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RESEARCH ARTICLE

OCCUPATIONAL RADIO FREQUENCY ELECTROMAGNETIC FIELD (RF-EMF) EXPOSURE AND IT ASSOCIATION WITH PHYSIOLOGY PARAMETERS OF OUTDOOR MALE AIRPORT WORKERS IN SEPANG, MALAYSIA

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ABSTRACT

This cross-sectional study conducted to determine the associations between exposure to radiofrequency electromagnetic field (RF-EMF) at workplace on physiological parameters of male airport workers. Forty-seven respondents exposed to RF-EMF during working hours (exposed) and 47 administration workers (comparative). RF-EMF exposure describe by electric field (V/m), magnetic field (A/m) and power density (W/m^2) at three specific heights (0.5m, 1.0m and 1.6m). Body core temperature, blood pressure and pulse rate representing physiological parameters. Results showed there was significant differentiation for all types of current exposure of RF-EMF and no significant different of physiology parameters between exposed and comparative group. There was significant relationship between the RF-EMF parameters with systolic blood pressure before working and diastolic blood pressure before and after working; there was significant relationship between the magnetic field and pulse rate after working; there was significant relationship between the power density and pulse rate after working. The regression test showed working location and working duration also influence the physiology parameters. In conclusions, this study suggests that changes in physiology parameters among airport male workers were not only due to exposure of RF-EMF but also influenced by working duration, working location, fasting, smoking, drinking coffee and stress.

KEYWORDS

Non-ionising, radiations, workplace exposure, radio frequency

1. INTRODUCTION

Radio Frequency Electromagnetic Field (RF-EMF) is a type of non-ionizing radiation. RF-EMF is a wave which has the frequency range between 10 MHz to 300 GHz and it is also known as micro wave [1,2]. It is an electromagnet field which has the longest range of wave and very suitable to be used in exchanging data as a communication tool. The sources of RF-EMF are the FM radio (30 – 300 Hz), mobile phone, television broadcasting, microwave oven, medical diathermy (0.3 – 30 GHz), radar, satellite networking, microwave communication (3 -30 GHz) and the sun (3 – 300 GHz) [1-3]. Nowadays, people are exposed to the sources of microwave radiation (RF-EMF) that are human made which are far over the safe range of exposure than the natural sources due to the advancement of the EMF telecommunication system. This phenomenon had increased the level of radiation and had caused the electromagnet pollution. This pollution will increase the direct risk towards one's health [2-4].

RF-EMF is proven to contribute problems to blood pressure, reduce the heartbeat, increase the human body core temperature, increase the quantity of electric charge in human body which will consequently cause problems to the flow of the electric charge in the body, to change some of the body chemical system, enzyme system and human hormone such as Melatonin and the risk to develop cancer cells in human body is higher [5-12]. Thus, World Health Organization (WHO) had launched the international electromagnetic field project in 1996 [3]. This project is meant to collect the scientific data on the effects to human body caused by EMF exposure in between the range of 0 to 300 GHz. The data will be used as a baseline information to set the minimum limit of EMF exposure to protect worker's health.

2. MATERIALS AND METHODS

This study was done through cross-sectional. Workers from two appropriate units were selected which are the BHS (Baggage Handling System) and TTS unit (Track Transit System). While the comparative group consists of workers who is working in the Administration Building of Universiti Putra Malaysia (UPM) Serdang, Selangor where they are not exposed directly from any source of RF-EMF in their working areas. Respondents of both groups are matched in terms of age, gender and nationality which are Malaysian. Selection of the study sample used was purposive sampling which the respondents were selected according to inclusion criteria such as age between 21 to 40 years old, male workers, Malaysian citizens and have no chronic diseases related to physiology, such as high blood pressure and heart disease.

Questionnaires were used to obtain background information from the selected respondents. It was conducted in person where the researchers asked the respondents verbally face to face. All gathered data were analyzed using Statistical Pakage for Science Social (SPSS) and Microsoft Excel. EMR radiation meter 300 equipped with the E Field Probe Type 8 Made in Germany which have been selected to measure the strength of RF-EMF exposure. This measurement tool is suitable for measuring the RF-EMF frequency sources of 100 KHz to 3 GHz. In this study, the RF-EMF exposure levels were measured in terms of electric field (V/m), the magnetic field (A/m) and power density (W/m2) for three different heights of 0.5m, 1.0m and 1.6m. The body core temperature of the respondents was determined by an Instant Ear Thermometer Omron model MC-510. Before the readings were taken, respondents were asked to rest for at least 30 minutes [6]. Thermometer is then inserted into the ear (ear canal). The respondents were also asked to clean their ears before the measurements were taken because the earwax will affect the accuracy of the measured temperature readings. The body core temperature will be measured two times in room temperature before and after going for work.

The blood pressure was measured using sphygmomanometer and stethoscope. The reading was taken by a qualified nurse from the KLIA Health Quarantine Centre and Health Centre of UPM. The respondents were advised not to eat too much, doing active physical activities and asked not to actively smoking (for smoker only) at least 30 minutes before the measurements were taken [5]. They were also asked to stay relax in a quiet room which was comfortable and equipped with air condition before the reading of their blood pressure were taken. Subsequently, the respondents were asked to sit down and put their left hands on the table. Their sleeves were made sure not to be too tight. The blood pressure *kuf* will be wrapped around the left arms of the respondents and must be at the same level with their heart position. The measurements were taken twice. The pulse rate was then taken by pressing the respondents' wrists using two fingers. Pulses counted in one minute. The respondents were also advised not to talk and not to move a lot while the reading was taken as it could affect the blood pressure and the pulse rate [5].

This research ethical clearence was approved by the Research Ethics Committee of Faculty of Medical and Health Sciences, Universiti Putra Malaysia (UPM/FPSK/BSKPP2011-1/5465), and involvement of respondents is based on a written agreement with filling a consent form. Respondents may withdraw at any time if they do not agree or are not satisfied with any study procedures.

3. RESULTS AND DISCUSSIONS

Table 1: Exposure of electric field, magnetic field and power density among study population.

Variables	Exposed (n=47)	Comparative (n=47)	Z value	p value
	(Median) Mean ± S.D.			
Electric field at height 0.5m (V/m)	(0.72) $0.74 \pm 9.857 \times 10^{-2}$	(0.69) $0.69 \pm 2.475 \times 10^{-2}$	-3.014	0.003**
Electric field at height 1.0m (V/m)	(0.73) $0.75 \pm 9.148 \times 10^{-2}$	(0.68) $0.69 \pm 2.635 \times 10^{-2}$	-3.648	<0.001**
Electric field at height 1.6m (V/m)	(0.73) $0.75 \pm 9.268 \times 10^{-2}$	(0.68) $0.69 \pm 2.633 \times 10^{-2}$	-3.305	0.001**
Magnetic field at height 0.5m (A/m)	(0.0020) $2.0 \times 10^{-3} \pm 2.725 \times 10^{-4}$	(0.0018) $1.84 \times 10^{-3} \pm 4.91 \times 10^{-5}$	-4.549	<0.001**
Magnetic field at height 1.0m (A/m)	(0.0020) $2.06 \times 10^{-3} \pm 2.561 \times 10^{-4}$	(0.0018) $1.85 \times 10^{-3} \pm 5.03 \times 10^{-5}$	-5.117	<0.001**
Magnetic field at height 1.6m (A/m)	(0.0020) $2.05 \times 10^{-3} \pm 2.796 \times 10^{-4}$	(0.0019) $1.85 \times 10^{-3} \pm 5.05 \times 10^{-5}$	-3.789	<0.001**
Power density at height 0.5m (W/m^2)	(0.0015) $1.57 \times 10^{-3} \pm 3.683 \times 10^{-4}$	(0.0013) $1.33 \times 10^{-3} \pm 6.00 \times 10^{-5}$	-4.813	<0.001**
Power density at height 1.0m (W/m^2)	(0.0015) $1.59 \times 10^{-3} \pm 3.514 \times 10^{-4}$	(0.0013) $1.35 \times 10^{-3} \pm 7.18 \times 10^{-5}$	-4.740	<0.001**
Power density at height 1.6m (W/m^2)	(0.0015) $1.56 \times 10^{-3} \pm 3.628 \times 10^{-4}$	(0.0014) $1.36 \times 10^{-3} \pm 5.68 \times 10^{-5}$	-3.468	0.001**

N = 94
** Significant at p<0.01 (*Mann-Whitney U Test)*

Table 1 show the differences of electric field (V/m), the magnetic field (A/m) and power density (W/m^2) between the exposed and the comparative groups for three different heights of 0.5m, 1.0m and 1.6m. It is found that there were differences between the heights of the three RF-EMF parameters for the two respective groups. *Mann-Whitney U* test have shown significant differences at p <0.01 for all types of RF-EMF exposure levels among the exposed group and comparative group. Table 2 shows the differences in physiological parameters between the exposed and comparative groups. The *Mann-Whitney U* statistical analysis for the not normal distribution proved that there is no significant difference between the exposed and comparative group for all physiological parameter.

Table 2: Physiology parameters of study populations.

Variables	Exposed (n=47)	Comparative (n=47)	Z value	p value
	(Median) Mean ± S.D.			
Body core temperature before work (^{o}C)	(35.9) 35.9 ± 0.32	(36.0) 36.0 ± 0.36	-1.411[a]	0.158
Body core temperature after work (^{o}C)	(35.9) 35.9 ± 0.34	(35.9) 35.8 ± 0.31	0.992[b]	0.324
Systolic pressure before work (mmHg)	(114) 116.3 ± 7.07	(118) 117.6 ± 5.88	-0.984[a]	0.325
Systolic pressure after work (mmHg)	(118) 116.3 ± 6.87	(118) 117.2 ± 5.98	-0.471[a]	0.638

Diastolic pressure before work (mmHg)	(78) 76.0 ± 5.22	(80) 77.5 ± 4.14	-1.175 [a]	0.240
Diastolic pressure after work (mmHg)	(78) 76.8 ± 5.74	(78) 76.4 ± 4.68	-0.097 [a]	0.923
Heart rate before work (pulse/minute)	(70) 69.9 ± 7.18	(68) 67.3 ± 6.59	1.826[b]	0.071
Heart rate after work (pulse/minute)	(68) 70.0 ± 7.49	(68) 66.7 ± 4.91	-1.846 [a]	0.065

N = 94
[a] *Mann-Whitney U* Test
[b] Ujian T

The RF-EMF exposure was higher among the exposed group compared to the comparative group. The difference of min electric field, magnetic field and power density between the exposed and comparative groups was about 0.75V/m, 2.1x10-3 A/m and 1.59x10-3 W/m2. This significant difference is due to different radar systems in KLIA. This includes the air traffic control tower, Victor Kilo Lima (VKL), Surface Movement Radar (SMR), Terminal Approach Radar, Transportable Radar [13]. RF-EMF exposure of between 1 MHz to 10 GHz can increase the tissue temperature consistently exceeds 1°C [3,14]. According to research, respondents who were exposed to 2.5 GHz RF-EMF experienced pain and warm on their skin not to mention that the temperature of the skin surface was increased 1°C for every 10 minutes [15,16]. However, the findings of this study have shown no significant relationship between body core temperature and RF-EMF. This is because the exposure to RF-EMF in KLIA airport is not too strong, which is only about 0.73V/m (electric field), 0.0002 A/m (magnetic field) and 0.0015 W/m2 (power density). In addition, the radar system frequency in KLIA is approximately 100 MHz to 800 MHz and its consistently maintain and monitor by KLIA Occupational Health Officer.

Additionally, respondents' workplace also affects the strength of RF-EMF exposure. Majority of respondents are working in the building which a total of 34 (72.4%) respondents of the exposed group. There are only five (10.6%) respondents working out of the building and eight (17%) respondents working at the basement. As a result, majority of respondents are not exposed to high RF-EMF as compared to those whom are working outside the building and at the basement as well as those in air-conditioned room. As a matter of fact, there are many studies claimed that there is no significant relationship between blood pressure and the exposure to RF-EMF. In the previous study that compared the systolic and diastolic blood pressure among workers who were exposed to RF-EMF and workers who were not exposed to RF-EMF at a television station, found no significant changes in the study parameter [17].

T-tests for normal distribution is also shown no significant differences between the exposed and comparative group for all physiological parameter. Table 3 shows the differences in physiological parameters before working and after working of the exposed group. The *Wilcoxon Signed Ranks* test shown that there are no significant differences for all the physiological parameters studied. A study which measures the heart rate parameter and blood pressure for employees in AM broadcast station and to a comparative group, there was no clinically significant between the RF-EMF and the heart rate parameter and blood pressure [5]. In addition, a study conducted among U.S. Navy pilots who guide the planes equipped with sophisticated RF-EMF to control group pilots, have proven that the rate of admission to hospital based on cardiovascular system disease had no significant difference [13].

Table 3: Physiology parameters between before and after working hours among exposed group.

Variables	(Median) Mean ± S.D.		Z value	p value
	Before working	After working		
Body core temperature (°C)	(35.90) 35.90 ± 0.318	(35.90) 35.88 ± 0.343	-0.007	0.995
Systolic pressure (mmHg)	(114.00) 116.26 ± 7.073	(118.00) 116.34 ± 6.869	-0.109	0.913
Diastolic pressure (mmHg)	(78.00) 75.96 ± 5.217	(78.00) 76.81 ± 5.743	-1.196	0.232
Heart rate (pulse/minute)	(70.00) 69.87 ± 7.180	(68.00) 70.04 ± 7.489	-0.329	0.742

N = 94
Wilcoxon Signed Ranks Test

Increased body temperature has the same effect as having the heat pressure. RF-EMF exposure can cause the sympathetic efferent activity to increase with the increased blood pressure at rest between 5 to 10 mmHg due to the vasoconstriction effect which the decreasing of the blood vessels diameter will cause the decreased blood flow and the increased blood pressure [6,18,19]. *Spearman's Rho* correlation test showed a significant correlation of diastolic blood pressure before diastolic working (before the RF-EMF exposure) is more significant than diastolic blood pressure after working (after RF-EMF exposure). Therefore, we can conclude that the significant relationship was not caused by the exposure to RF-EMF.

The analysis of *General Linear Model (GLM)* was conducted on each confounding factors which are the monthly income (RM), working duration (months), smoking habit, coffee drinking habit, living near to the substation, the respondent's workplace and the type of transportation they drive to work, which is found that there is a significant correlation between the factors of respondent's workplace and the working duration of the exposed group. GLM analysis was conducted to test the effect of RF-EMF (electric field, magnetic field and power density for the three heights) and systolic blood pressure before working, diastolic blood pressure before working, diastolic blood pressure after working and the pulse rate after working which consequently found that there is a significant relationship of the correlation test. By controlling the confounding factors which have the significant correlation; the respondent's workplace and the working duration (months), it is found that there is a significant influence between RF-EMF and certain physiological parameters (Table 4, 5, 6). However, the effect is weaker than the adjusted R^2 regression model which has described the small percentage of it.

Table 4: Exposure of RF-EMF parameters with confounding factors that influence the systolic pressure among exposed group after working hours.

Variables	β coefficient	t value	p value
Constant	189.6	9.641	<0.001**
Working experience (months)	-0.145	-3.299	0.002**
Electric field at height 0.5m (V/m)	231.1	2.058	0.047*
Electric field at height 1.0m (V/m)	-419.1	-3.025	0.005**
Magnetic field at height 1.0m (A/m)	-42678.0	-2.369	0.024*

N = 47
** Significant at $p<0.01$
* Significant at $p<0.05$

General Linear Model Test (Model Type III)

F value = 0.708, p = 0.405

R^2 value = 0.480, Adjusted R^2 = 0.316

Systolic pressure after working hours (mmHg)

= 189.646 – 0.145 working experience (months) + 231.1 electric field at height 0.5m (V/m) – 419.1 electric field at height 1.0m (V/m) – 42678.0 magnetic field at height 1.0m (A/m)

Table 5: Exposure of RF-EMF parameters with confounding factors that influence the diastolic pressure among exposed group after working hours.

Variables	β coefficient	t value	p value
Constant	124.7	8.999	<0.001**
Work locations	4.5	2.517	0.017*
Working experience (months)	-0.110	-3.540	0.001**
Magnetic field at height 1.0m (A/m)	-31849.3	-2.510	0.017*
Power density at height 1.0m (W/m²)	30610.3	2.494	0.018*

N = 47

** Significant at $p<0.01$
* Significant at $p<0.05$

General Linear Model Test (Model Type III)

F value = 0.421, p = 0.520

R^2 value = 0.526, Adjusted R^2 = 0.377

Diastolic pressure after working hours (mmHg)

= 124.7 + 4.5 work locations – 0.110 working experience (months) – 31849.3 magnetic field at height 1.0m (A/m) + 30610.3 power density at height 1.0 (W/m²)

Table 6: Exposure of RF-EMF parameters with confounding factors that influence the heart rate among exposed group after working hours.

Variables	β coefficient	t value	p value
Constant	73.4	3.474	0.001**
Power density at height 1.6m (W/m²)	39488.5	2.281	0.029*

N = 47

** Significant at $p<0.01$
* Significant at $p<0.05$

General Linear Model Test (Model Type III)

F value = 0.570, p = 0.454
R^2 value = 0.464, Adjusted R^2 = 0.296

Heart rate after working hours

= 73.4 + 39488.5 power density at height 1.6 (W/m²)

Correlation tests revealed that the electric field, magnetic field and power density are not significantly related to the pulse rate before the working but has a significant relationship to the pulse rate after working. However, all the r values are positive which has shown the direct relationship. This means that the higher the exposure to RF-EMF the higher the pulse rate is. However, the high exposure to RF-EMF will lower the pulse rate. In the previous study, there was a significant decrease in heart rate [15]. The decrease heart rate from 73.5 to 67.7 beats per minute for women and 64.6 to 59.5 beats per minute for men. Therefore, a significant correlation of pulse rate after working is not because of the RF-EMF exposure, but may be caused by other factors such as smoking, drinking coffee habit, work and emotional pressure and anxiety during the pulse measurement [15,19,20].

The study of the controlled mix factors found that the association is only significant for systolic blood pressure before working with workplace factor, diastolic blood pressure before working with workplace factor and pulse rate after working with the working hour factor. However, after mixing the factors of the respondents working duration (months) and workplace is in controlled, it is found that there is only a significant difference between the systolic blood pressure before working with the magnetic field at a height of 1.0m and an electric field at the height of 0.5m and 1.0m; diastolic blood pressure before working with the power density at a height of 1.0m and field magnet at a height of 1.0m; diastolic blood pressure after working with the magnetic field at a height of 1.0m; the pulse rate after working with the power density at a height of 1.6m. However, the relationship is weaker than the adjusted R^2 regression model which describes the percentage of the effect is small. In fact, the effect of RF-EMF is cumulative and requires a longer period to see the real effects of changes in physiological parameters of the respondents.

4. CONCLUSIONS

Overall, the exposure to RF-EMF does not have any significant relationship to body core temperature before going for work, body core temperature after coming back from work, systolic blood pressure after working and pulse rate before going for work but it has a significant relationship to systolic blood pressure before going for work, diastolic blood pressure before going for work, systolic blood pressure after working and diastolic blood pressure after working. However, the study has found that this significant relationship is not caused by the exposure to RF-EMF but contributed by other factors such as working duration, working location, fasting, smoking, drinking coffee and stress. The male worker at KLIA Airport was safe from hazardous exposure to RF-EMF in their related working areas.

As a matter of fact, the design of this study is one of the limitations. This study did not gauge the relationship between the dose of exposure and its effect. The study gathered the data at only one-time interval and did not represent the total overall exposure, unlike the prospective and cohort studies which require a longer period. The respondents involved were only 47 males between the ages of 21 to 40 years old and only the physiological parameters were studied. Therefore, a more comprehensive study should be carried out by the employer party so that more respondents will be involved not to mention the female and senior workers to participate in that different study design. A more thorough investigation will be able to identify the real risks of working on RF-EMF exposure. Apart from that, the employer may seek advice from other parties such as universities (Public Institute of Higher Learning), NIOSH (National Institute of Occupational Safety & Health), DOSH (Department of Occupational Safety & Health) and MINT (Malaysia Institute of Nuclear Technology) to conduct a more comprehensive study. The research should be able to ensure that the workplace involved has a higher RF-EMF exposure since this study only covered some areas of the airport. In fact, there are areas at the airport which have a higher RF-EMF exposure than the studied area.

In addition, the employers should carry out more frequent medical examinations of the workers to detect any changes and symptoms associated with the RF-EMF exposure from their workplace. If the workers health is proved to have any effect from the RF-EMF exposure, appropriate actions should be taken. Some of the proposed recommendations are to change the workplace structure to lessen the RF-EMF exposure, the working hours of exposure to RF-EMF is reduced by rotation of work system and to provide PPE (Personal Protective Equipment) to employees who are directly exposed to RF-EMF at work.

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