Hypersensitivity to RF Fields Emitted From CDMA Cellular Phones: A Provocation Study

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With the number of cellular phone users rapidly increasing, there is a considerable amount of public concern regarding the effects that electromagnetic fields (EMFs) from cellular phones have on health. People with self-attributed electromagnetic hypersensitivity (EHS) complain of subjective symptoms such as headaches, insomnia, and memory loss, and attribute these symptoms to radio frequency (RF) radiation from cellular phones and/or base stations. However, EHS is difficult to diagnose because it relies on a person’s subjective judgment. Various provocation studies have been conducted on EHS caused by Global System for Mobile Communications (GSM) phones in which heart rate and blood pressure or subjective symptoms were investigated. However, there have been few sham-controlled provocation studies on EHS with Code Division Multiple Access (CDMA) phones where physiological parameters, subjective symptoms, and perception of RF radiation for EHS and non-EHS groups were simultaneously investigated. In this study, two volunteer groups of 18 self-reported EHS and 19 non-EHS persons were tested for both sham and real RF exposure from CDMA cellular phones with a 300 mW maximum exposure that lasted half an hour. We investigated not only the physiological parameters such as heart rate, respiration rate, and heart rate variability (HRV), but also various subjective symptoms and the perception of EMF. In conclusion, RF exposure did not have any effects on physiological parameters or subjective symptoms in either group. As for EMF perception, there was no evidence that the EHS group better perceived EMF than the non-EHS group.

Key words: RF exposure; subjective symptoms; provocation study; heart rate variability; perception

INTRODUCTION

Among Korea’s 47 million population, the number of cellular phone subscribers reached more than 40 million in 2006 [Park, 2007]. Social concerns regarding the possible effects of electromagnetic fields (EMFs) emitted from cellular phones on human health have increased accordingly. The number of people with self-attributed electromagnetic hypersensitivity (EHS) who complain of various subjective symptoms such as headaches, insomnia, nervousness, distress, fatigue, and short-term memory loss has increased as well [Aringer et al., 1997; Röösli et al., 2004].

According to studies conducted in Sweden and California, USA, the size of the population that has experienced one or several of various EHS symptoms was 1.5% and 3.2%, respectively [Hillert et al., 2002; Levallois et al., 2002]. These studies were limited and only gave very crude indications of the numbers of people with EMF-attributed symptoms. Röösli et al. [2004] reported that sleep disorder (58%), headache (41%), nervousness or distress (19%), fatigue (18%), and concentration difficulties (16%) were the most common

Grant sponsors: Korea Science and Engineering Foundation (KOSEF), grant funded by the Korea Government (MEST) (No. R01-2007-000-20819-0); Korea Health 21 R&D Project, MIHWAF, Republic of Korea (No. A040032).

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Received for review 3 April 2008; Final revision received 21 April 2009

DOI 10.1002/bem.20518
Published online 23 June 2009 in Wiley InterScience (www.interscience.wiley.com).
complaints in Switzerland. People with complaints most frequently related their symptoms to exposure to mobile phone base stations (74%) followed by mobile phones (36%), cordless phones (29%), and power lines (27%). This implies that EHS could not only deteriorate the quality of individual patients’ lives, but also cause an increase of social expenses for health care.

Mueller et al. [2002] found that 7 of 63 subjects showed statistically significant results that pointed to the existence of a small 50 Hz EMF-sensitive subgroup within the study group that consisted of 49 EHS and 14 non-EHS persons. However, there was no difference in EMF perception between the subjects with and without self-reported hypersensitivity, suggesting that subjective hypersensitivity is not a prerequisite for the ability to perceive EMF and vice versa. Frick et al. [2005] reported that their experiment using transcranial magnetic stimulation did not support the hypothesis that subjectively electrosensitive patients suffered from a physiological hypersensitivity to EMFs stimuli. Another study by Kwon et al. [2008] also provided lack of evidence for the existence of electromagnetic perception to the Global System for Mobile Communications (GSM) mobile phone EMF. In a recent review, Röösli [2008] concluded that the available provocation studies do not indicate that people can perceive radio frequency (RF)-EMF or that symptoms are directly invoked by them. There is no explanation for the symptoms other than a psychosomatic mechanism.

Braune et al. [1998] found increased resting blood pressure of healthy subjects during RF exposure from 900 MHz GSM cellular phones. However, another study by Braune et al. [2002] revealed that when 40 healthy young females and males were exposed to sham and real RF EMF for 2 days, all of the measured variables including blood pressure, heart rate, peripheral blood flow, norepinephrine, and epinephrine in the blood were not related to EMF. Tahvanainen et al. [2004] reported that the use of 900 and 1800 MHz GSM cellular phones for 35 min did not acutely affect the blood pressure or heart rates of 32 healthy subjects. Parazzini et al. [2007] also reported that 900 MHz GSM cellular phone exposure (2 W) for 26 healthy young volunteers had no statistically significant effect on mean heart rate and most of the other heart rate variability (HRV) parameters, although a weak interaction was observed between some HRV parameters and RF exposure. Hietanen et al. [2002] also reported no relationship of EMF from the 900 MHz Nordic mobile telephone (NMT), which is an analog cellular protocol used in Europe, 900 MHz GSM, and 1800 MHz GSM cellular phones with changes in physiological responses such as blood pressure or respiration rate or with subjective symptoms in the EHS group. From these previous studies, GSM exposure seemed to have no effect on heart rate, respiration rate, or HRV for healthy or EHS subjects.

The power spectrum of HRV has been known to be an effective quantitative measure to evaluate the action of sympathetic and parasympathetic nerves of the autonomic nervous system [Akselrod et al., 1981; Pomeranz et al., 1985; Hjortskov et al., 2004; Parazzini et al., 2007]. Our study first obtained HRV from electrocardiograms (ECG) and then acquired the power spectrum of HRV. There are three peaks in the power spectrum of HRV. The first peak is the very low-frequency power (VLFP) that appears at less than 0.04 Hz, the second peak is the low-frequency power (LFP) that appears at 0.04–0.15 Hz, and the third peak is the high-frequency power (HFP) that appears at 0.15–0.4 Hz [Parazzini et al., 2007]. HFP reflects the effects on the parasympathetic nerve by the respiratory sinus arrhythmia (RSA), whereas LFP reflects the effects on the sympathetic and parasympathetic nerves. Therefore, LFP/HFP was used as an index for the balance of autonomic nerve activity in this study. Although various interpretations have been proposed for VLFP, a clear conclusion has not yet been made. Accordingly, it has been excluded from most studies evaluating the autonomic nervous system [Akselrod et al., 1981; Pomeranz et al., 1985].

Code Division Multiple Access (CDMA) is a digital wireless technology transmitting simultaneous signals over a shared portion of the spectrum using the 800 MHz band and the 1.9 GHz personal communications services (PCS) band, and it has become widely used in North America. However, few studies on EHS have been conducted with CDMA cellular phones, except our previous study that examined the physiological effects of RF exposure from CDMA cellular phones on teenagers and adults [Nam et al., 2006]. Moreover, studies that investigated physiological parameters, subjective symptoms, and EMF perception simultaneously for both the EHS and non-EHS groups are very rare. Studies that have investigated the various physiological parameters include: Pomeranz et al. [1985], Braune et al. [1998], Hjortskov et al. [2004], Tahvanainen et al. [2004], Parazzini et al. [2007]. The following studies reported various subjective symptoms: Aringer et al. [1997], Koivisto et al. [2001], Hietanen et al. [2002], Hillert et al. [2002], Wilen et al. [2006], Eltiti et al. [2007], Oftedal et al. [2007], Röösli [2008]. A few EMF perception studies include: Mueller et al. [2002], Leitgeb and Schrottner [2003], Rubin et al. [2006], Kwon et al. [2008].

In this study, we measured heart and respiratory rates for both the EHS and non-EHS groups and then obtained the HRV using measured heart rate. In
addition, the subjects were asked to describe EMF perception and subjective symptoms such as headaches, fatigue, dizziness, etc., during sham/real exposure and non-exposure sessions. The aim of this study was to test whether EMF from CDMA cellular phones influences heart rate, HRV, respiratory rate, or gives rise to subjective symptoms in EHS and non-EHS subjects. Furthermore, the other aim of this study was to compare EHS and non-EHS subjects’ ability to distinguish between real and sham EMF.

MATERIALS AND METHODS

Subjects

A total of 37 subjects participated in this experiment: 18 EHS subjects (8 males and 10 females; 26.1 ± 3.4 years) and 19 non-EHS subjects (10 males and 9 females; 25.0 ± 2.3 years). There were no statistical differences in the ages ($P = 0.272$), male–female ratios ($P = 0.746$), smoking ($P = 1.000$), body mass index (BMI; $P = 0.491$), cellular phone usage/day ($P = 0.351$), and usage period (years) ($P = 0.731$) between either of the groups. All of the healthy EHS subjects described themselves as hypersensitive to RF fields emitted only by CDMA cellular phones and not to ELF (extremely low frequency) fields. They were recruited by advertisements at the Yonsei University Hospital System (YUHS). Self-reported EHS subjects concerned with payment for volunteering were excluded from this study. The non-EHS group included healthy graduate school students and hospital staff. All subjects in this study used CDMA phones in their daily lives. All subjects were informed of the purpose and procedure of the experiment and were asked to give a written consent to it in advance. The Institutional Review Board (IRB) of the YUHS approved the full protocol of this study (Project number: 4-2006-0301).

Physiological Measurement

Figure 1 shows a complete experiment setup to evaluate EHS during CDMA cellular phone usage. The subjects’ heart rates, respiration rates, and HRV were obtained with a PolyG-I (Laxtha, Daejeon, Korea) and MP100 (BIOPAC, Goleta, CA) by an unseen operator and data were transferred to a nearby notebook PC (SV20, Samsung Electronics, Suwon, Korea) using Telescan 0.9 (Laxtha) and AcqKnowledge3.73 (BIOPAC) for analyses. The PolyG-I-recorded ECG through Ag–AgCl electrodes (2223, 3 M, St. Paul, MN) placed on both arms and the right leg of participants, as shown in Figure 1. Respiratory inductance plethysmography (RIP) was used to measure respiration rate. A coiled band was worn around subjects’ abdomens to measure inductance changes resulting from cross-sectional change. We also monitored the temperature change of facial skin facing cellular phones to ensure that the subjects were unaware that the phone was operating. A temperature module (SKT100C, BIOPAC) and a skin temperature sensor (TSD202B, BIOPAC) that was attached to the cheek facing the cellular phone’s keypad were used. The accuracy of the temperature sensor was 0.2 °C. The skin resistance level (SRL) was measured with a galvanic skin response amplifier (GSR100C, BIOPAC). The middle and fourth fingers were wrapped with 3 M mesh-type electrodes to investigate changes in average skin resistance [Nam et al., 2006].

Subjective Symptoms and Perception of EMF

Persons with symptoms like headaches, insomnia, fatigue, etc., cannot be confirmed by only measuring physiological changes such as heart rate, respiration, and HRV. In this study, nine subjective symptoms such as redness, itching, warmth, fatigue, headaches, dizziness, nausea, palpitation and indigestion were evaluated through verbal surveys that were graded on a four-point scale used by Koivisto et al. [2001] during their measurement of physiological variables. In addition, perception of RF exposure was investigated every 5 min during the entirety of the sessions. Subjects were asked nine times to answer the question “Do you feel EMF right now?”

Experimental Setups and Procedures

The lab was used exclusively for this experiment and there was no other electrical equipment present except our instruments in order to minimize
background field levels as shown in Figure 1. The background ELF and RF fields in the lab were measured to ensure that subjects were not influenced by the background fields. The average ELF electric and magnetic fields were measured at 2.3 ± 0.1 V/m and 0.04 ± 0.02 μT, respectively, using an ELF survey meter (HI-3604, Holaday, Minnetonka, MN) and ELF gauss meter (EMDEX-II, ENERTECH, Campbell, CA). The RF field was measured at 0.7 ± 0.0 V/m with a frequency range from 824 to 849 MHz using a radiation meter (SRM 3000, Narda GmbH, Pfullingen, Germany).

A conventional headset was modified to contain a folder-type CDMA phone (SCH-V300S, Samsung Electronics) on the left side as shown in Figure 2. The lower part of the cellular phone with the keypad was wrapped with a 5 mm thick insulating material so that the subject would not be aware of whether the phone was operating through its generated heat. The insulating material of the battery side was cut open to allow battery heat to dissipate. To confirm the insulation effect, changes in facial skin temperature were measured throughout the experiment. According to the CDMA phone manufacturer’s information, the spatial peak specific absorption rate (SAR) for the SCH-V300S was 1.22 W/kg averaged over 1 g of brain tissue, which was measured by the Radio Research Agency in Korea. Its transmitting frequency range was 824.64–848.37 MHz and the carrier frequency was 835 MHz. The phone was set to the test mode that radiates continuous clipped sine waves with a maximal transmission power of 300 mW.

Sham and real exposures were conducted to minimize test bias resulting from a subject recognizing the operational state of the cellular phone (single blind). Before the experiment, subjects were made to rest in the supine position on the experimental bed for at least 10 min. Since having a conversation over the phone might affect the subject’s mental conditions or physiological functions, measurements were made without any actual conversation. 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 in order to maintain the subject’s physiological rhythm. The order of sham and real exposures for a subject was randomly assigned to minimize experiment bias. The numbers of EHS and non-EHS that had sham exposure first were 10 of 18 and 11 of 19, respectively.

The duration of each exposure session was 64 min as shown in Figure 3. Physiological data were collected with the headset on the subject’s head at four different stages: pre-test rest (stage I), after 15 min of exposure (stage II), after 31 min of exposure (stage III), and 10 min after exposure termination (stage IV). At each stage, ECG, respiration, and facial temperature were simultaneously measured during the first 5 min of the stage because of the long data requirement for HRV. The four shaded areas are periods during which they were questioned regarding various symptoms, and each period lasted approximately 1 min.

Questions regarding RF perception were asked every 5 min from just before exposure started to 11 min after exposure ceased. The “o” and “x” indicated timings when RF perception was inquired for exposure (real/sham) and for non-exposure, respectively. During exposure sessions, the RF perception question was asked five times during exposure and four times subjects were asked nine times. During sham exposure sessions, subjects were asked nine times. The total number of inquiries was: 185 (5 × 37) during exposure and 481 (13 × 37) during non-exposure, where 37 (19 + 18) was the total number of subjects. Room temperature was recorded and kept constant throughout the experiment.

Fig. 2. The headset with an insulated folder-type cellular phone attached. The insulating material of the battery side was cut open to allow heat from the battery to dissipate.

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the experiment, because this factor could considerably affect outcomes. The temperature was \(22.5 \pm 1.1 \, ^\circ C\) and relative humidity was \(56.1 \pm 4.4\%\). After applying paired \(t\)-test, there were no significant differences between real and sham sessions in temperature \((P = 0.336)\) and humidity \((P = 0.329)\).

Data Analysis and Statistical Process

As for ECG and respiration, data from the first minute were selected from the 5 min recording. As for temperature, the first 1-min data were picked up from the 5 min recording and averaged for analysis. For HRV, the \(R-R\) intervals were acquired from the measured 5 min of ECG data and its power spectrum was obtained using software (TeleScan Ver.2.8, Laxtha). LFP/HFP was calculated with HRV power spectrum to analyze changes in the autonomic nervous system. To analyze the relative change in LFP/HFP, the resting LFP/HFP of real and sham exposures was 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 physiological effects of exposure and duration with the CDMA cellular phone use on heart rate, respiration rate, and LFP/HFP for each group. Bonferroni post hoc test followed the two-way ANOVA to investigate any difference in LFP/HFP between each stage for each group. Since subjective symptoms were ordered data, the non-parametric statistical method of Wilcoxon signed-rank test was used for analysis. All the \(P\)-values between real and sham exposures were obtained for four stages of nine symptoms for both the EHS and non-EHS groups. The total number of the \(P\)-values was 72 \((4 \times 9 \times 2)\).

There were two sessions of sham and real for each EHS and non-EHS person and nine perception inquiries for each session. For each session, there was one inquiry in the pre-exposure stage, five inquiries in sham or real exposure stage, and three inquiries in post-exposure stage. Nine perception accuracies of EHS and non-EHS groups were obtained for the sham and real exposures as percentages of correct answer. Paired \(t\)-test was applied to examine significant differences between the EHS and non-EHS groups for the exposure and non-exposure. Exposure or non-exposure perception accuracy refers to accuracy during exposure or non-exposure. It was calculated by dividing the number of total correct answers by the number of total questions given during exposure or non-exposure.

RESULTS

Skin Temperature

Figure 4 shows temperature changes in facial skin facing a cellular phone at rest, 15 and 30 min of exposure, and 10 min after exposure with sham and real exposures for EHS and non-EHS individuals. For the EHS group, there were no statistically significant differences between sham and real exposures \((P = 0.304)\), or between each stage \((P = 0.055)\). For the non-EHS group, there were no statistically significant differences between sham and real exposures \((P = 0.587)\), or between each stage \((P = 0.085)\).

Skin Conductance

Our previous study found that average SRL significantly decreased due to RF exposure from CDMA phones in the teenage group without any questions regarding symptoms or RF perception [Nam et al., 2006]. However, in the present study, while responding to questions regarding symptoms and RF radiation perception, 10 of the 37 subjects showed considerably varied skin conductance because of increased sweat secretion resulting from excited sympathetic nervous systems [Critchley, 2002]. Even though different degrees of slopes or baseline drifts were observed in four subjects as shown in Figure 5A–D, conductance increased abruptly during the questioning period in four subjects, whereas it kept quite stable before the inquiry period. In three subjects, conductance had slight ups and downs even after answering the questions, as shown in Figure 5B–D. Accordingly, it was found that even responding to a few questions could stimulate the sympathetic nervous system. Based on the above findings, skin conductance measurement was assumed to be inappropriate and thus not adopted in this study.

Heart and Respiration Rates

Figure 6 shows the heart and respiration rates at each stage for the sham and real exposures in the EHS and non-EHS groups. The error bars indicate standard
deviations. For the EHS group, there were no statistically significant differences between sham and real exposures in heart \((P = 0.645)\) and respiration rates \((P = 0.108)\), or between each stage in heart \((P = 0.097)\) and respiration rates \((P = 0.987)\). Also for the non-EHS group, there were no statistically significant differences between sham and real exposures in heart \((P = 0.395)\) and respiration rates \((P = 0.210)\), or between each stage in heart \((P = 0.101)\) and respiration rates \((P = 0.329)\).  

**LFP/HFP**

There were no significant differences between sham and real exposures in LFP/HFP at each stage for the EHS and non-EHS groups \((P > 0.05)\) as shown in Figure 7. As for the EHS group in Figure 7A, statistically significant differences were found for LFP/HFP ratios obtained at some of the stages \((P = 0.001)\). By applying Bonferroni multiple comparison test, we found that there were significant ratio differences between at rest and 15 min of real exposure \((P = 0.038)\), and between at rest and 10 min after sham exposure ceased \((P = 0.017)\). However, no difference was found between sham and real exposures \((P = 0.383)\) without an interaction effect between exposure and its stage \((P = 0.246)\).  

For the non-EHS group, as shown in Figure 7B, statistically significant differences were found for...
LFP/HFP ratios obtained at some stages \( (P = 0.019) \). By applying the Bonferroni test, we found that there were significant ratio differences between at rest and 30 min of real exposure \( (P = 0.039) \), and between at rest and 10 min after sham exposure ceased \( (P = 0.002) \). As in the EHS group, however, there were no statistically significant differences between sham and real exposures \( (P = 0.658) \) without an interaction effect between exposure and its stage \( (P = 0.389) \). It was observed that LPF/HPF monotonically increased at each exposure stage during sham exposure in both groups. The other finding was that the standard deviations of LFP/HFP in the EHS sham group are larger than those in the non-EHS sham group reflecting larger variability in the EHS group.

**Subjective Symptoms**

Neither the EHS nor non-EHS groups showed statistically significant differences between real and sham exposures for all nine subjective symptoms surveyed, which included redness, itching, warmth, fatigue, headache, dizziness, nausea, palpitation, and indigestion. All 72 (9 symptoms \( \times \) 4 stages \( \times \) 2 groups) \( P \)-values between real and sham exposures were larger than 0.05, ranging from 0.056 to 1.000. The smallest \( P \)-value of 0.056 was for warmth at 30 min exposure in the non-EHS group.

**Perception Accuracy**

The accuracy of the nine inquiries for the EHS and non-EHS groups was calculated in the real and sham sessions as shown in Figure 8. In the case of the sham sessions (Fig. 8A), the accuracy of the non-EHS group showed itself to be higher than that of the EHS group, except for the first inquiry. One interesting point in the EHS group during the real session (Fig. 8B) was the accuracy in showing monotonic increases in inquiry numbers 7 (61\%), 8 (72\%), and 9 (89\%) after stopping real exposure. This may be due to the delayed effect of the previous real exposure period. However, for real exposure of the non-EHS group, there was no accuracy difference between inquiry numbers 1 (100\%) and 7, 8, and 9 (100\%). Therefore, this effect was not shown in the real exposure session for the non-EHS group.

The real exposure accuracy for the EHS and non-EHS groups was 43.3\% and 3.2\%, respectively, while the non-exposure accuracy for the EHS and non-EHS groups was 73.9\% and 95.1\%, respectively. Statistical analysis showed a significant difference between the...
EHS and non-EHS groups in perception accuracy during exposure and non-exposure ($P = 0.000, 0.001$). This significant statistical difference resulted from the bias that EHS persons believe they can feel EMF while non-EHS persons do not believe they can feel it.

**DISCUSSION**

As there have been few reports conducted on EHS attributed to CDMA phones, and the RF characteristics of CDMA and GSM phones are quite different, it is not possible to directly compare the results of this study with others. There have been a few studies on symptoms in relation to Universal Mobile Telecommunication System (UMTS) or Wide CDMA (WCDMA) base station-like exposure [Regel et al., 2006; Riddervold et al., 2008; Furubayashi et al., 2009], but the frequency used in these studies were 2.14 GHz different from the 835 MHz of CDMA, which was used in our study.

Neither the EHS group nor the non-EHS group showed significant differences in heart rate and respiration rate between real and sham exposures or as a function of duration. In the case of LFP/HFP, however, there were significant differences between some stages for both groups, whereas there was neither a difference between sham and real exposures nor an interaction effect between exposure and its stage for either group. Even though the experiments were performed during the day, drowsiness was observed in approximately half of all subjects due to being in a comfortable posture for more than an hour in a quiet room. When the examiner noticed any subject’s drowsiness, he made a noise to wake the subject up. Such a continuous increase of LFP/HFP from rest to 15 and 30 min, and 10 min after the end of the session during sham exposures of both groups is assumed to have been caused by sleep deprivation during the 64-min experiment. Zhong et al. [2005] reported that sleep deprivation could increase LFP and LFP/HFP. A method to minimize this unwanted phenomenon should be investigated in future study. If a method is secured, HRV could be made more reliable. Because of the relatively small number of subjects and the large standard deviations of LFP/HFP in our study, the statistical power of LFP/HFP was smaller than 0.8, which is assumed to be a minimum value.

For symptoms related to RF-EMF exposure, there were no significant differences in any of the subjective symptoms between the sham and real exposures for either group. Previous studies did not find associations between symptoms and RF-EMF exposure for healthy subjects [Koivisto et al., 2001; Fritzer et al., 2007] and EHS subjects [Hietanen et al., 2002; Regel et al., 2006; Ofstedal et al., 2007]. In a previous study, EHS individuals had an increased arousal score as well as borderline significant increased tension and anxiety scores when exposed to a UMTS base station signal compared to sham [Elitti et al., 2007]. There were two studies using GSM mobile phones that reported no significant difference in various subjective symptoms between sham and real exposures for EHS and non-EHS groups [Rubin et al., 2006; Wilen et al., 2006].

Although the EHS group’s accuracy during exposure (43.3%) was 40.1% higher than that of the non-EHS group (3.2%), the EHS group’s accuracy during non-exposure (73.9%) was 21.2% lower than that of the non-EHS group (95.1%). These results could be attributable to the fact that many subjects in the EHS group answered “Yes” to the question “Do you feel EMF right now?” because most of them had bias that they could feel EMF. On the other hand, the non-EHS group showed higher accuracy in perception during non-exposure because they assumed that they could not feel EMF. In a recent review, Röösli [2008] also concluded that the vast majority of individuals who claimed to be able to detect low-level RF-EMF were not able to do so under double-blind conditions.

**CONCLUSION**

There have been numerous studies on EHS due to RF exposure from GSM cellular phones that showed various results depending upon experimental methods and procedures. However, there have been few studies that investigated physiological parameters, subjective symptoms, and EMF perception simultaneously using CDMA phones for the EHS and non-EHS groups. Our study found no significant differences in LFP/HFP at each exposure stage between real and sham exposures in either group, but observed monotonically increased LFP/HFP at each exposure stage during sham exposure in both groups. Therefore, it would be more appropriate to use a less comfortable chair instead of the comfortable bed used in this study and over the shortest experiment duration possible, without weakening the experiment, to avoid drowsiness in a future study. Usage of heart rate or HRV with unwanted drowsiness may falsely indicate the effects of RF radiation by mobile phones on the autonomic nervous system.

Another important finding of this study is that skin resistance or conductance level is not an appropriate parameter to investigate the autonomic nervous system because of an abrupt conductance change observed while investigating subjective symptoms or the perception of EMF. However, it is still a good parameter for investigating the autonomic nervous system if there are no inquiries for subjective symptoms or RF perceptions involved in the test.
In conclusion, 300 mW exposures from CDMA phones did not have any effects on heart or respiration rate or subjective symptoms in either group. As for EMF perception, there was no evidence that the EHS group better perceived EMF than the non-EHS group. Lastly, this study regarding the perception of EMF showed the possibility of a delayed exposure effect in the EHS group. In future studies, the number of subjects should be increased in order to have greater statistical power than 0.8 for HRV analysis.

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