

An Analytical Comparison in Electroencephalography and Electrocardiography under Pulsed Magnetic Field and Acupuncture Stimulus on Acupoint PC9

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We have investigated the changes of electroencephalography (EEG) and electrocardiography (ECG) under pulsed magnetic field (PMF) and acupuncture stimulus on acupoint PC9. In order to compare quantitatively the effect of PMF and acupuncture stimulus, the difference of alpha activities are calculated from EEG spectra, and the spectrum curves of ECG were analyzed in the frequency domain of heart rate variability (HRV). The increase of alpha activities after both stimuli could be explained that the impulse of stimulus on PC9 might pass through sensory nerve following meridian and approach the cerebral cortex, causing the central nervous system (CNS) to be activated for pacifying emotion and calming the mind. The decrease in sympathovagal activity of HRV after both stimuli indicates that parasympathetic nerves were activated and the sympathetic nerves were in constrained condition. These findings suggest that PMF could be patient-friendly alternative non-invasive medical treatment for influencing human physiology, in comparison with acupuncture inserting the needle and inducing nervous and anxious state to subject.

Keywords : pulsed magnetic field stimulus, acupuncture, electroencephalogram, alpha activity, heart rate variability, autonomic nervous system

1. Introduction

Exposure to pulsed magnetic field (PMF) has been shown to have a therapeutic uses for a variety of medical conditions including musculoskeletal disorders, rheumatological disorders, soft-tissue regeneration, nerve, and neurological disorders including mental stress, etc. [1]. As recent increasing attention on PMF stimulus to human body, diverse studies are being conducted to elucidate its effects on human physiology [1]. For example, Ieran M *et al.* reported that low frequency PMF was useful for healing of skin ulcers of venous origin in humans and Riva Sanseverino *et al.* led to the conclusion that magnetic field treatment was an excellent physical therapy in cases of joint diseases by means of PMF treatment at extremely low frequencies and intensities to 3,014 patients

[2, 3]. In addition, Richards T. L *et al.* demonstrated a statistically significant effect of PMF stimulus on patient performance scales and on alpha electroencephalography (EEG) magnitude during a language task [4]. Our group has also shown the effects of autonomic nervous system (ANS) and microvascular blood system under the pulsed electromagnetic fields [5, 6].

On the other hand, acupuncture in traditional Chinese medicine has been a tool of medical treatment for influencing human physiology during the past few decades and is used clinically to relieve pain and a wide variety of mostly chronic disorders. Many studies have attempted to elucidate its mechanism of action and R. Melzack and P.D. Wall proposed the theory for how acupuncture affects the nervous system called the gate theory [7, 8]. Recently Sakatani K *et al.* also evaluated the effects of acupuncture on ANS and frontal lobe activities because acupuncture is known to be helpful in treating ANS dysfunction caused by mental stress [9].

There are several acupoints known to sedation and tonification point, which induce a relaxed mental state if those points are stimulated. An acupoint PC9 among them, in this study, was chosen as application of external stimulus

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to investigate correlation of EEG alpha activity in the human brain and heart rate variability (HRV) and to understand its specific effects on cerebral function and the ANS. The location of the acupoint PC9 is in the center of the tip of the middle finger, and one of pericardium meridian points.

Among several bio-signals measured from human body, EEG, the recording of electrical activity along the scalp, and electrocardiography (ECG) are known to be non-invasive tools with no side effect and provide real-time information on autonomic nervous activity. An increase of alpha wave power in the frequency range of 8-13 Hz in EEG activity reflects the relaxation and diminishing stress and tension. Therefore, the change in alpha wave power will be especially effective for explanation of autonomic nervous functions in the central nervous system (CNS) [5]. On the other hand, frequency analysis of oscillation in R-R intervals of ECG has been widely applied to assess HRV as a marker of autonomic nervous activity. In most physiological conditions of ANS, the efferent sympathetic and parasympathetic branches have opposing actions: the sympathetic system enhances automaticity, whereas the parasympathetic system inhibits it. Accordingly, the power spectral analysis of HRV provides the explanation of the activity of the sympathetic and vagal components of the ANS on the sinus node of the heart. The aim of the current study was, by using EEG and ECG signal, to investigate the effects of PMF and acupuncture stimulus on acupoint PC9, respectively, with quantitative comparison.

2. Experimental Method

Our PMF stimulator system was designed to generate a PMF with a maximum intensity variation of 0.67 T at a transition time of 0.075 ms, with pulse intervals of 2 Hz. The schematic diagrams of the measurement system and PMF waveforms generated from our stimulator were described in our previous paper [10]. Fig. 1(a) shows the location of the acupoint PC9. The photographs of experimental setup of PMF stimulus and insertion of acupuncture needle for the measurement of EEG and ECG are shown in Fig. 1(b) and (c), respectively.

In this study, 6 healthy male subjects participated with written consent before the study. Since EEG and ECG signals were very sensitive to surrounding noisy environment, as well as mental state of the subject, the subject was asked to take a rest for approximately 30 min. prior to PMF and acupuncture treatment. MP150 system (BIOPAC Systems, Inc., Santa Barbara, CA, USA) and Acknowledge programs were used to analyze both the EEG and ECG data.

The EEG and ECG data were measured with the sub-

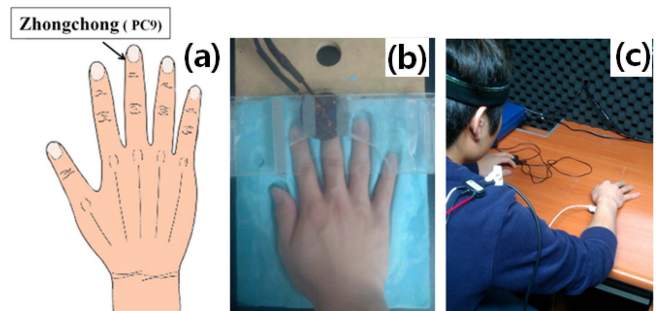


Fig. 1. (Color online) (a) The location of the acupoint PC9, (b) the photographs of experimental setup of PMF stimulus and (c) insertion of acupuncture needle for the measurement of EEG and ECG.

ject alert, but with eyes closed and recorded for 3-min resting before PMF and acupuncture stimulus and continuously during stimulus and after removing stimulus in order to find out whether there were any changes in psychophysiological parameters; alpha activity and HRV. In order to compare quantitatively the effect of PMF and acupuncture stimulus, the difference of alpha activities are calculated from EEG spectra compared with before and after stimulus, and the spectrum curves of ECG were analyzed in the frequency domain of HRV.

Fig. 2(a) is a continuous enlarged raw EEG data set, and (b) and (c) showed the extracted alpha band of power spectra before and after PMF/Acupuncture stimulus, respectively. Enlarged raw ECG data set and its power spectral density calculated using fast Fourier transformation (FFT) are shown in Fig. 2(d) and (e), respectively. Low frequency component (LF: 0.04-0.15 Hz) as a sympathetic index and high frequency component (HF: 0.15-0.4 Hz) as a parasympathetic index are expressed in Fig. 2(e). In order to obtain the information of sympathetic and parasympathetic activities of the ANS, LF/HF power ratio (LHR) as a reflection of sympathovagal activity was calculated from the normalized LF and HF power divided by total power.

3. Results and Discussion

Since our previous study has reported the PMF stimulus of 3-4 min on PC9 is suitable to increase alpha activity inducing a relaxed mental state, the duration of PMF stimulus, in the present work, was fixed to 3 min. to see the changes in EEG alpha activities [5, 10]. But acupuncture stimulus was manipulated for 10 min according to conventional acupuncture therapy. Fig 3 shows the changes in EEG alpha activities before and after stimulus for (a) PMF and (b) acupuncture, respectively, for selected 4

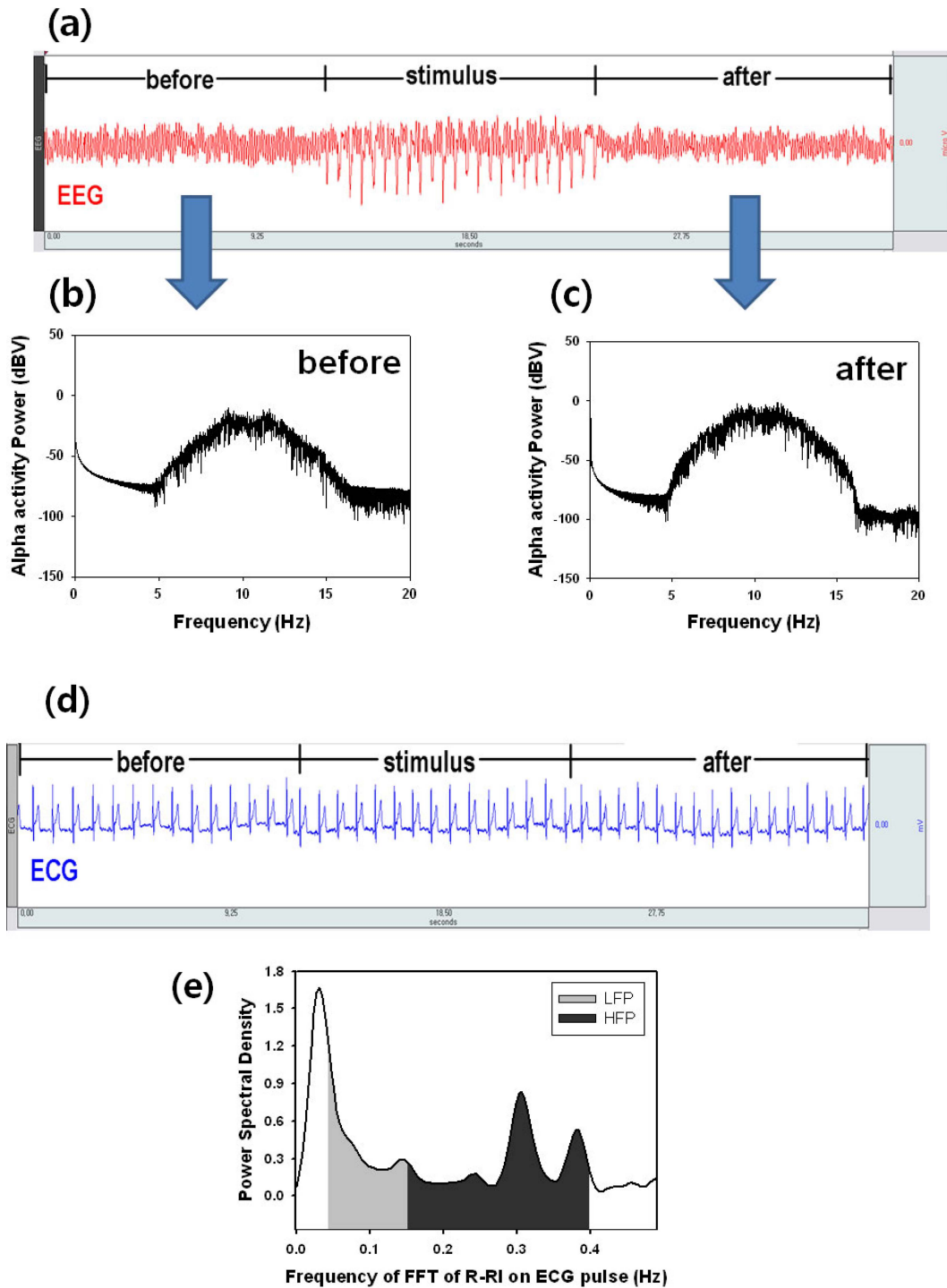


Fig. 2. (Color online) (a) A continuous enlarged raw EEG data set and the extracted alpha band of power spectra (b) before and (c) after PMF/Acupuncture stimulus. (d) Enlarged raw ECG data set, (e) its power spectral density calculated using fast Fourier transformation (FFT). Low frequency power (LF: 0.04-0.15 Hz) as a sympathetic index and high frequency power (HF: 0.15-0.4 Hz) as a parasympathetic index are expressed in grey and black color, respectively.

different subjects. The alpha activities before stimulus are indicated by the grey color, and those after stimulus are indicated by the black color. The increase of alpha activities

occurred in the range of 6-47% after PMF stimulus and 8-83% after acupuncture stimulus. This phenomenon could be explained that the impulse of stimulus on PC9 might

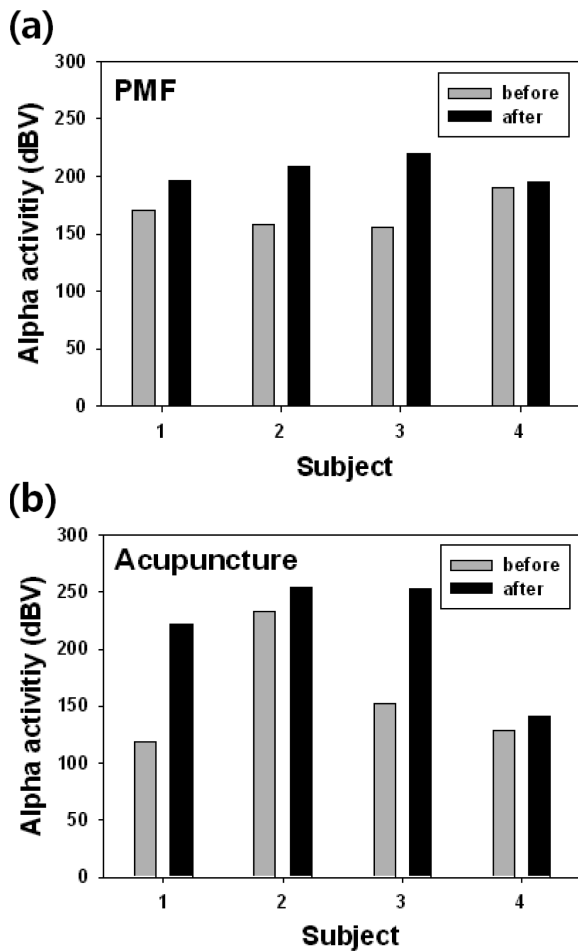


Fig. 3. Changes in EEG alpha activities before and after stimulus for (a) PMF and (b) acupuncture for 4 selected subjects. The alpha activities before stimulus are indicated by the grey color, and those after stimulus are indicated by the black color. The increase of alpha activities occurred in the range of 6-47% after PMF stimulus and 8-83% after acupuncture stimulus.

pass through sensory nerve following meridian and approach the cerebral cortex, causing the CNS to be activated for pacifying emotion and calming the mind.

Fig. 4 showed the LHR before, during and after stimulus of (a) PMF and (b) acupuncture, respectively. LHR, the indices of sympathetic activity after stimulus were obviously less than that of before stimulus in both cases of PMF and acupuncture. Lower LHR means that LF power is decreased and HF power is increased. These results indicate that the parasympathetic nerves were activated after both stimuli and the sympathetic nerves were in constrained condition. The higher LHR during both stimuli seems to be related to a state of tension and anxiety of subjects. The results of present study, from the observation of increase in alpha activity and lower LHR, provide scientific evidence that both stimuli of PMF and acupuncture on PC9 could

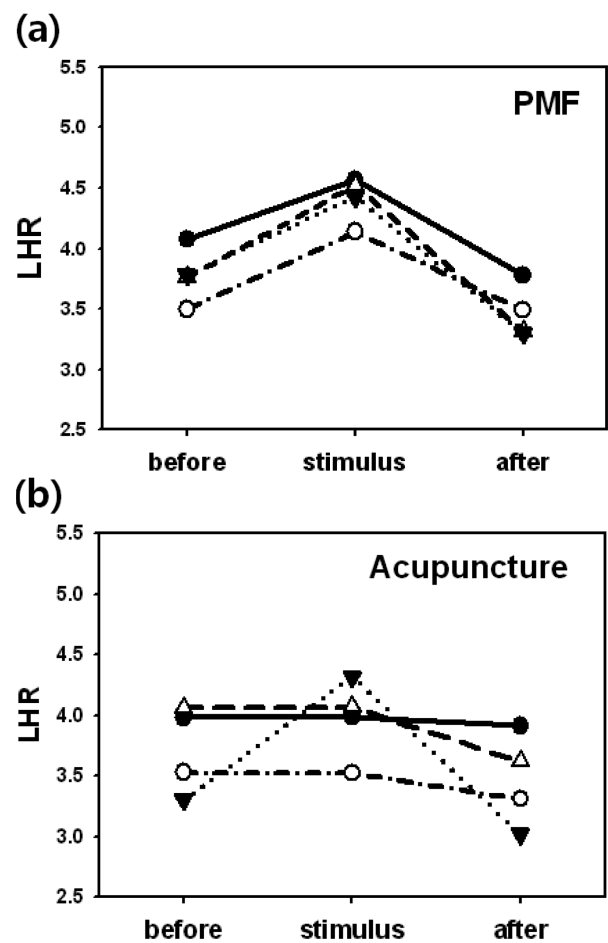


Fig. 4. The ratio of low frequency power and high frequency power (LHR) before, during and after (a) PMF stimulus (b) acupuncture stimulus, respectively. LHR, the indices of sympathetic activity after stimulus were obviously less than that of before stimulus in both cases of PMF and acupuncture.

lead to relaxation, calmness and reduction of tense feelings. Therefore PMF stimulus result in the same effect as that of acupuncture applied to the acupoint PC9, which boost the parasympathetic activity of ANS.

Accordingly, compared to the acupuncture inducing tense and impatient feeling due to its invasive treatment, PMF could be an alternative non-invasive medical treatment for influencing human physiology. Since our work was preliminary study which was done in six subjects, additional studies about the possible correlation between change in EEG alpha activity and the change in each LHR need to be performed with a large number of subjects and various conditions.

4. Conclusions

In the present study we have measured EEG and ECG

signal before, during, after PMF and acupuncture stimulus on PC9 and analyzed the signals using FFT in order to see the relaxed mental states. Using quantitative spectral analysis, marked increase in EEG alpha activity and decrease in LHR after PMF and acupuncture stimulus were observed. Our results provide scientific evidence that both stimuli on PC9 could lead to relaxation, calmness and reduction of tense feelings. And PMF could be an alternative non-invasive medical treatment for influencing human physiology, in comparison with acupuncture inserting the needle and inducing nervous and anxious state to subject.

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