Original Article

The Effect of Occupational Exposure to Magnetic Fields on Sleep Quality among Workers in a Combined Cycle Power Plant: A Cross-sectional Study

Somayeh Rahimimoghadam[1,2], Mohammad Nourmohammadi[3], Mahdi Jalali[1,2], Mojtaba Emkani[4], Sanaz Rahimabadi[5], Danial Soleymani-Ghoozhdi[6]

[1]Workplace Health Research Center, Neyshabur University of Medical Sciences, Neyshabur, Iran, [2]Department of Occupational Health Engineering, Neyshabur University of Medical Sciences, Neyshabur, Iran, [3]Department of Occupational Health Engineering, Mashhad University of Medical Sciences, Mashhad, Iran, [4]Department of Occupational Health, Faculty of Health, Social Determinants of Health Research Center, Gonabad University of Medical Sciences, Gonabad, Iran, [5]Student Research Committee, Neyshabur University of Medical Sciences, Neyshabur, Iran, [6]Social Determinants of Health Research Center, Gonabad University of Medical Sciences, Gonabad, Iran

Abstract

Aim: Occupational exposure to electromagnetic fields has attracted attention due to potential health effects. This cross-sectional study investigates the impact of static magnetic fields (SMFs) exposure on the sleep quality of workers in a combined cycle power plant. **Methods:** A total of 185 workers participated in this study. Magnetic flux density was measured using the calibrated HI-3550 magnetic field personal monitor. The Pittsburgh Sleep Quality Index Questionnaire was employed to assess the sleep quality. Data analysis was conducted using the SPSS version 19 software, employing ANOVA, logistic regression, and Chi-square statistical tests. **Results:** The participants had an average age of 42.16 ± 5.03 years and an average work experience of 15.29 ± 3.38 years. The average magnetic flux density of the SMF, measured at 22.65 ± 2.23 m. The average sleep quality score was 7.25 out of 21. Among the workers, 46.48% reported poor sleep quality, while 53.52% reported good sleep quality. In addition, workers exposed to higher magnetic field levels were more likely to have poor sleep quality compared to those with lower exposure ($P < 0.05$). The analysis of various factors affecting sleep quality indicated significant associations with marital status, age, and exposure to magnetic fields. Results show with the increase of each unit of age, the chance of having bad sleep quality increased by 0.32 units (95% confidence interval [CI]: 0.11–0.56). Furthermore, with the increase of each unit of magnetic field exposure, the chance of having bad sleep quality increased by 0.16 units (95% CI: 0.09–0.34). **Conclusion:** The findings suggest that even exposure to magnetic fields below the permissible limits may contribute to poor sleep quality. As magnetic field exposure increases, the likelihood of experiencing poor sleep quality also rises.

Keywords: Occupational exposure, Pittsburgh Sleep Quality Index, power plant, sleep quality, static magnetic field

Introduction

The process of industrialization has significantly increased the amount of electrical equipment in workplaces, leading to a broader range of workers being exposed to both general and occupational electromagnetic fields (EMFs).[1] EMFs, including static, low-frequency, and radiofrequency (RF) magnetic fields, have the potential to cause adverse biological effects on human cells and tissues.[2-5]

Magnetic fields are generated in two forms: alternating fields (varying with frequency) and static fields, arising from both natural and artificial sources.[5] Alternating magnetic fields vary in intensity and direction over time, with the frequency of this oscillation measured in hertz (Hz). The common sources include electrical power systems (e.g. power lines and household appliances), RF devices, and industrial

Access this article online

Quick Response Code:

Website: https://journals.lww.com/IJEH

DOI: 10.4103/ijehe.ijehe_49_24

Address for correspondence: Dr. Danial Soleymani-Ghoozhdi, Social Determinants of Health Research Center, Gonabad University of Medical Sciences, Gonabad, Iran.
E-mail: daniel.soleymani74@gmail.com

How to cite this article: Rahimimoghadam S, Nourmohammadi M, Jalali M, Emkani M, Rahimabadi S, Soleymani-Ghoozhdi D. The effect of occupational exposure to magnetic fields on sleep quality among workers in a combined cycle power plant: A cross-sectional study. Int J Env Health Eng 2025;14:4.

Received: 05-10-2024, **Revised:** 28-01-2025,
Accepted: 29-01-2025, **Published:** 31-03-2025

equipment. The behavior of these fields depends heavily on their frequency. For example, low-frequency EMFs, like those from power lines (50–60 Hz), are relatively weak but are constantly present in the daily life. High-frequency EMFs, like those from radio waves or microwaves, can penetrate tissues and may interact with biological systems. In contrast, static magnetic fields (SMFs) are constant and have a frequency of 0 Hz. They are created by permanent magnets or coils that carry direct currents (DCs).[6] The Earth's magnetic field is a natural example of a SMFs. Strong DC (static) magnetic fields are generated by medical diagnostic devices such as magnetic resonance imaging (MRI) systems, as well as by nuclear fusion experimental devices, metallurgical processes, power plants, and superconducting magnets.[1,4,7-12] The American Conference of Governmental Industrial Hygienists (ACGIHs) recommends threshold limit values of 60 mT for whole body exposure and 600 mT for limb exposure to SMFs during an 8-h workday. In addition, the maximum threshold limits are set at 2 T for the whole body and 20 T for the limbs in the extreme exposure conditions.[1,13,14] Furthermore, the Iran National Standards Organization has established an occupational exposure limit (OEL) of 200 mT for magnetic fields with frequencies <1 Hz. This limit serves as a guideline to ensure the safety of workers exposed to such fields for extended periods.[15]

The International Agency for Research on Cancer (IARC) classifies extremely low-frequency magnetic fields (ELF-MFs) as Group 2B, which means they are possibly carcinogenic to humans based on limited evidence.[3] In contrast, SMFs are classified as Group 3, indicating that they are not classifiable as to their carcinogenicity in humans due to insufficient evidence. This distinction reflects the current understanding of the potential health risks associated with these different types of magnetic fields.[16] Furthermore, numerous studies have demonstrated that exposure to such fields can disrupt neuroendocrine activity and lead to a range of health issues, including genotoxic effects, stress, depression, fatigue, headaches, stomach aches, learning difficulties, anxiety, and sleep disturbances.[3,10,17-21] Furthermore, some researchers have shown that exposure to SMFs associated with MRI usage is correlated with unpleasant symptoms, including vertigo, nausea, unusual drowsiness, severe headaches, sleep disorders, and concentration difficulties among staff.[22-25]

Many studies have demonstrated an association between occupational and nonoccupational exposure to EMF and the risk of certain types of cancer, including leukemia, brain tumors, and breast cancer; however, not all studies confirm this association.[26-28] In addition, numerous studies have reported noncancerous effects resulting from exposure to magnetic fields. A study conducted by Li *et al*. showed that high exposure to EMF can lead to sleep disorders in women.[29] In another study, Yousefi and Nasiri[30] reported that workers at high-voltage substations in Tehran exhibited the symptoms of depression, paranoia, obsessive-compulsive disorder, interpersonal sensitivity, anxiety, aggression, phobias, and psychosis. Furthermore, Sharifi Fard *et al*.[31] demonstrated that long-term exposure to magnetic fields, even when below the limits recommended by the International Commission on Nonionizing Radiation Protection, can exacerbate psychiatric disorders, including sleep disturbances.

Among various job categories, power plant workers are exposed to elevated levels of EMF due to the presence of equipment such as generators, turbines, internal combustion engines, and cooling towers.[8,12] This heightened exposure increases the potential risk of health complications for workers. Workers who experience frequent and prolonged exposure to these fields appear to be at a higher risk.[1] Therefore, implementing strategies to mitigate EMF exposure is essential for protecting worker health. In recent years, several studies have explored the effects of magnetic field exposure on health, including sleep quality.[1,2,4,8,10,18,20] However, only a limited number of these studies have specifically focused on power plant workers, despite their frequent exposure to magnetic fields in the workplace.[12,32] Based on this information, the present study aims to investigate the effect of occupational exposure to SMFs on sleep quality among workers in a combined cycle power plant.

Materials and Methods

Study population

This descriptive and analytical cross-sectional study was conducted in a Combined Cycle Power Plant in Iran. The study population consisted of 185 workers exposed to the SMF. Demographic information including age, work experience, marital status, and smoking, was recorded by a checklist. All of the study subjects were male and worked at the same company (a power plant). They were nearly identical in terms of working hours, income, and socio-economic status.

The inclusion criteria for the study required participants to have a minimum of 1 year of full-time work experience in a power plant, refrain from heavy exercise, and avoid the use of stimulants such as coffee or drugs. In addition, participants were not permitted to hold a second job that could significantly influence the results. The exclusion criteria included the use of antioxidant supplements (e.g. Vitamins E and C, selenium, and beta-carotene) and a lack of willingness to participate in the study.

Participants were provided with a comprehensive explanation of the study's objectives and methodology before its commencement, and they subsequently signed a consent form. This work was approved by the Ethics Committee from the Neyshabur University of Medical Sciences, under the process number IR.NUMS.REC.1400.041.

Measurement of magnetic field exposure

The magnetic flux density (mT) was measured using the calibrated HI-3550 magnetic field personal monitor (Holaday, USA) across the three axes (X, Y, and Z). According to the National Institute for Occupational Safety and Health guidelines, magnetic field measurements were taken at three regions (head, abdomen, and legs) in all areas where workers were active.[33]

Sleep quality assessment

The Pittsburgh Sleep Quality Index (PSQI) was employed to evaluate the sleep quality.[34,35] The validity of the PSQI in Persian language has been evaluated and the interval validity of the questionnaire (Cronbach's alpha coefficient) was 0.83 in previous studies.[36] This questionnaire consists of 19 questions organized into seven components: (1) subjective sleep quality, (2) sleep latency, (3) sleep duration, (4) sleep efficiency, (5) sleep disturbances, (6) use of sleep medication, and (7) daytime dysfunction. Each component is scored on a Likert scale ranging from 0 to 3. The sum of the seven components forms a total score that ranges from 0 to 21. Any score between 0 and 6 is considered as good sleep quality, between 6 and 10 as rather low sleep quality, and between 11 and 21 as poor sleep quality.[36,37] The PSQI has been translated into several languages, with the Persian (Farsi) version being used in this study. Various validation efforts have been conducted for different groups in Iran.[38-41]

Statistical analysis

Statistical Data analysis was conducted using the IBM SPSS software version 19 made by SPSS Inc. in USA. The normality of the data was assessed using the Kolmogorov–Smirnov test, which confirmed that the data followed a normal distribution. To describe the data, centrality and dispersion indices, such as mean and standard deviation (SD) for quantitative variables, and frequency and percentage indices for qualitative variables, were used. Consequently, Chi-square tests, one-way ANOVA, and regression analysis were employed for the data analysis. A significance level of <0.05 was used

Results

The study population consisted of 185 men with a mean age ± SD of 42.16 ± 5.03 years. The average work experience of the workers was 15.29 ± 3.38 years. Among the workers, 86.4% were married, 18.37% were smokers, and 67.5% expressed satisfaction with their work. The results of measuring the magnetic field (mean ± SD) in the head, abdomen, and legs of workers are presented in Table 1. Result of A one-sample *t*-test showed that the average magnetic flux density of the SMF, measured at 22.65 ± 2.23 mT, was significantly below the TLVs of 60 mT ($P = 0.035$).[13] The results of the one-way ANOVA test revealed a significant difference in magnetic field exposure across the different body area ($P < 0.001$), indicating that the exposure levels in the legs area were higher than those in the head-and-abdomen regions.

Table 1: Average magnetic field measurements in three body regions (milli Tesla)

Body area	Mean±SD	Maximum	Minimum
Head	21.91±2.58	28.45	16.45
Abdomen	20.79±1.78	26.22	14.12
Legs	25.30±2.35	32.65	13.17

SD: Standard deviation

Before completing the sleep quality questionnaire, workers self-reported their sleep quality over the past month as follows: 37.11% rated their sleep quality as very good, 23.61% as almost good, 28.59% as almost bad, and 10.69% as very bad. However, after completing the PSQI questionnaire and calculating the total sleep quality score, the average score was 7.25 out of 21. Based on the PSQI scoring, 46.48% of workers were categorized as having unfavorable sleep quality, while 53.52% were categorized as having favorable sleep quality. In addition, 30.18% of participants reported using sleeping pills to assist with falling asleep. The components of the sleep quality index are detailed in Table 2.

The analysis of various factors affecting sleep quality indicated significant associations with marital status, age, and exposure to magnetic fields [Table 3]. Since the dependent variable, sleep quality, is a binary qualitative variable (categorized as desirable or undesirable), logistic regression was employed to identify the influencing factors and assess the impact of each independent variable (e.g. age, gender, and marital status) on sleep quality. Logistic regression results showed that workers whose were single had 1.87 times (95% confidence interval [CI]: 1.07–9.40) more chance of adverse sleep quality. Furthermore, with the increase of each unit of age, the chance of having bad sleep quality increased by 0.32 units (95% CI: 0.11–0.56). Furthermore, with the increase of each unit of magnetic field exposure, the chance of having bad sleep quality increased by 0.16 units (95% CI: 0.09–0.34).

Discussion

The impact of the SMF on sleep quality at a Combined Cycle Power Plant was assessed in a cross-sectional study. Magnetic field levels in the inspected areas were below the TLVs set by ACGIH. This result is consistent with the findings of Suri *et al*. study,[8] who reported that ELF-MF levels at all measurement stations in the selected power plant was below the OEL recommended by the Iranian Occupational Exposure Review and Adjustment Limit, as well as the TLVs (0.2–60 mT). Furthermore, Alizadeh *et al*. demonstrated that the magnetic field intensity at employees' locations in the electricity industry was below OEL.[4] In addition, Bagheri Hosseinabadi *et al*., in separate studies, demonstrated that occupational exposure to ELF-EMFs in thermal power plants was below the OEL.[3,12]

The results indicated that even exposure below these limits may negatively affect sleep quality, as workers with higher levels of exposure demonstrated poorer sleep quality than those with lower exposure ($P < 0.05$). Graham and Cook similarly reported a direct association between magnetic field exposure and sleep disturbances, noting a linear relationship between magnetic field intensity and the frequency of sleep-related issues.[42] In their study, Barsam *et al*. examined the effects of

Table 2: The frequency of sleep problems in workers exposed to magnetic fields

Sleep-related problems	It has not occurred in the past month, *n* (%)	Less than once per week, *n* (%)	Once or twice per week, *n* (%)	Three or more times per week, *n* (%)
It takes more than 30 min for the person to fall asleep	99 (53.51)	43 (23.24)	29 (15.68)	14 (7.57)
Waking up in the middle of the night or very early in the morning	103 (55.68)	35 (18.92)	40 (21.62)	7 (3.78)
A compulsion to get up and go to the bathroom	122 (65.94)	19 (10.27)	28 (15.14)	16 (8.65)
An inability to breathe easily	136 (73.51)	29 (15.68)	10 (5.41)	10 (5.41)
Coughing or loudly snoring	112 (60.54)	31 (16.76)	27 (14.59)	15 (8.11)
Feeling very cold	139 (75.14)	15 (8.11)	18 (9.73)	13 (7.03)
Feeling of extreme heat	160 (86.49)	9 (4.86)	13 (7.03)	3 (1.62)
Having a nightmare	129 (69.73)	33 (17.84)	15 (8.11)	8 (4.32)
Having pain	128 (69.19)	14 (7.57)	17 (9.19)	26 (14.05)
Other factors (such as stress, etc.)	145 (78.38)	14 (7.57)	19 (10.27)	7 (3.78)

Table 3: Variables predicting sleep quality among the workers

	Good sleep quality, *n* (%)	Poor sleep quality, *n* (%)	Total frequency, *n* (%)	*P*
Education level				
Under diploma	10 (5.4)	15 (8.1)	25 (13.5)	0.56
Diploma and postgraduate diploma	45 (24.3)	68 (36.75)	113 (61)	
Bachelor's degree and higher	22 (11.8)	25 (13.5)	47 (25.40)	
Job satisfaction				
Yes	24 (12.97)	23 (13.5)	47 (25.40)	0.26
No	24 (12.97)	36 (19.45)	60 (32.43)	
Almost	28 (15.13)	50 (27)	78 (42.16)	
Smoking				
Yes	11 (5.94)	23 (13.5)	34 (18.37)	0.37
No	52 (28.1)	99 (53.5)	151 (81.6)	
Marital status				
Single	5 (2.7)	20 (10.81)	25 (13.5)	0.03*
Married	94 (50.81)	69 (37.29)	160 (86.48)	
Quantitative variables				
Age	39.64±4.44	44.69±5.63		0.04*
Height	173±6.41	174±6.60		0.41
Weight	80±5.82	84±4.19		0.37
BMI	25.44±3.18	26.83±4.40		0.88
Work experience	14.37±2.99	16.22±3.77		0.31
Exposure to magnetic field	19.62±2.26	25.69±2.20		0.04*

*Chi-square tests. BMI: Body mass index

exposure to extremely low-frequency EMFs on sleep quality among workers in high-voltage substations. The findings revealed that overall sleep quality was poor in both the case and control groups; however, a higher proportion of individuals in the case group experienced poor sleep quality compared to those in the control group. Notably, the difference in sleep quality between the two groups was not statistically significant. In addition, this study indicated a direct correlation between occupational exposure to average magnetic flux density and the total score on the PSQI.[11] In another study, Monazzam *et al*. found that 61% of employees exposed to ELF-MFs in a petrochemical complex experienced sleep disorders, compared to only 4.5% in the control group.[10] Bagheri Hosseinabadi *et al*. also found that chronic exposure to magnetic fields negatively impacted the sleep quality in power plant workers. Their results indicated that workers in the exposed group had significantly worse sleep quality compared to those in the unexposed group. In addition, while increased exposure to ELF-EMF was associated with reduced sleep quality, no clear linear relationship between the level of exposure and sleep quality was established.[12] Similarly, Liu *et al*. conducted a cross-sectional study in an electric power plant and found that long-term occupational exposure, as well as daily exposure to ELF-EMF, significantly reduced sleep quality.[32] In contrast, Ayoobi *et al*. investigated the effects of exposure to ELF-MFs at three specific frequencies (10, 14, and 18 Hz) on the skull area (C3, Cz, and C4 regions) of healthy young adults. Despite 3 min of exposure to a magnetic field strength of 200 µ Tesla, their findings indicated no significant change in sleepiness scores.[43]

A significant strength of this study lies in its targeted focus on electromagnetic radiation exposure among power plant workers, rather than the general population. This specificity ensures more accurate exposure measurements in a controlled occupational setting, reducing the variability associated with diverse exposure sources in broader populations. Unlike studies such as Ayoobi *et al*.,[43] which involved brief and localized exposure under experimental conditions, our study evaluated real-world, long-term whole-body exposure levels in an occupational setting, thereby providing more applicable insights into workplace health risks. Our study does have certain limitations. First, as a cross-sectional study, it is susceptible to recall bias, which may affect the accuracy of participants' reports regarding exposures and outcomes. In addition, the reliance on subjective sleep parameters, such as self-reported sleep quality and duration, could be considered a limitation, as these measures may not fully capture objective aspects of sleep disturbances. However, several studies have found that self-reported sleep data can be comparable to physiological measurements to some degree.[44] In addition, research has indicated that a single question regarding sleep status can serve as a valid indicator of overall sleep quality.[45] The alteration of circadian rhythms is a primary factor contributing to sleep disorders among shift workers. However, Liu *et al*.[32] found that the association between EMF exposure and poor sleep quality remained consistent when analyzing data specifically from shift workers. The outcomes for this group were comparable to those observed in the entire sample, suggesting that the impact of EMF exposure on sleep quality does not differ significantly based on shift work status.

In summary, this study contributes to the existing literature by providing a comprehensive assessment of magnetic field exposure among power plant workers and its impact on sleep quality. The results not only confirm previous observations but also highlight the significance of occupational health considerations in managing ELF-EMF exposure levels. To enhance the validity and generalizability of the findings to larger populations and workers exposed to magnetic fields, future research should consider conducting a large-scale study that includes a control group or a longitudinal cohort (longitudinal) study.

Conclusion

Our study examined the relationship between magnetic field exposure and sleep quality among 185 employees at a Combined Cycle Power Plant. The average intensity of the SMF measured was significantly below the TLVs. The results indicated that exposure levels in the leg region were higher than those in the head-and-abdomen regions. Among the participants, 46.48% reported unfavorable sleep quality, while 53.52% experienced favorable sleep quality. In addition, 30.18% of the workers used sleeping pills to aid in falling asleep. Overall, workers with poor sleep quality were exposed to higher levels of the magnetic field compared to those with good sleep quality ($P < 0.05$). The results of this study suggest that exposure to magnetic fields may contribute to sleep disturbances and disorders.

Acknowledgments

The authors would like to thank all the workers who participated in this study.

Financial support and sponsorship

This project was approved and financially supported by Neyshabur University of Medical Sciences (No. 132).

Ethics code

This work was approved by the Ethics Committee from the Neyshabur University of Medical Sciences, under the process number IR.NUMS.REC.1400.041.

Conflicts of interest

There are no conflicts of interest.

Authors' contributions

Somayeh Rahimimoghadam: Investigation, writing – review and editing, formal analysis; Mohamad Normohamadi: Investigation, sampling; Mehdi Jalali: Investigation, writing – review and editing; Mojtaba Emkani: Investigation, writing – review and editing. Sanaz Rahimabadi: Investigation, Danial Soleymani-ghoozhdi: Writing original draft, and writing – review and editing.

References

1. Ghotbi Ravandi MR, Mardi H, Khanjani N, Barkhordari A. Occupational exposure to steady magnetic fields and its effect on workers blood indices at an electrolysis unit. J Magn 2016;21:255-60.
2. Moslemi S, Ghotbi Ravandi MR, Zare S, Tohidi Nik H. Measuring and assessing the effects of extremely low-frequency electromagnetic fields (ELF-EMF) on blood parameters and liver enzymes of personnel working in high voltage power stations in a petrochemical industry. Heliyon 2023;9:e15414.
3. Bagheri Hosseinabadi M, Khanjani N, Mirzaii M, Norouzi P, Atashi A. DNA damage from long-term occupational exposure to extremely low frequency electromagnetic fields among power plant workers. Mutat Res Genet Toxicol Environ Mutagen 2019;846:403079.
4. Alizadeh S, Zendehdel R, Asadi S, Ranjbarian M, Mahmoodi Meymand M, Motevalian M, *et al.* Effect of extremely low frequency magnetic field on the quantity and structure of hemoglobin of employees in electricity industry. Pathobiol Res 2018;22:1-5.
5. Rathebe P, Weyers C, Raphela F. Exposure levels of radiofrequency magnetic fields and static magnetic fields in 1.5 and 3.0 T MRI units. SN Appl Sci 2021;3:157.
6. Bagheri Hosseinabadi M, Khanjani N, Norouzi P, Mirbadie SR, Fazli M, Mirzaii M. Oxidative stress associated with long term occupational exposure to extremely low frequency electric and magnetic fields. Work 2021;68:379-86.
7. Soleymani-Ghoozhdi D, Parvari R, Jahani Y, Mehdipour-Raboury M, Faghihi-Zarandi A. A new analytical method based on Co-Mo nanoparticles supported by carbon nanotubes for removal of mercury vapor from the air by the amalgamation of solid-phase air removal. Anal Methods Environ Chem J 2022;5:22-35.
8. Suri S, Dehghan SF, Sahlabadi AS, Ardakani SK, Moradi N, Rahmati M, *et al.* Relationship between exposure to Extremely Low-Frequency (ELF) magnetic field and the level of some reproductive hormones among power plant workers. J Occup Health 2020;62:e12173.
9. Bagheri Hosseinabadi M, Khanjani N, Ebrahimi MH, Biganeh J. Estimation of thermal power plant workers exposure to magnetic fields and simulation of hazard zones. Radiat Prot Dosimetry

2020;190:289-96.
10. Monazzam MR, Hosseini M, Matin LF, Aghaei HA, Khosroabadi H, Hesami A. Sleep quality and general health status of employees exposed to extremely low frequency magnetic fields in a petrochemical complex. J Environ Health Sci Eng 2014;12:78.
11. Barsam T, Monazzam MR, Haghdoost AA, Ghotbi MR, Dehghan SF. Effect of extremely low frequency electromagnetic field exposure on sleep quality in high voltage substations. Iranian J Environ Health Sci Eng 2012;9:15.
12. Bagheri Hosseinabadi M, Khanjani N, Ebrahimi MH, Haji B, Abdolahfard M. The effect of chronic exposure to extremely low-frequency electromagnetic fields on sleep quality, stress, depression and anxiety. Electromagn Biol Med 2019;38:96-101.
13. ACGIH. Threshold limit values for chemical substances and physical agents and biological exposure indices. In: ACGIH Worldwide, Signature Publications. ACGIH United States; 2024.
14. Decat G, Belgium V. Occupational exposure assessment of the static magnetic flux density generated by Nuclear Magnetic Resonance Spectroscopy for biochemical purposes. 2007;3:513-6. [doi:10.2529/PIERS060907140707].
15. Iran National Standards Organization. Non-Ionizing Radiation Exposure Limits. 3rd ed. Tehran, Iran: INSO 8567; 2024. Available from: https://standard.inso.gov.ir/. [Last accessed on 2024 Oct 04] (In Persian).
16. IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. Non-ionizing radiation, part 1: Static and extremely low-frequency (ELF) electric and magnetic fields. IARC Monogr Eval Carcinog Risks Hum 2002;80:1-395.
17. El-Helaly M, Abu-Hashem E. Oxidative stress, melatonin level, and sleep insufficiency among electronic equipment repairers. Indian J Occup Environ Med 2010;14:66-70.
18. Szemerszky R, Zelena D, Barna I, Bárdos G. Stress-related endocrinological and psychopathological effects of short- and long-term 50Hz electromagnetic field exposure in rats. Brain Res Bull 2010;81:92-9.
19. Herrero AI, Sandi C, Venero C. Individual differences in anxiety trait are related to spatial learning abilities and hippocampal expression of mineralocorticoid receptors. Neurobiol Learn Mem 2006;86:150-9.
20. Mattsson MO, Simkó M. Is there a relation between extremely low frequency magnetic field exposure, inflammation and neurodegenerative diseases? A review of *in vivo* and *in vitro* experimental evidence. Toxicology 2012;301:1-12.
21. Zhadin MN. Review of Russian literature on biological action of DC and low-frequency AC magnetic fields. Bioelectromagnetics 2001;22:27-45.
22. de Vocht F, Batistatou E, Mölter A, Kromhout H, Schaap K, van Tongeren M, *et al.* Transient health symptoms of MRI staff working with 1.5 and 3.0 Tesla scanners in the UK. Eur Radiol 2015;25:2718-26.
23. Wilén J, de Vocht F. Health complaints among nurses working near MRI scanners – A descriptive pilot study. Eur J Radiol 2011;80:510-3.
24. Zanotti G, Ligabue G, Gobba F. Subjective symptoms and their evolution in a small group of magnetic resonance imaging (MRI) operators recently engaged. Electromagn Biol Med 2015;34:262-4.
25. Schaap K, Portengen L, Kromhout H. Exposure to MRI-related magnetic fields and vertigo in MRI workers. Occup Environ Med 2016;73:161-6.
26. Erren TC. A meta-analysis of epidemiologic studies of electric and magnetic fields and breast cancer in women and men. Bioelectromagnetics 2001;22:S105-19.
27. Kheifets L, Monroe J, Vergara X, Mezei G, Afifi AA. Occupational electromagnetic fields and leukemia and brain cancer: An update to two meta-analyses. J Occup Environ Med 2008;50:677-88.
28. Floderus B, Persson T, Stenlund C, Wennberg A, Ost A, Knave B. Occupational exposure to electromagnetic fields in relation to leukemia and brain tumors: A case-control study in Sweden. Cancer Causes Control 1993;4:465-76.
29. Li CY, Chen PC, Sung FC, Lin RS. Residential exposure to power frequency magnetic field and sleep disorders among women in an urban community of Northern Taiwan. Sleep 2002;25:428-32.
30. Yousefi HA, Nasiri P. Psychological effects of occupational exposure to electromagnetic fields. Res Health Sci 2006;6:18-21. Available from: https://jrhs.umsha.ac.ir/Article/303. [Last accessed on 2024 Oct 05].
31. Sharifi Fard M, Nasiri P, Monazzam MR. Measurement of the magnetic fields from high-voltage (230 kV) substations in Tehran and assessment of their effects. Iran J Med Phys 2010;7:49-56.
32. Liu H, Chen G, Pan Y, Chen Z, Jin W, Sun C, *et al.* Occupational electromagnetic field exposures associated with sleep quality: A cross-sectional study. PLoS One 2014;9:e110825.
33. Bowman JD, Kelsh MA, Kaune WT. Manual for Measuring Occupational Electric and Magnetic Field Exposures. United states: National Institute for Occupational Safety and Health, Division of Biomedical and Behavioral Sciences; 1998. Available from: https://stacks.cdc.gov/ view/cdc/5254. [Last accessed on 2024 Oct 04].
34. Buysse DJ, Reynolds CF 3rd, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh sleep quality index: A new instrument for psychiatric practice and research. Psychiatry Res 1989;28:193-213.
35. Emkani M, Khanjani N. Sleep quality and its related factors in intercity bus drivers. Mil Med 2012;14:137-41. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84864475587&partnerID=40&md5=b9d273232b269a53e1bc9ee496 b2e939. [Last accessed on 2024 Oct 05].
36. Mohammadyan M, Moosazadeh M, Borji A, Khanjani N, Rahimi Moghadam S. Exposure to lead and its effect on sleep quality and digestive problems in soldering workers. Environ Monit Assess 2019;191:184.
37. Shochat T, Tzischinsky O, Oksenberg A, Peled R. Validation of the Pittsburgh sleep quality index Hebrew translation (PSQI-H) in a sleep clinic sample. Isr Med Assoc J 2007;9:853-6.
38. Farrahi J, Nakhaee N, Sheibani V, Garrusi B, Amirkafi A. Psychometric properties of the Persian version of the Pittsburgh sleep quality index addendum for PTSD (PSQI-A). Sleep Breath 2009;13:259-62.
39. Nazifi M, Mokarami H, Akbaritabar A, Kalte HO, Rahi A. Psychometric properties of the Persian translation of Pittsburgh sleep quality index. Health Scope 2014;3:e15547.
40. Chehri A, Brand S, Goldaste N, Eskandari S, Brühl A, Sadeghi Bahmani D, *et al.* Psychometric properties of the Persian Pittsburgh sleep quality index for adolescents. Int J Environ Res Public Health 2020;17:7095.
41. Farrahi Moghaddam J, Nakhaee N, Sheibani V, Garrusi B, Amirkafi A. Reliability and validity of the Persian version of the Pittsburgh sleep quality index (PSQI-P). Sleep Breath 2012;16:79-82.
42. Graham C, Cook MR. Human sleep in 60 Hz magnetic fields. Bioelectromagnetics 1999;20:277-83.
43. Ayoobi F, Shamsizadeh A, Shafiei SA. The effect of local extremely low frequency magnetic field on student sleepiness. Neurol Res 2017;39:1080-5.
44. Mohler E, Frei P, Fröhlich J, Braun-Fahrländer C, Röösli M, QUALIFEX-Team. Exposure to radiofrequency electromagnetic fields and sleep quality: A prospective cohort study. PLoS One 2012;7:e37455.
45. Dean GE, Redeker NS, Wang YJ, Rogers AE, Dickerson SS, Steinbrenner LM, *et al.* Sleep, mood, and quality of life in patients receiving treatment for lung cancer. Oncol Nurs Forum 2013;40:441-51.