (n=2) of the participants had hypothermia and only one participant experienced hyperthermia while working in the MRI units. Concentration difficulties were reported by 19.05% (n=8) of participants, but only one (2.38%) participant reported to have been diagnosed with hypertension since working in MRI units. Twenty-one percent of the participants suffered from blurred vision while working in the MRI units, and 19.05% were diagnosed with vitamin deficiencies. Of the 9.52% (n=4) participants who reported to have used a welding machine since working as an MRI staff member, 50% (n=2) used the welding machine 12 months ago and the other two (50%) reported to have used the machine three months earlier. One (2.38%) of 42 participants had a breast prosthesis, while 26.19% (n=11) reported to have tattoos on their bodies. Among the 42 participants, 26.19% (n=11) were smokers.

DISCUSSION

The information obtained from the questionnaires indicated that the majority of study participants - about 40.48% - reported vertigo, a metallic taste (26.19%), nausea and blurred vision (21.43%), as well as vitamin deficiency and concentration difficulties (19.05%). Exposure of HCWs to SMFs from MRI units causes the development of transient exposure-related effects (De Vocht *et al*., 2006). According to Chakeres and De Vocht (2005), nurses and radiologists working with 1.5, 3.0 and 7.0 T MRI units are exposed to high levels of SMFs and exposure-related symptoms such as vertigo, nausea,a metallic taste and illusions of movement are often reported. Vertigo is the most pronounced symptom in relation to MRI and was reported by 20 (8.6%) participants who were exposed to SMFs and time-varying magnetic fields (Schaap *et al*., 2016). This is consistent with the results (20 participants) of the present study, with a prevalence of 20% amongst radiographers, 50% nurses, 100% cleaners, 100% maintenance engineers, 40% student radiographers and 50% of medical physicists. In 2014, Schaap et al. reported vertigo and a metallic taste in the mouth as the main exposure symptoms driven by exposure-response association amongst workers working with 1.5 and 3.0 T MRI scanners. In the said study, vertigo and a metallic taste in the mouth were reported to be absent during non-MRI shifts and were observed to be transient with a duration of less than 15 minutes. In a review study by Franco *et al*. (2008), short-term exposure to SMFs was reported to induce vertigo, nausea and a metallic taste in the mouth amongst workers during head or body movement in the MRI units with SMFs up to 8 T. Changes in the blood pressure, decreased working memory and an increased heart rate were reported amongst workers exposed to SMFs and time-varying magnetic fields from 1.5 and 3.0 T MRI scanners (Franco *et al*., 2008). The a priori exposure-related effects reported in this study are consistent with the results obtained in other studies (Schaap *et al*., 2014; Schaap *et al*., 2016; Franco *et al*., 2008) that investigated the induced effects with exposure-response amongst MRI staff.

Only 2.38% of the participants reported hypertension as one of the SMFs exposure priori related health effect. Bongers *et al*. (2018) studied long-term exposure to SMFs and the development of hypertension amongst MRI staff with long-term experience working with MRI units. In the said study, it was found that the development of hypertension was not associated with confounders, that is, smoking and BMI, however, it was associated with cumulative SMF exposure acquired in not less than 10 years. In this study, the reported hypertension was found with the cleaner participants, who, according to this study, reported to have more than 10 years' experience working in MRI units. The results also indicated hypothermia amongst 4.76% (n=2) of the study participants. Extremely low temperatures are associated with the development of hypothermia and in the MRI facilities, it is associated with exposure to helium (Westbrook *et al*., 2005). The prevalence of hypothermia reported in this study was amongst radiographers (13.33%). The MRI radiographers constantly were exposed to low temperatures (17 to 21o C) in the MRI room as liquid nitrogen is used to cool off the scanners and heat experienced by patients during the examination. Two (4.76%) participants reported to experience insomnia, which lasted for a week. According to Schaap *et al*. (2014), insomnia and a headache together are health effects caused by short-term exposure to SMF, which in most cases, has been suggested as the health effects that outlast the exposure by night, following the exposure scenario from 1.5 and 3.0 T MRI scanners (De Vocht *et al*., 2015; Wilen and De Vocht, 2011).

The exposure effects, such as thermal implications ofless blood supplied to tissues related to RF energy were not reported in this study. However, a relatively small number of participants reported cataracts, increased body temperature, which could induce hyperthermia, and depression. The increase in body temperature is associated with exposure to RF energy (Shellock, 2000). If a larger area of the body is exposed to RF induced heat, the localised body tissues will have an increased temperature, however, individuals' underlying health conditions play a vital role in the thermoregulatory responses. According to Shellock (2000), heart rate, oxygen saturation, blood pressure, respiratory rate and cutaneous blood flow are important physiological variables which determine the responses to thermal load. No literature was found to validate exposure of MRI staff to RF energy and development of cataracts and depression. However, Shellock and Schaltz (1992) indicated that exposure of the cornea to induced temperature as a result of RF energy amongst patients undergoing MRI examinations can elevate the corneal temperature by 1.8 to 3.3o C with the highest temperature of 34.4o C. Although cataracts have been reported in experimental rats after exposure to RF energy, the data cannot be extrapolated to humans, as physiological and anatomical characters of cornea between humans and experimental animals are significantly different (Shellock, 2000). The reported cataracts in this study could be associated with socio-environmental factors, however, further studies are needed to validate exposure of MRI staff to RF energy and the development of cataracts. The reported depression also could have resulted from socio-environmental factors, as there is relatively no literature that validates a relationship between exposure to MRI-related electromagnetic fields and depression; however, this could be a finding that needs to be investigated in future studies.

Although this study did not include a control population and was based on self-reporting of a priori related and unrelated health effects, the results indicated that the prevalence of reported health effects is associated with exposure to SMFs and RF energy emitted by 1.5 and 3.0 T MRI scanners. The results are also consistent with priori related and priori unrelated health effects found in other studies and this validates the scientific arguments on exposure-related health effects amongst MRI staff. This study necessitates the development of pertinent health and safety models that will reduce the reported health effects in 1.5 and 3.0 T MRI units. The use of PPE is primarily associated with the job that the HCWs perform and in this study 38.10% (n=16) reported not to wear PPE, while 65.38% did not wear PPE when working with MRI units. The European Council's Directive 40 (2004), indicates that it is necessary for all employees exposed to MRI-related electromagnetic fields to receive information on control measures (including the use of

PPE), and appropriate health surveillance to prevent adverse effects of exposure. The following health effects, namely depression, vitamin deficiency and cataracts were reported during data collection, however, these findings could not be validated by previous studies. These health effects need to be further investigated on a large study population and should include a control group, as this could be major findings in as far as occupational exposure to MRI-related fields is concerned. Future studies should also investigate the association between the reported health effects and patterns of exposure amongst HCWs. A significant need exists to associate a specific field intensity with duration and frequency of exposure together with the health outcomes. Although the study population was relatively small due to a shortage of MRI facilities in the Mangaung metropolitan region, this study confirms that exposure to SMFs and RF energy from 1.5 and 3.0 T MRI scanner is associated with the reported health outcomes.

Acknowledgement

The authors wish to acknowledge Ms. Raheemah Panker for her assistance during data collection

REFERENCES

Bongers, S., Slottje, P., Kromhout, H (2018): Development of hypertension after long-term exposure to static magnetic fields among workers from a magnetic resonance imaging device manufacturing facility. Environmental Research, 164, 565–573.

Chakeres, D.W. & De Vocht, F (2005): Static magnetic field effects on human subjects related to magnetic resonance imaging systems. Progress in Biophysics and Molecular Biology, 87(2–3), 255–65.

De Vocht, F., Batistatou, E., Mölter, A., Kromhout, H., Schaap, K., Van Tongeren, M., Crozier, S., Gowl, P. & Keevil, S (2015): Transient health symptoms of MRI staff working with 1.5 and 3.0 Tesla scanners in the UK. European Radiology, 25 (9), 2718–2726.

De Vocht, F., Batistatou, E., Molter, A., Kromhout, H., Schaap, K. & Van Tongeren, M (2015): Transient health symptoms of MRI staff working with 1.5 and 3.0 T scanners in the UK. European Journal of Radiology, 25, 2718–2726.

De Vocht, F., van Drooge, H. & Engels, H (2006): Exposure, health complaints and cognitive performance among employees of an MRI scanners manufacturing plant. Journal of Magnetic Resonance Imaging, 23 (2), 197–204.

European Council (2004): Directive 2004/40/EC of the European Parliament and of the Council of 29 April 2004 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (eighteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC). Official Journal of the European Union, 159, 1–26.

Franco, G., Perduri, R. & Murolo, A (2008): Health effects of occupational exposure to static magnetic fields used in magnetic resonance imaging: A review. La Medicina del lavoro, 99 (1), 16-28.

Gorlin, A., Hoxworth, J.M., Pavlicek, W., Thunber,g C.A. & Seamans, D (2015): Acute vertigo in an anesthesia provider during exposure to a 3T MRI scanner. Med Devices (Auckl), 8; 161–166. doi: 10.2147/MDER.S76474.

Karpowicz, J. & Gryz, K (2006): Health Risk Assessment of Occupational Exposure to a Magnetic Field from Magnetic Resonance Imaging Devices. International Journal of Occupational Safety and Ergonomics (JOSE), 12 (2), 155–166.

Karpowicz, J., Hietanen, M. & Gryz, K (2007): Occupational risk from static magnetic fields of MRI scanners. Environmentalist, 27, 533–538. DOI 10.1007/s10669-007-9064-1.

SCENIHR (2015): Opinion on potential health effects of exposure to electromagnetic fields. Bioelectromagnetics, 36, 480– 4. doi:10.1002/bem.21930

Schaap, K., Christopher-De Vries, Y., Crozier, S., De Vocht, F. & Kromhout, H (2014): Exposure to Static and Time-Varying Magnetic Fields from Working in the Static Magnetic Stray Fields of MRI Scanners: A Comprehensive Survey in the Netherlands. Annals of Occupational Hygiene, 58 (9), 1094–1110. https://doi.org/10.1093/annhyg/meu057

Schaap, K., Christopher-De Vries, Y., Mason, C.K., De Vocht, F., Portengen, L, & Kromhout, H (2014): 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. Occupational & Environmental Medicine, 71, 423-429.

Schaap, K., Portengen, L. & Kromhout, H (2016): Exposure to MRI-related magnetic fields and vertigo in MRI workers. Occup. Environ. Med. 73, 161–166.

Shellock, F.G. & Schaltz, C.J (1992): Increased corneal temperature caused by MR imaging of the eye with a dedicated local coil. Radiology, 192 (185), 697-699.

Shellock, F.G (2000): Radiofrequency energy-induced heating during MR procedures. Journal of Magnetic Resonance Imaging, 12, 30-36.

Vijayalaxmi, Fatahi M. & Speck, O (2015): Magnetic resonance imaging (MRI): A review of genetic damage investigations. Mutat Res Rev Mutat Res, 764, 51–63. doi:10.1016/j.mrrev.2015.02.002.

Westbrook, C., Kaut, Roth C. & Taibot, C (2005): Magnetic Resonance Imaging (MRI) in practice (3rd edition). Blackwell Science Ltd. Blackwell Publishing Ltd. ISBN-13:978-14051-2787-5.

Wilén, J. & De Vocht, F (2011): Health complaints among nurses working near MRI scanners: A descriptive pilot study. European Journal of Radiology, 80, 510–513.

Zanotti, G., Ligabue, G., Korpinen, L. & Gobba, F (2016): Subjective symptoms in magnetic resonance imaging operators: Prevalence, short-term evolution and possible related factors. Med. Lav. 107, 263–270