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EHS subjects do not perceive RF EMF emitted from smart phones better than non-EHS subjects *

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Abstract— **As the use of smart phones increases, social concerns have arisen concerning the possible effects of radio frequency-electromagnetic fields (RF-EMFs) emitted from wideband code division multiple access (WCDMA) mobile phones on human health. The number of people with self-reported electromagnetic hypersensitivity (EHS) who complain of various subjective symptoms, such as headache, insomnia, etc., has also recently increased. However, it is unclear whether EHS subjects can detect RF-EMFs exposure or not. In this double-blind study, two volunteer groups of 17 EHS and 20 non-EHS subjects were investigated in regards to their perception of RF-EMFs with real and sham exposure sessions. Experiments were conducted using a WCDMA module inside a dummy phone with an average power of 24 dBm at 1950 MHz and a specific absorption rate of 1.57 W/kg using a dummy headphone for 32 min. In conclusion, there was no indication that EHS subjects perceive RF-EMFs better than non-EHS subjects.**

I. Introduction

WITH the increasing usage of the third Generation (3G) mobile phones, social concerns have arisen concerning the possible effects of radio frequency-electromagnetic fields (RF-EMFs) emitted from mobile phones on human health. The World Health Organization (WHO) classified RF-EMFs as possibly carcinogenic to humans as Group 2B based on a conclusion drawn from limited evidence from both human and animal studies [1].

A number of people with self-reported electromagnetic hypersensitivity (EHS) are characterized by a variety of non-specific symptoms that differ from individual to individual. Cross-sectional survey studies in various countries reported that EHS subjects experience non-specific subjective symptoms (e.g., headache, dizziness, fatigue, sleep disorder) associated with EMF exposure: 1.5 % in Sweden [2], 3.2 % in California [3], and 5 % in Switzerland [4]. For some individuals, the symptoms can change their lifestyle.

Electromagnetic sensibility refers to the ability to perceive an EMF without necessarily developing non-specific health symptoms attributed to EMF exposure [5]. While many studies have examined electromagnetic sensibility of Global System for Mobile Communications (GSM), only a few provocation studies involving WCDMA have been conducted [6]. Mueller et al. reported that there were no significant differences in the ability to detect EMF between EHS and non-EHS groups [7]. In the study by Hietanen et al., EHS subjects were examined for their ability to determine the perception of EMF, none of the subjects could distinguish real EMF exposure from sham exposure [8]. Kwon reported that there was no evidence to indicate that EHS subjects can detect EMF exposure [9]. However, Leitgeb et al. reported that EHS subjects with significantly increased electromagnetic sensibility could be differentiated from the non-EHS groups [5].

Proper design of experimental studies is critical to testing electromagnetic perception of EMF. Therefore, comprehensive study of whether EHS is caused by RF-EMFs exposure or not is imperative. In this double-blind study, we compared perception percentage of RF-EMFs from mobile phone in 17 EHS and 20 non-EHS subjects using a WCDMA module inside a dummy phone.

II. Materials and Methods

A. *Experimental setups*

The lab was exclusively used for this experiment, and all other electrical devices were unplugged, except for our instruments, in order to minimize background field levels. Background extremely low frequency (ELF) fields in the laboratory were measured to ensure that subjects were not influenced by them. The average ELF electric and magnetic fields were measured at 1.8 ± 0.0 V/m and 0.02 ± 0.01 μT, respectively, using an electric and magnetic field analyzer (EHP-50C, NARDA-STS, Milano, Italy). The RF field was measured at 0.05 ± 0.00 V/m with a microwave frequency range from 1920 to 1980 MHz using a radiation meter (SRM 3000, Narda GmbH, Pfullingen, Germany).

In order to have better control over exposure, WCDMA modules with Qualcomm chipsets (baseband: MSM6290, RF: RFR6285, power management: PM6658) were used to

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generate WCDMA RF instead of a regular smart phone. The WCDMA modules continuously transmitted at a mean output power of 24 dBm at 1950 MHz, which was measured using the E5515C Wireless Communication Test set (Agilent, Santa Clara, CA). The modules were inserted into a dummy phone [10] and the location of the module was varied to meet the recommendation of 1.6 W/kg for the general public Specific Absorption Rate $(SAR)_{1g}$, according to the IEEE Standard [11]. The SAR measurements were made with a DASY 4 measurement system (SPEAG, Zurich, Switzerland) and the Twin SAM (specific anthropomorphic mannequin) phantom was filled with head tissue-equivalent liquid according to the Federal Communications Commission, with a mass density of 1000 kg/m^3. The measured dielectric properties of the liquid were σ = 1.41 S/m and ε_r = 39.7 for the WCDMA frequency range. When the antenna of the module was positioned 67.5 mm from the ear reference point (ERP) of the dummy, the averaged peak spatial SAR_{1g} was measured to be 1.57 W/kg at 1950 MHz in left cheek position [12]. The electric field was 6.9 V/m and power drift was -0.001 dB in the ERP

The module was connected via a 5 m USB cable and a USB type ammeter to a portable laptop computer (X-note R500, LG electronics, Korea), which controlled the module and monitored electrical current to check exposure conditions (Fig.1). The laptop computer was remotely controlled from another outside desktop computer to satisfy the double-blind study. The dummy phone was attached to the subject's head using an earplug and headset to fix it at the ERP next to the cheek [13]. The phone was held at a distance of 3 mm from the ear using a piece of wood for insulation so that the subjects would not be aware of whether the phone was working through its battery-generated heat [14]. The phone was constructed only with plastic and rubber, but without any metal [13], [15].

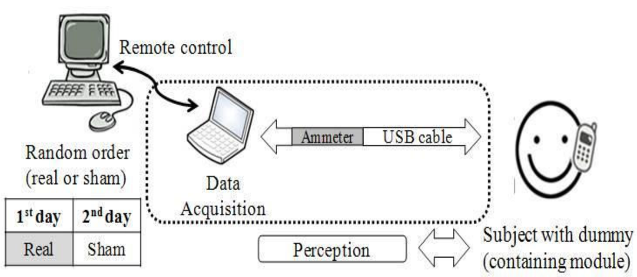

Figure 1. Exposure system and block diagram

B. Subjects

As Schröttner et al. reported, determination of EHS subjects was crucial to this provocation study [4]. Therefore, we utilized the accredited EHS screening tool developed by Eltiti et al. [16]. We adopted the following criteria to identify EHS individuals: (1) a total symptom score greater than or equal to 26 out of a maximum score of 228 (57 symptoms, each ranked from 0 for "not at all" to 4 for "a great deal"), (2) the individual explicit attribution of his or her symptoms to exposure to only a WCDMA mobile phone, (3) and current symptoms cannot be explained by pre-existing chronic diseases.

The experiment was performed as a double-blind study with a total of 37 subjects: 17 EHS and 20 non-EHS subjects. There were no statistical differences in male-female ratios (p=0.75), age (p=0.87), height (p=0.71), weight (p=0.44), body mass index (p=0.24), non-smoker-smoker ratios (p=1.00), computer usage time (p=0.99), TV viewing time (p=0.96), or mobile phone usage periods (p=0.33) between the two groups (Table 1). The symptom scores for the EHS and non-EHS groups using the Eltiti's scale were 59.7 ± 35.3 and 8.8 ± 7.5, respectively. None of the EHS or non-EHS subjects failed to attend the second day of testing after attending the first day.

The subjects were advised not to consume caffeine, smoke or exercise and to sleep enough before the experimental day in order to minimize confounding factors. All subjects who were recruited by advertisements at the Yonsei University Hospital System (YUHS) were informed of the purpose and procedure of the experiment, and were required to give written consent to participate in this study. The Institutional Review Board (IRB) of the YUHS approved the protocol of this study (Project number: 1-2010-0030).

TABLE I. DEMOGRAPHIC DATA OF SUBJECTS

	EHS	**Non-EHS**	***P*-value**
Subjects	17	20	-
Male : Female	8:9	11:9	0.75
Age (year)	30.1±7.6	29.4±5.2	0.87
Height (cm)	167.9±7.5	167.6±8.0	0.71
Weight (kg)	63.2±11.9	60.3±11.5	0.44
BMI (kg/m^2)	22.3±2.9	21.3±2.3	0.24
Non-Smoker:Smoker	15:2	18:2	1.00
Computer usage time (hour/day)	4.4±2.9	5.0±3.8	0.99
TV viewing time (hour/day)	1.6±1.3	1.5±1.1	0.96
Mobile phone usage periods (year)	10.9±3.0	11.6±2.6	0.33
Symtpoms score	59.7±35.3	8.8±7.5	-

C. Procedures

The duration of each exposure session was 64 min as shown in Fig. 2 [17]. Questions regarding EMF perception were asked every 5 min, starting just after pre-exposure period. Subjects were asked to answer the question "Do you believe that you are exposed right now?" nine times during each session. In the real exposure session, the EMF perception question was asked five times during exposure and four times during non-exposure. In the sham exposure session, it was asked nine times during non-exposure. The marks "o" and "x" were used to indicate the times when EMF was perceived correctly or incorrectly during the periods of exposure (real or sham) and non-exposure, respectively. In the EHS group, the total number of inquiries was 17 (1 x 17) during pre-exposure, 75 (5 x 17) during exposure, and 51 (3 x 17) during post-exposure, for a total of 153 (9 x 17) data points. In the non-EHS group, the total number of inquiries was 20 (1 x 20) during pre-exposure, 100 (5 x 20) during exposure, and 60 (3 x 20) during post-exposure, for a total of 180 (9 x 20) data points.

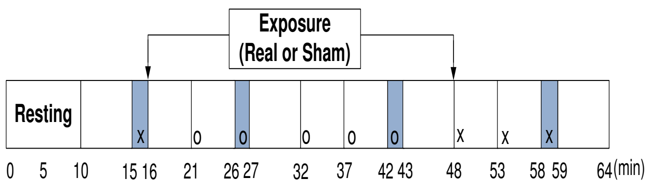

Figure 2. Experimental procedure

D. Data analysis

Wilcoxon signed-rank test was performed to investigate any significant differences in the pre-exposure period for the same condition before exposure, in the exposure period for testing whether the subject could detect the fields, and in the post-exposure for delay effects which occurred several minutes after the exposure period, in both groups. Kruskal-Wallis test was performed to test whether the subjects were in the same condition throughout all the sham exposure sessions. The Mann-Whitney U-test was applied to examine significant differences in the percentages of those who believed they were being exposed between the EHS and non-EHS groups for the exposure and non-exposure.

III. Results

A Wilcoxon signed-rank test was performed to investigate any significant differences in pre-exposure, exposure, and post-exposure between the sham and real exposure sessions in either group (Table 2). In the EHS group, there were no significant differences in pre-exposure (p=0.66), exposure (p=0.45), and post-exposure (p=1.00). For the non-EHS group, there were also no significant differences in pre-exposure (p=1.00), exposure (p=0.18), or post-exposure (p=1.00). To test whether the subjects were in the same condition throughout all the sham exposure sessions, we applied the Kruskal-Wallis test and found no difference in the percentages of those who believed they were being exposed among pre-exposure, sham exposure and post-exposure in the EHS (p=0.26) and non-EHS groups (p=0.43).

Fig. 3A, B shows the percentages of subjects who believed they were being exposed according to the inquiry numbers of the EHS and non-EHS groups in the sham and real exposure sessions, respectively. Even though there were significant differences between the EHS and non-EHS groups during the real exposure session in Fig. 3B, there were also significant differences during the sham exposure session in Fig. 3A. Therefore, it seems that the significant differences between the EHS and non-EHS groups during real exposure were not caused by true real exposure. The same reasoning applies to the significant difference during post-exposure in both the sham and real exposure sessions. Even though the percentages of belief of being exposed in the EHS group were higher than those of the non-EHS group in all inquiry numbers during real exposure in Fig. 3B, higher percentages were also observed for pre-exposure, sham exposure and post-exposure for both sessions.

TABLE II. Percentages of those who believed they were being exposed during pre-exposure, exposure, and post-exposure, and P-values for sham and real exposures in the EHS and Non-EHS groups.

Group	Session	Pre-exp (%)	P-value	Exp (%)	P-value	Post-exp (%)	P-value
EHS (n=17)	Sham	41.2	0.66	61.2	0.45	62.8	1.00
	Real	47.1		65.9		62.8	
Non-EHS (n=20)	Sham	0.0	1.00	8.0	0.18	6.7	1.00
	Real	0.0		5.0		6.7	

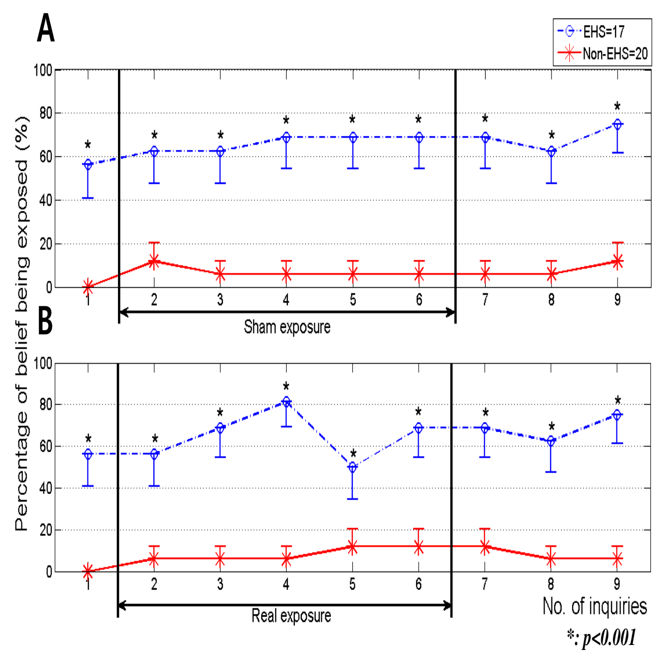

Figure 3. Percentage of those who believed they were being exposed for the nine inquires in the EHS and non-EHS groups for sham (A) and real (B) exposure sessions. Asterisks indicate statistical significance in the percentages of percieved exposure between the EHS and non-EHS groups.

IV. Discussion and Conclusion

There were no significant differences in the percentages of whose who believed they were being exposed between the post-real and post-sham exposures in the EHS and non-EHS groups. There were also no significant differences in the percentages of perceived exposure in the pre-exposure periods between the real and sham exposures in the EHS and non-EHS groups. There were no differences in the percentages of perceived exposure among the pre-exposure, sham exposure, and post-exposure periods in the EHS and non-EHS groups. Therefore, our experimental protocol seems minimally biased since we confirmed that there were no delayed effects, no differences in pre-exposure condition, and no differences in the percentages of those who believed they were being exposed among the pre-exposure, sham exposure, and post-exposure periods.

Even though the percentage of the EHS group who believed they were being exposed during the real exposure was high (65.9 %), the percentage of that during the sham was also high (61.2 %). There was no significant difference between these percentages. In conclusion, there is no indication that EHS subjects perceive EMFs emitted from WCDMA mobile phones better than non-EHS subjects.

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