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Physiological Variables and Subjective Symptoms by 60 Hz Magnetic Field in EHS and Non-EHS Persons

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Abstract— **Electromagnetic hypersensitivity (EHS) is a set of claims of adverse medical symptoms self attributed by exposure to electromagnetic field. In this study, we simultaneously investigated both physiological changes (heart rate, respiration rate, and heart rate variability) and subjective symptoms to determine the origin of EHS. Two volunteer groups (15 self-reported EHS and 16 non-EHS participants) were tested under both sham and real exposure to 12.5 μT magnetic fields at 60 Hz that lasted a half an hour. The magnetic field exposure did not have any effect on physiological variables or subjective symptoms in either group. We conclude that the subjective symptoms did not result from exposure to 12.5 μT magnetic field at 60 Hz.**

I. Introduction

WITH the increasing usage of electrical devices, there are growing social concerns about the biological effects of electromagnetic fields (EMF) on human health. The commercial power frequency is 50 or 60 Hz, which is in the extremely low frequency (ELF) range. Accordingly, the number of people who complain of various symptoms such as headache, exhaustion, insomnia etc. is on the rise. Complaining of symptoms attributed to EMF is called electromagnetic hypersensitivity (EHS) or self-attributed EHS. It has been reported that the EHS population accounts for the 1.5 % of the population of Sweden, 3.2 % of California in the USA, and 5% of Switzerland [1]-[3]. Röösli et al. reported that sleep disorder (58%), headache (41%), nervousness or distress (19%), fatigue (18%), and concentration difficulty (16%) with multiple answer allowed as the most common complaints in Switzerland [4]. This implies that EHS could not only deteriorate the quality of life for individual patients, but could also increase social expenses for health care. Eltiti et al. categorized EHS by evaluating subjective judgment [5].

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However, the diagnostic method for EHS is not clear, and the origin of EHS has not been completely identified [5]-[7]. Therefore, a more comprehensive method is necessary to understand whether EHS is caused by real perception to the EMF or by other factors.

In this double-blind study, two volunteer groups of 15 subjects with self-reported EHS and 16 non-EHS subjects were tested under both sham and real exposure to 12.5 μT magnetic fields at 60 Hz, lasting a half an hour. We measured heart and respiration rates for both the EHS and non-EHS groups, and then obtained heart rate variability (HRV) using the measured heart rate. In addition, the subjects were asked to describe their subjective symptoms during the sham/real exposure and non-exposure sessions. The aim of this study was to test whether a 60 Hz magnetic field influenced heart rate, respiration rate and HRV, or gave rise to subjective symptoms in EHS and non-EHS persons.

II. Materials and Methods

A. Subjects

A total of 31 subjects participated in the experiment: 15 EHS (10 males and 5 female; 26.2 ± 2.7 years) and 16 non-EHS persons (11 males and 5 females; 25.6 ± 3.1 years). There was no statistical difference in age (P = 0.586), male-female ratio (P = 1.000), smoking (p = 1.000), body mass index (P = 0.572), cellular phone usage period (P = 0.654), computer usage/day (P = 0.682), or TV viewing time/day (P = 0.892) between the two groups.

As Schröttner et al. [8] reported, determination of EHS subjects is crucial to this provocation study, so we utilized an accredited EHS screening tool developed by Eltiti et al. [5]. They proposed that the following criteria be used to identify EHS individuals: (1) a total symptom score greater than or equal to 26 of the maximum score of 228 (57 symptoms, each rated from 0 for "not at all" to 4 for "a great deal"), (2) individuals who explicitly attributed his or her symptoms to exposure to EMF-producing objects, and (3) individuals whose current symptoms cannot be explained by a pre-existing chronic illness.

All subjects were recruited through an advertisement by Yonsei University Health System (YUHS), were informed of the purpose and procedure of the experiment, and were asked to give written consent to it before joining the study. The Institutional Review Board (IRB) of the YUHS approved the protocol of this study (Project number: 4-2008-0152).

B. Physiological Measurement

Fig. 1 shows the complete experimental setup for evaluating EHS during the 60 Hz magnetic exposure. The subjects' heart rate, respiration rate, and HRV were obtained with a PolyG-I (Laxtha, Daejeon, Korea), which is a computerized polygraph system. The data were transferred to a nearby Compaq notebook computer (NX6120, HP, Palo Alto, CA) and analyzed using Telescan 0.9 (Laxtha; data acquisition software), and Complexity (Laxtha; data analysis software). The PolyG-I recorded electrocardiography (ECG) through Ag-AgCl electrodes (2223, 3M, St. Paul, MN) placed on both arms and the right leg of participants as shown in Fig. 2. We first obtained heart rates from ECG and then acquired HRV and the power spectrum of HRV. High-frequency power (HFP) reflects the effects on the parasympathetic nervous system by the respiratory sinus arrhythmia (RSA), whereas low frequency power (LFP) reflects the effects on the sympathetic and parasympathetic nervous system [9]. In this study, LFP/HFP was used as an index for balance of autonomic nerve activity. Respiratory inductance plethysmography was used to measure respiration rates. A coiled band was worn around the subject's upper abdomen to measure inductance changes resulting from cross-sectional change as shown in Fig. 2.

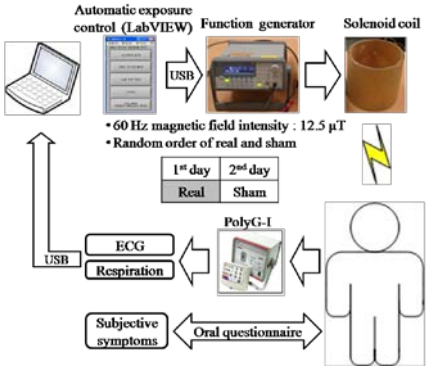

Fig. 1. Experimental configuration of 60 Hz magnetic field exposure.

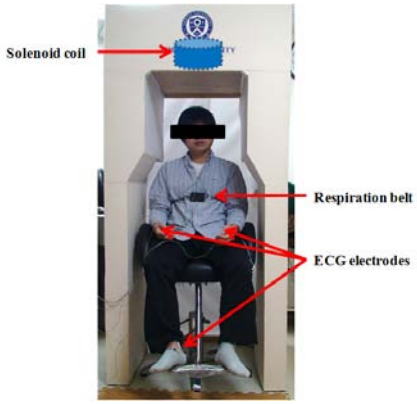

Fig. 2. Photo of experimental setup.

C. Subjective Symptoms

Symptoms such as headache, insomnia, fatigue, etc. cannot be confirmed by measuring only physiological changes such as heart rate, respiration, HRV, etc. In this study, eight subjective symptoms (throbbing, itching, warmth, fatigue, headache, dizziness, nausea, and palpation) were evaluated through verbal surveys which were graded on a four-point scale ranging from 1 to 4 points established by Koivisto et al. [10] during their measurement of physiological variables.

D. Experimental Setups and procedures

The lab was used exclusively for this experiment, and all other electrical devices were plugged off except our instruments in order to minimize background field levels. The background ELF fields in the laboratory were measured to ensure that they did not exert influence on the subjects. The average ELF electric and magnetic fields were measured as 0.8 ± 0.0 V/m and 0.03 ± 0.00 μT, respectively, using an electric and magnetic field analyzer (EHP-50C, NARDA-STS, Milano, Italy).

The magnetic field generator consisted of an arbitrary function generator (33220A, Agilent, Santa Clara, CA) and solenoid coils with 2,000 turns, radius of 20 cm, height of 20 cm, and coil thickness of 0.7 mm. The output of the function generator was controlled by LabVIEW 2009 software (National Instruments, Austin, TX) as shown in Fig. 1. The solenoid coil was placed 20 cm higher than the top of the participant's head and covered with fabric so as not to be seen by subjects. The distance from the bottom of the coil to the top of the subject's head was maintained at 20 cm by adjusting the chair height to expose the top of the head at 12.5 μT. We selected 12.5 μT because it was the strongest magnetic field measured right under most transmission lines in South Korea, according to the Korea Electric Power Corp. [11]. The subjects were told not to take in caffeine, smoke, drink, or exercise, and they were advised to sleep enough 24 hours before the experiment day to minimize confounding factors.

Sham and real exposures were conducted to minimize test bias resulting from a subject and an experimenter recognizing the operational state of the magnetic field generator (double blind). Each subject was tested for sham exposure on the first day and for real exposure on the second day, or vice versa. No matter which came first, sham or real exposure, the second session was always given at approximately the same time of the day as the first day in order to maintain the subject's physiological rhythm. The orders of sham and real exposures for a subject were randomly assigned and counter-balanced by our automatic exposure control program using LabVIEW2009 to minimize experimental bias (Fig. 1).

The duration of each experimental procedure was 64 min, as shown in Fig. 3. Before the experiment, subjects were made to rest in a sitting position for at least 10 min. Physiological data were collected for 5 min at four different stages: pre-test rest (stage I), after 11 min of exposure (stage II), after 27 min of exposure (stage III), and 11 min after exposure termination

(stage IV) [12]. The duration of exposure was determined based on other reports [7], [12]. At each stage, ECG and respiration were simultaneously measured for 5 min because of the long data requirement for HRV [13]. The four shaded areas are periods during which they were questioned regarding the eight symptoms, and each period lasted for approximately 1 min. Room temperature was recorded and constantly kept at 23.9 ± 1.1 °C throughout the experiment, because this factor could considerably affect the outcome. The relative humidity was 43.9 ± 10.1%. After applying the paired t-test, there were no significant differences in temperature (P = 0.781) and humidity (P = 0.968) between the real and sham sessions.

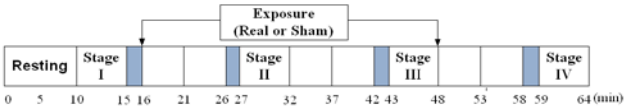

Fig. 3. Experimental procedure for measuring physiological variables and investigating symptoms [12].

E. Data Analysis

For HRV, the R-R intervals (from the peak of one QRS complex to the peak of the next) were acquired from the measured 5 min of ECG recording, and its power spectrum was obtained using software (TeleScan Ver.2.8, Laxtha). LFP and HFP were derived from the power spectrum of HRV by the area between 0.04 ~ 0.15 Hz and 0.15 ~ 0.4 Hz, respectively. LFP/HFP was calculated with the HRV power spectrum to analyze changes in the autonomic nervous system. To analyze the relative changes in LFP/HFP, the resting LFP/HFP of the real and sham exposures were set at 100%.

A repeated two-way ANOVA test was performed using SPSS software (SPSS 10, SPSS, Chicago, IL) with a significance level of 0.05 to investigate the physiological effects of exposure and duration of magnetic field exposure on heart rate, respiration rate, and LFP/HFP for each group. A Bonferroni post-hoc test followed the two-way ANOVA in order to investigate any differences in LFP/HFP between each stage in the groups. Since subjective symptoms were ordered data, the non-parametric statistical method of the Wilcoxon signed-rank test was used for analysis. All P-values between the real and sham exposures were obtained for the four stages of the eight symptoms in both groups. The total number of P-values obtained was 64 (4 stages * 8 symptoms * 2 groups).

III. Result

A. Physiological Variables

For the non-EHS group, there were no significant differences in heart rate (P = 0.064 and 0.278), respiration rate (P = 0.245 and 0.200), or LFP/HFP (P = 0.816 and 0.212), between real and sham exposures and between each stage. Fig. 4(a) shows the relative changes in LFP/HFP for the non-EHS group. For the EHS group, there were no significant differences in heart rate (P = 0.780 and 0.922) or respiration rate (P = 0.128 and 0.293), between real and sham exposures and between each stage. LFP/HFP did not differ significantly between the real and sham exposures (P = 0.782), but showed significant difference between each stage (P = 0.001) as shown in Fig. 4(b).

B. Subjective Symptoms

The EHS group showed no significant differences in the four stages between the two sessions for any of the eight symptoms surveyed, which included throbbing, itching, warmth, fatigue, headache, dizziness, nausea, and palpation. The non-EHS group also showed no significant differences in the four stages between the sham and the real sessions for any of the eight symptoms surveyed except warmth in stage II (P = 0.046), where the mean ± SD of the warmth survey for the sham and real exposures were 1.25 ± 0.45 and 1.00 ± 0.00, respectively. This significant difference clearly did not result from exposure but from other factors, because the mean point of the sham exposure was higher than that of the real exposure.

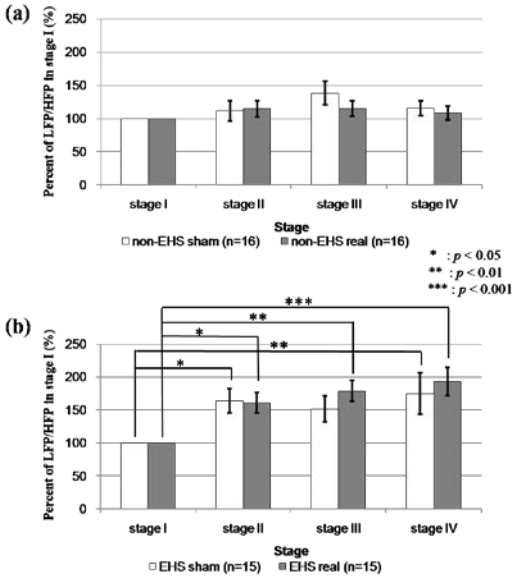

Fig. 4. Relative changes (%) in LFP/HFP during sham and real exposure sessions for non- EHS (a) and EHS (b) groups, with the resting stage I set at 100 %. Error bar indicates standard error.

IV. Discussion

Neither the EHS group nor the non-EHS group showed significant differences in heart and respiration rates between real and sham exposures or between the stages. In the case of LFP/HFP, however, there were significant differences between some stages during both real and sham sessions in the EHS group only. Hjortskov et al. reported that psychological stress could result in increased LFP/HFP [14]. As EHS individuals have more anxiety than non-EHS ones, according to Mueller et al. [15], EHS people seem to be more sensitive to environmental factors than non-EHS people [16]. Therefore, in Figure 4 (b), the significant increase in LFP/HFP along with time in the sham session in the EHS group could have resulted

from psychological stress with experimental time, regardless of exposure.

For symptoms related to magnetic field exposure, the non-EHS group showed significantly increased warmth only during non-exposure ($P = 0.046$) while the EHS group did not. This finding is not reasonable and may have resulted from factors other than exposure.

V. Conclusion

There have been numerous studies of EHS due to ELF exposure that yielded various results depending upon the experimental methods and procedures. However, only a few studies simultaneously examined these two factors: physiological variables and subjective symptoms in both EHS and non-EHS groups. In this study, we measured changes in physiological variables and subjective symptoms simultaneously. We conclude that 12.5 μT magnetic fields at 60 Hz exposure did not have any effects on heart rate, respiration rate, or subjective symptoms in EHS and non-EHS groups.

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