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Effects of Electrical Acupuncture on Acupoint BL15 Evaluated in Terms of Heart Rate Variability, Pulse Rate Variability and Skin Conductance Response

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Abstract: In this research, heart rate variability (HRV), pulse rate variability (PRV) and human skin conductance (SC) of all acupoints on Heart Meridian were used to evaluate the effects of electrical acupuncture (EA) on acupoint BL15 (Bladder Meridian). Ten healthy volunteers (aged 23 ± 6) were selected as the control group on the first day, and then used again as the experimental group on the second day. The control group received sham EA during the study, while subjects of the experimental group were stimulated by 2 Hz EA on acupoint BL15 for 10 minutes. Electrocardiogram (ECG), wrist blood pressure pulse meter and skin conductance response (SCR) device were used to measure and analyze HRV, PRV and SCR for the two groups before and after stimulation. From the spectrum analysis of ECG and pulse pressure graph, we found that the EA applied on BL15 could induce a significant increase in the normalized high frequency power (nHFP) component of HRV and PRV, as well as a significant decrease in the normalized low frequency power (nLFP) part ($p < 0.05$). Moreover, both the heart rate and pulse rate were reduced in the analysis of the time domain of ECG and PRV. Furthermore, most of the SCR values at acupoints were decreased after stimulation. These results also indicate that the stimulation of BL15 by EA could cause relaxation, calmness and reduce feeling of tension or distress.

Keywords: Heart Rate Variability; Pulse Rate Variability; Skin Conductance Response; Electrical Acupuncture.

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Introduction

Electrical Acupuncture

Electrical acupuncture (EA) is the application of an electrical current to acupoints of the body to generate a slight pulsation through the needle into the muscle and meridian pathway. It is commonly used in Chinese medical practice for the treatment of pain, hypertension and heart disease (Cao *et al.*, 1998; Chu *et al.*, 2004; Williams *et al.*, 1991; Saku *et al.*, 1993; Tukmachi *et al.*, 2004). Numerous experimental and clinical studies have been performed to investigate the efficacy of EA (Schroedera and Barrb, 2001). Previous studies have speculated that acupuncture stimulates some sensory nerves or the autonomic nervous system and induces the recovery of blood circulation (Nishijo *et al.*, 1997; Tam and Yiu, 1975; Williams *et al.*, 1991). However, the mechanism by which EA produces its effects is not yet fully understood. In particular, it has been previously reported that traditional acupuncture using needles actually induces a change in heart rate variability (HRV) (Haker *et al.*, 2000). In light of these findings, we further speculate that the stimulation of acupoint BL15 by EA also modulates certain functions of the autonomic nervous system. This modulation could affect heart and blood pulse rates. Therefore, we monitored the electrocardiogram (ECG) and pulse rate variability (PRV), and performed spectrum analysis to better understand the mechanisms of EA.

As for the chosen stimulation frequency, a previous study of HRV showed that mild acupuncture could enhance vagal activities and suppress sympathetic activities (Wang *et al*., 2002a). In the research on EA, 2 Hz stimulation has often been used to represent the low-frequency mild acupuncture, and 100 Hz stimulation to represent the high-frequency excited acupuncture (Ku and Zou, 1993). Another experiment showed that 2 Hz was more efficient than 100 Hz EA on acupoint ST36 as evaluated by electrogastrography (EGG) (Chou *et al*., 2003). Furthermore, 2 Hz was used to stimulate mice and cause the induced depressor response in another previous study (Ku and Zou, 1993). These studies indicated that the low frequency of 2 Hz EA might be more effective in regulating the autonomic nerves.

Heart Rate Variability and Pulse Rate Variability

HRV and PRV have been considered recently as quantitative measurements for monitoring autonomic nervous activity (Akselrod *et al.*, 1981; Constant *et al.,* 1999; Gungormus and Buyukkurt, 2003; Maehara *et al.,* 2004; Pomeranz *et al*., 1985; Sharpley, 1994). They can also be used to investigate the correlation between autonomic function and acupuncture in Chinese medicine (Li *et al*., 2003). In recent years, several digital signal processing algorithms have been applied to heart rate signals to find the relation of HRV with the autonomic function, and to explore the change in HRV in pathological situations (Bonnet and Arand, 1997). Furthermore, the heart rate changes rapidly according to external stimulation and physiological alternation. Therefore, HRV could be a convenient monitoring index to reveal physiological conditions during syncope, myocardial infarction and anesthesia.

Combined with other physiological signals, it provides more information and aid for diagnosis. In addition, the relation of frequency bands and sympathovagal effects obtained from previous studies has revealed that the low frequency (LF band, 0.04~0.15 Hz) is mainly mediated by the sympathetic nervous system and the high frequency (HF band, 0.15~0.4 Hz) is effected by the parasympathetic nervous system (Hydman *et al.*, 1971; Sands *et al.*, 1989; Saul *et al.*, 1988).

Skin Conductance Response

According to previous studies, skin conductance response (SCR), which is a measure of the skin's conductance between two electrodes, is typically measured by applying a small DC (0.5 V) signal through two electrodes placed on the skin (Comunetti *et al*., 1995; Liao *et al*., 1998; Reichmanis *et al*., 1976). The change in conductance was a function of sweat gland activity (Cao *et al.*, 1990; Olyaei *et al*., 2004; Usichenko *et al*., 2003). An increase in conductivity arises through increased skin moisture, pre-secretory activity of the sweat gland cell membranes or both. Skin conductance (SC) would change by activity of the subjects' autonomic nervous system, or more specifically, their sympathetic nervous system. Several studies have used this method to investigate the change in human moods or the mechanism of autonomic system (Christie and Friedman, 2004; Roth *et al*., 1998). In Chinese medicine, SC was measured to be significantly higher at acupoint locations (Zytkowski, 1999). Other researchers have used this characteristic to evaluate the effect of acupuncture in the treatment of patients (Zhu *et al*., 1998). In journals of both neural medical science and acupuncture in Chinese medicine, SCR has been shown to be a useful parameter for evaluating activity of the human nervous system (Babichenko, 2000; Hsu *et al.*, 2002; Wang *et al.*, 2002b; Weng *et al.*, 2002).

Heart Meridian

As shown in Fig. 1, this channel on the skin begins at the center of the armpit (HT1). From here, the channel descends along the inner aspect of the arm, through the inner end of the elbow crease, and continues down to the tip of the little finger by the corner of the nail on the thumb side (HT9). In Chinese medical theory, this meridian is an important channel, which can reflect the situation, function or disease of heart. Therefore, we used the SCR meter to monitor the change of all these acupoints in this research.

BL15 (*Xin-Shu/Heart-Shu*)

In traditional Chinese medicine, the 15th acupoint of Bladder Meridian (Fig. 2) is located 1.5 inch (about 3.8 cm) lateral to the lower border of the spinous process of the fifth thoracic vertebra (T5). It is an important acupoint usually used for curing heart disease such as cardiac arrhythmia, heart pain and irregular pulse. In addition, it is very close to the sympathetic innervations to the heart (David and Teitelbaum, 2000; Helms, 1995; Korr,

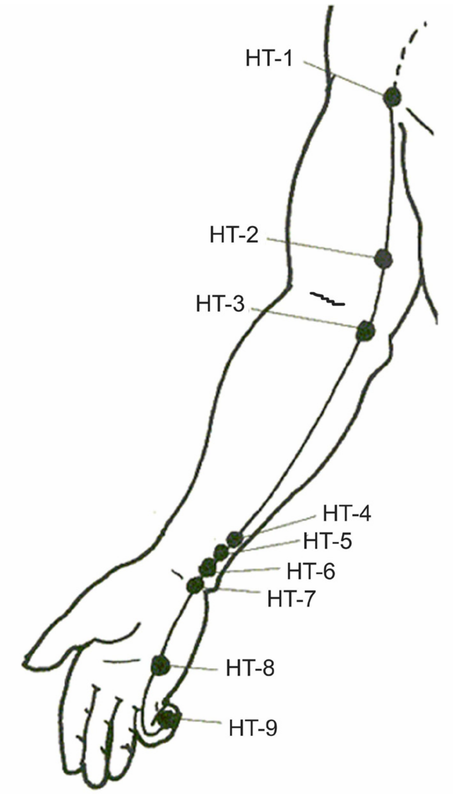

Figure 1. All of the acupoints on Heart Meridian.

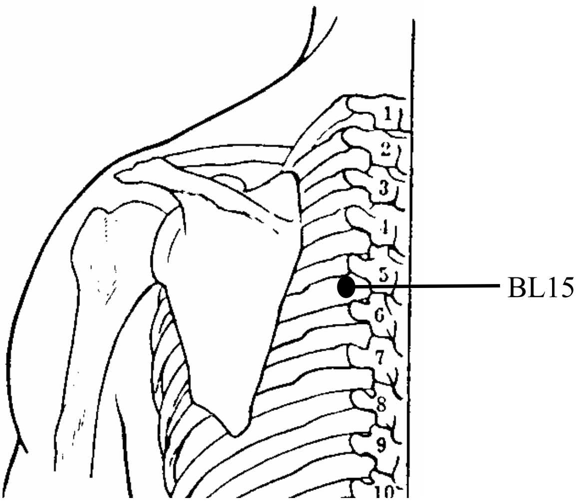

Figure 2. The location of BL15.

1979). Anatomically, the heart is regulated by plexus cardiacus which contains vagus, T1-T4 and part of T5 sympathetic nerves (Bishop and Peterson, 1976). In 2003, Sitdikov showed that breaking the vagus of rats would decrease the heart rate immediately (Sitdikov *et al.*, 2003). The acupoint used in this study, BL15, is above the sympathetic nerve at T5, and the distribution of current from 2 Hz EA is very close to plexus cardiacus. In another previous study, blockage of the signal transduction pathway could be done by raising the threshold of nerves with electrical stimulation of the spinal cord (Aronow and Frishman, 2004). Therefore, we assumed that the stimulation of BL15 with EA might affect the conduction of sympathetic nerves of plexus cardiacus, thus altering the heart rate. Furthermore, in research on Chinese medicine, needle acupuncture was used to stimulate BL15 of frogs, and the results showed decrease of the heart rate, which might indicate that BL15 had a calming effect (Hsiung, 1989). With these findings, we decided that BL15 was an appropriate choice for studying the relation among EA and the variation of autonomic nerves, heart rate and pulse rate.

Objectives

Previous studies showed that stimulation of BL15 would cause a change of heart rate (Han *et al.*, 1994; Li and Pang, 1999; Ting, 2002). Moreover, the change of heart rate would affect the variance of the SC of acupoints on the Heart Meridian (Hsiung, 1989). It has been recognized that the sympathetic nerves of plexus cardiacus and heart meridian could reflect the functional variations of the heart (Rong and Zhu, 2002). It has also been shown that there is a specific change of H^+ concentration in the Heart Meridian of rabbits suffering from arrhythmia induced by aconitine (Wang *et al.*, 1996). These papers demonstrated that the Heart Meridian could reflect functional changes of heart. Furthermore, several studies have shown that SC could have a direct relationship with human meridians and the autonomic nervous system (Cao *et al.*, 1990; Olyaei *et al.*, 2004; Weng *et al.*, 2004a and b). Therefore, in this paper the SC of all acupoints on the Heart Meridian were analyzed to evaluate the relationship between the heart rate, blood PRV and the Heart Meridian when BL15 was stimulated by EA.

Methods

Ten healthy volunteers (aged 23 ± 6) were selected as the control group on the first day, and then used again as the experimental group on the second day. Subjects were positioned in a quiet environment with stable humidity and temperature during the experimental period. Prior to the experiment, subjects were allowed to rest for at least 30 minutes to calm down and maintain a steady mood (Fig. 3). The control group received sham EA during the study, while subjects of the experimental group were stimulated by 2 Hz electrical stimulation applied on a needle (0.30 mm diameter; 25 mm long) inserted into the acupoint BL15 for 10 minutes. The parameters such as HRV, PRV and SCR of all acupoints (HT1-HT9) on the Heart Meridian were measured before and after stimulation. All the values from the control and experimental groups were compared with Student’s t-test.

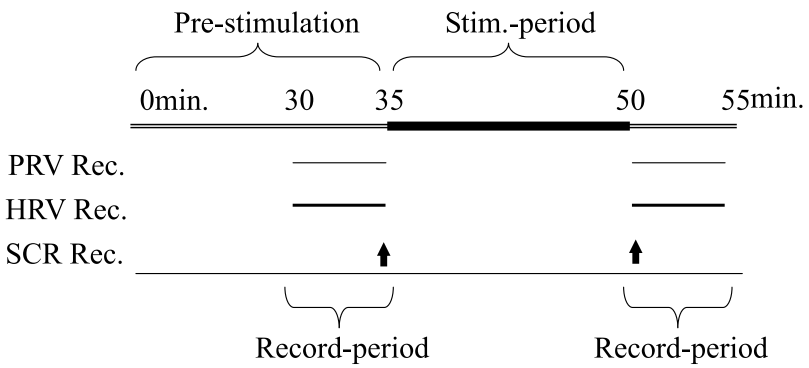

Figure 3. Pre-stim: Before experiment, subjects were allowed to rest for 30 minutes to calm down and to maintain steady mood. Record-period: PRV, HRV and SCR were metered in this period. Stim-period: EA were used to stimulate BL15 in this period.

EZ-HRV (OkiiMURA Taiwan Co., Ltd) and Microsoft Excel programs were used to analyze both the HRV and PRV. In the time domain of ECG and pressure pulse graph, we obtained the average time of R-R interval (R-RI) of ECG (Fig. 4) and P-P interval (P-PI) of pressure pulse graph (Fig. 5). In the frequency domain analysis, the curves of R-RI (Fig. 6) and P-PI (Fig.7) were calculated by fast Fourier transform (FFT) (Figs. 8 and 9). The spectrum curves from FFT analysis were to define HF band (0.04 to 0.15 Hz) and LF band (0.15 to 0.4 Hz) and indicate the activities of sympathetic and parasympathetic nerves, respectively. High frequency power (HFP) and Low frequency power (LFP) were obtained by calculating the area below the curves of HF and LF in FFT, respectively. HFP and LFP were divided by Total Power (TP: the total area below the curve in FFT) to obtain the normalized high frequency power (nHFP) and normalized low frequency power (nLFP), respectively. The ratio of LFP and HFP (LFP/HFP ratio; LHR) were used to evaluate the information a sympathetic and parasympathetic activities of the autonomic nervous system (Peter and Barbara, 1995). Usually, 200–500 heartbeats of data were collected to analyze the variations of heart and pulse rates (Akselrod *et al.*, 1981). In this study, 5 minutes of data (about 300–400 heartbeats) were recorded to analyze the short-term effect of heart and pulse rates.

Results

Figures 10 and 11 showed that SCR values of both the right and left Heart Meridian were stable over 10 minutes for the control group. In the experimental group, after BL15 was stimulated by EA, the results showed that many SCR values were significantly decreased ($p < 0.05$), especially between the elbow and wrist (from HT3 to HT7) (Figs. 12 and 13). In the frequency and time domain analysis of HRV and PRV, Table 1 showed that there were no statistical changes in the control group before and after sham EA. Table 2 showed that the LF bands of HRV and PRV were statistically decreased, and the HF bands were

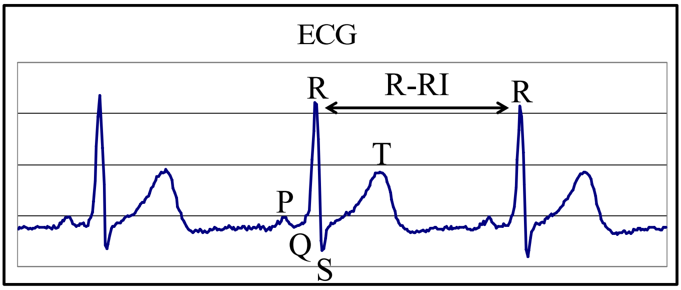

Figure 4. The trace of lead II ECG.

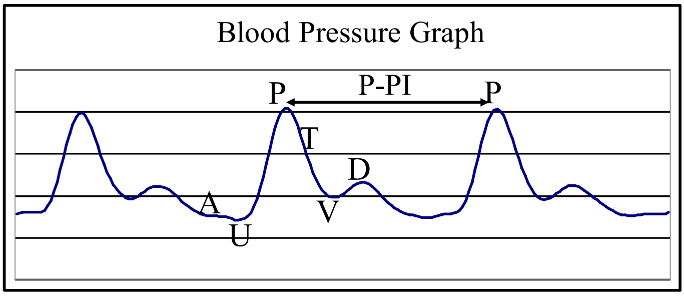

Figure 5. The trace of pressure pulse graph.

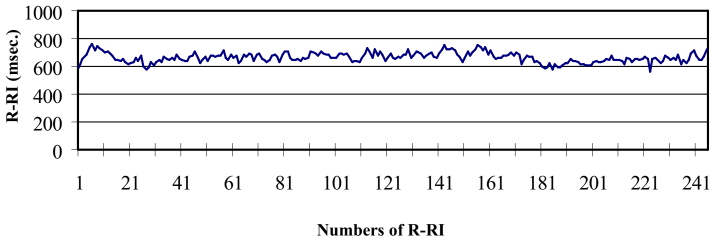

Figure 6. The curves of R-RI.

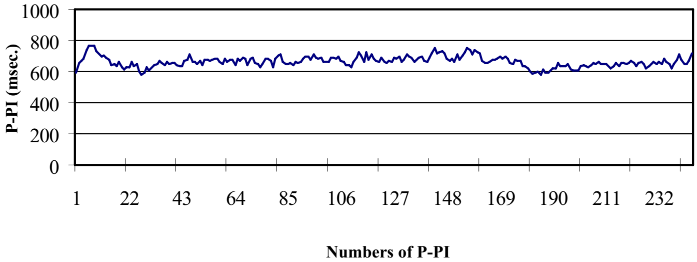

Figure 7. The curves of P-PI.

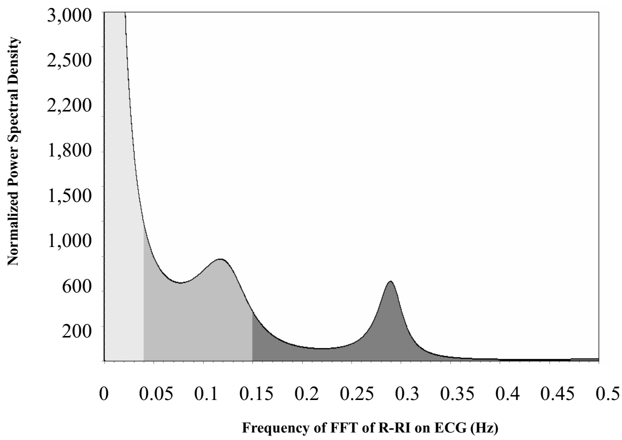

Figure 8. The curves of R-RI were calculated by fast Fourier transform (FFT).

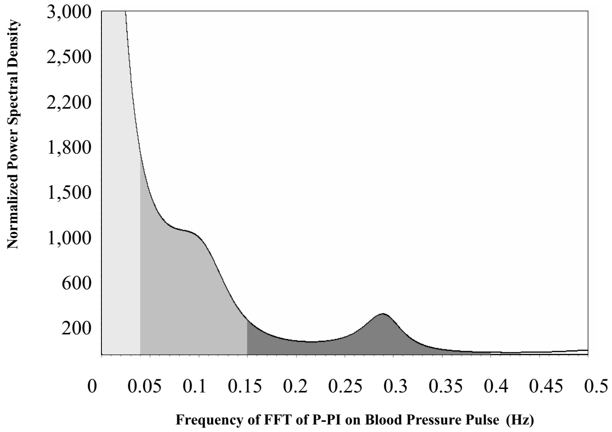

Figure 9. The curves of P-PI were calculated by fast Fourier transform (FFT).

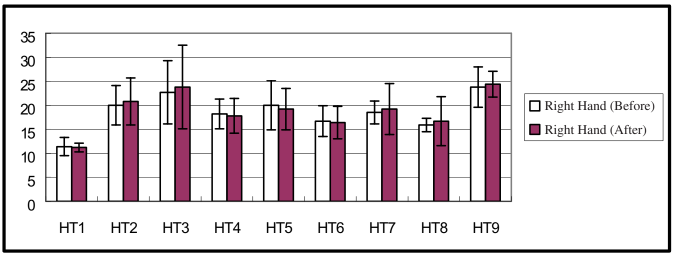

Figure 10. SCR values [unit = μSiemens (μS), Siemens = 1/R (Ω)] of all acupoints on right Heart Meridian before and after sham EA in the control group (n = 10).

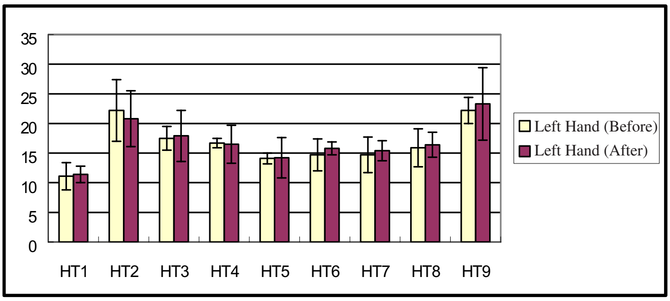

Figure 11. SCR values [μSiemens (μS)] of all acupoints on left Heart Meridian before and after sham EA in the control group (n = 10).

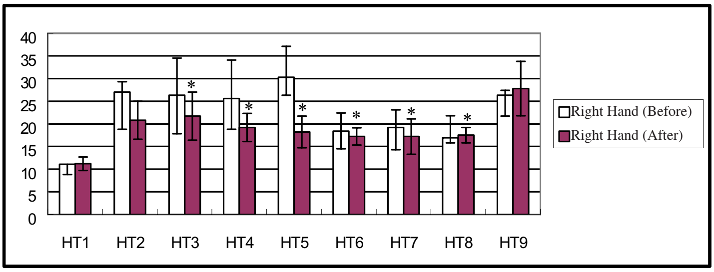

Figure 12. SCR values [μSiemens (μS)] of all acupoints on right Heart Meridian before and after EA stimulation in the experimental group (n = 10, $^*p < 0.05$).

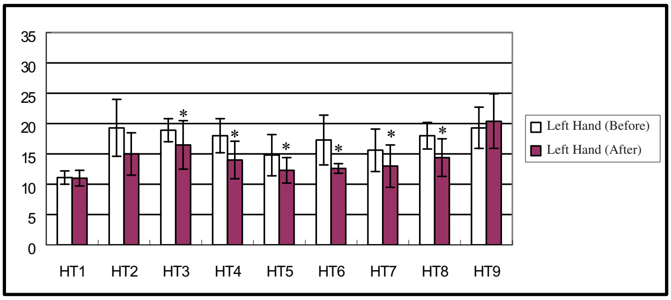

Figure 13. SCR values [μSiemens (μS)] of all acupoints on left Heart Meridian before and after EA stimulation in the experimental group (n = 10, $^*p < 0.05$).

increased in the experimental group ($p < 0.05$). In the time domain analysis, both the heart and pulse rates were decreased after stimulation in the experimental group ($p < 0.05$). These results indicated that the parasympathetic nerve was activated after stimulation, and the sympathetic nerve was in constrained condition (Sands *et al.*, 1989; Saul *et al.*, 1988).

Table 1. The Control Group: HRV and PRV Before and After Ten Minutes of Sham EA

			Before	After	
Frequency Domain Analysis	nLFP (HRV)	R-RI	0.52 ± 0.02	0.50 ± 0.03	*
	nLFP (PRV)	P-PI	0.48 ± 0.17	0.45 ± 0.15	*
	nHFP (HRV)	R-RI	0.18 ± 0.06	0.18 ± 0.07	*
	nHFP (PRV)	P-PI	0.22 ± 0.13	0.21 ± 0.16	*
	LHR (HRV)	R-RI	2.84 ± 0.24	2.84 ± 0.27	*
	LHR (PRV)	P-PI	2.26 ± 0.23	2.25 ± 0.25	*
Time Domain Analysis	HRV	R-RI	644.72 ± 24.05	644.21 ± 20.74	*
	PRV	P-PI	644.23 ± 20.17	644.67 ± 34.12	*

n = 10, $^{*}p < 0.05$.

Table 2. The Experimental Group: HRV and PRV Before and After EA Stimulation

			Before	After	
Frequency Domain Analysis	nLFP (HRV)	R-RI	0.51 ± 0.12	0.22 ± 0.23	*
	nLFP (PRV)	P-PI	0.49 ± 0.17	0.17 ± 0.25	*
	nHFP (HRV)	R-RI	0.18 ± 0.11	0.70 ± 0.15	*
	nHFP (PRV)	P-PI	0.21 ± 0.05	0.77 ± 0.10	*
	LHR (HRV)	R-RI	2.84 ± 0.21	0.31 ± 0.01	*
	LHR (PRV)	P-PI	2.26 ± 0.35	0.23 ± 0.02	*
Time Domain Analysis	HRV	R-RI	644.72 ± 20.12	749.21 ± 19.18	*
	PRV	P-PI	644.22 ± 24.18	747.67 ± 28.14	*

n = 10, $^{*}p < 0.05$.

Discussion

This experiment investigated how physiological parameters were affected by 2 Hz EA on the acupoint of BL15. The results showed that there was a considerable change in HRV, PRV and also the SCR of this acupoint.

In the analysis of frequency domain, the value of HRV indicated an increase in the power of high frequency and a decrease in the power of the low frequency domain. As shown by recent research, the HFP and parasympathetic nervous system are closely related, as is the LFP and sympathetic nervous system (Hydman *et al.*, 1971; Sands *et al.*, 1989; Saul *et al.*, 1988). Therefore, the results in this experiment reasonably showed that the parasympathetic nerve was activated after stimulation, and the sympathetic nerve was in constrained condition.

As a result, the analysis of HRV and PRV in the time domain indicate that EA stimulation decreased both the human heart and pulse rates. This corresponded to the increasing activities in the parasympathetic nervous system, and the decreasing activities in the sympathetic nervous system. But the mechanism of the pathway from BL15 to the heart was complex and not very clear. Future research can look into the examination of "postvagal tachycardia" to study the pathway of autonomic nerves (Loeb and Vassalle, 1979; Prystowsky and Zipes, 1985; Wang *et al.*, 1997b).

These results are closely related to the outcome found in the analysis of frequency domain. Moreover, most of the SCR at acupoints near elbow and wrist on Heart Meridian were decreased after stimulation. This was also an interesting discovery for the future research to observe different acupoints stimulated. Earlier studies investigating the SCR value stated that the conductance decreased when a human body was in a calm condition as the biological activity slows down (Roth *et al.*, 1998). The results from the analysis of HRV and PRV explained that the stimulation of BL15 by EA could cause relaxation, slow down of heart rate, calmness and reduce feelings of tension or distress. The findings in this study also correspond to the treatment effects of needle acupuncture on BL15 in traditional Chinese medicine.

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