J Acupunct Meridian Stud 2016;9(5):257–263

Available online at www.sciencedirect.com

Journal of Acupuncture and Meridian Studies

journal homepage: www.jams-kpi.com

RESEARCH ARTICLE

Comparison of the Effects of Manual Acupuncture, Laser Acupuncture, and Electromagnetic Field Stimulation at Acupuncture Point BL15 on Heart Rate Variability

Na Ra Lee [1], Soo Byeong Kim [2], Hyun Heo [3], Yong Heum Lee [1,*]

[1] *Eastern and Western Biomedical System Laboratory, Department of Biomedical Engineering, College of Health Science, Yonsei University, Wonju, South Korea*
[2] *Wellness Technology R&D Center, Human and Culture Convergence Technology R&D Group, Korea Institute of Industrial Technology, Ansan, South Korea*
[3] *Medical Computer System Laboratory, Department of Biomedical Engineering, College of Health Science, Yonsei University, Wonju, South Korea*
Available online 1 July 2016

Received: Jan 18, 2016
Revised: May 26, 2016
Accepted: Jun 2, 2016

KEYWORDS
acupuncture;
electromagnetic field;
heart rate variability;
laser acupuncture

Abstract
The aim of this study was to compare the influences of manual acupuncture, laser acupuncture, and electromagnetic field stimulation on the autonomic nervous system. We monitored the heart rate variability before and after stimulation to check the influence on the autonomic nervous system. The heart rate variabilities at low frequency (LF; 0.04–0.15 Hz) and high frequency (HF; 0.15–0.4 Hz) were analyzed to acquire LF/HF ratio. *Xinshu* (BL15) was selected as the stimulation point. Methods included manual acupuncture with a 1-cm depth and laser acupuncture at a wavelength of 660 nm and output power of 50 mW. An electromagnetic field of 2 Hz and 460 gauss (46 mT) was chosen. The LF and the LF/HF ratio were found to be lower in the manual acupuncture and the electromagnetic field groups, but to be higher in the laser acupuncture group. The HF

* Corresponding author. Eastern and Western Biomedical System Laboratory, Department of Biomedical Engineering, College of Health Science, Yonsei University, Wonju, Gangwon-Do 220–710, South Korea.
E-mail: koaim@yonsei.ac.kr (Y.H. Lee).

pISSN 2005-2901 eISSN 2093-8152
http://dx.doi.org/10.1016/j.jams.2016.06.002

was found to be lower in the laser acupuncture group, but higher in the manual acupuncture and the electromagnetic field groups. In conclusion, we found that manual acupuncture and electromagnetic field stimulation at BL15 activated the parasympathetic nervous system, whereas laser acupuncture at BL15 activated the sympathetic nervous system.

1. Introduction

Manual acupuncture is the typical treatment method in traditional Korean medicine (TKM). It is used for a wide range of conditions and especially for pain relief [1—3]. The therapeutic mechanisms of manual acupuncture remain controversial, but some researchers have found that manual acupuncture is effective at improving physical performance capacity and inducing sympathetic nerve activity [4,5]. Despite the therapeutic effects of manual acupuncture, there has been reluctance in accepting its use due to its invasiveness. For this reason, some researchers have proposed alternative, noninvasive methods for stimulating acupoints, such as laser acupuncture and electromagnetic fields [6—8]. Laser acupuncture involves stimulating acupoints by using low-intensity, nonthermal irradiation while an electromagnetic field can stimulate deep sites and induce bioelectric currents.

To confirm the efficacy of these methods compared with manual acupuncture, we analyzed their influences on the autonomic nervous system (ANS). By using positron emission tomography and functional magnetic resonance imaging, Takamoto et al [9] reported that manual acupuncture stimulation might deactivate the medial prefrontal cortex, presupplementary motor area, and supplementary motor area. The suppression of the central nervous system influences the ANS by increasing parasympathetic nervous activity and decreasing sympathetic nervous activity [9]. Similarly, Wu et al [10] reported that laser acupuncture could be used to help circadian rhythm disorders by modulating the ANS. Also, a combination of manual acupuncture and a pulsed electromagnetic field (PEMF) can decrease pupil size by inducing a biotransformation, signaling that the parasympathetic nerve system had been activated [11].

Although several studies have investigated the use of laser acupuncture and electromagnetic fields to stimulate acupoints, questions remain. Most of those studies were conducted individually, making it difficult to compare the effectiveness among manual acupuncture and noninvasive stimulation methods. Thus, continuing efforts to determine the therapeutic mechanisms and to analyze the differences among these methods are important.

Therefore, we investigated the influences of various stimulation methods on the ANS under identical conditions. For this purpose, manual acupuncture, laser acupuncture, and electromagnetic fields were used as stimulation methods, and *xinshu* (BL15) was selected as the stimulation point. To check the influences on the ANS, we measured the heart rate variability (HRV) before and after stimulation and analyzed time-domain and frequency-domain parameters.

2. Materials and methods

2.1. Participants

Fifty-six volunteers without a clinical history of heart or circulation disorders participated in this study (Fig. 1). All participants were randomly assigned into four parallel groups (nonstimulation, manual acupuncture, laser acupuncture, and electromagnetic field groups). The Institutional Review Board of Yonsei University. Wonju approved this study.

2.2. Acupuncture point selection

The acupuncture point BL15 is used to treat cardiac disorders in TKM. Previous studies have shown that manual acupuncture and electroacupuncture at BL15 are effective in treating patients with coronary heart disease and acute myocardial ischemia [12,13]. Furthermore, the anatomical localization of BL15 and cardiac sympathetic innervation correspond well [14,15]. For this reason, we selected BL15, which is located below and lateral to the fifth thoracic vertebra, as the stimulation point.

2.3. Stimulation methods

Generally, when an acupuncture needle is used to stimulate BL15 vertically, it is inserted to a depth of 0.642—1.07 cm. When an acupuncture needle is used to stimulate BL15 at an angle of 30°, it is commonly inserted to a depth of 3.12 cm. We used a vertical depth of 1 cm as a method of manual acupuncture, as the effects of basic acupuncture have been confirmed at this depth. In addition, we did not apply additional acupuncture techniques such as twisting and twirling the needle. Laser acupuncture has been used as an alternative to manual acupuncture in TKM to treat patients with peripheral artery disease and to activate HRV [16,17]. The penetration depth at wavelength between 600 nm and 1000 nm is enough to stimulate an acupoint [18]. Hence, the characteristics of laser diode widely used to laser acupuncture are between 600 nm and 1,000 nm in the red and infrared range and a power between 5 mW and 500 mW. Therefore, laser acupuncture involves noninvasive, low-intensity and nonthermal effect at skin. Because of these reasons, the mode of laser operation was selected in the continuous wave mode with a wavelength of 660 nm and an output power of 50 mW.

A PEMF (extremely low frequency: 0—300 Hz) has been used to treat pain, nerve disorders, and musculoskeletal disease [19]. It can be applied to wide regions or locally, for example, at an acupuncture point [8,11]. In this study, to

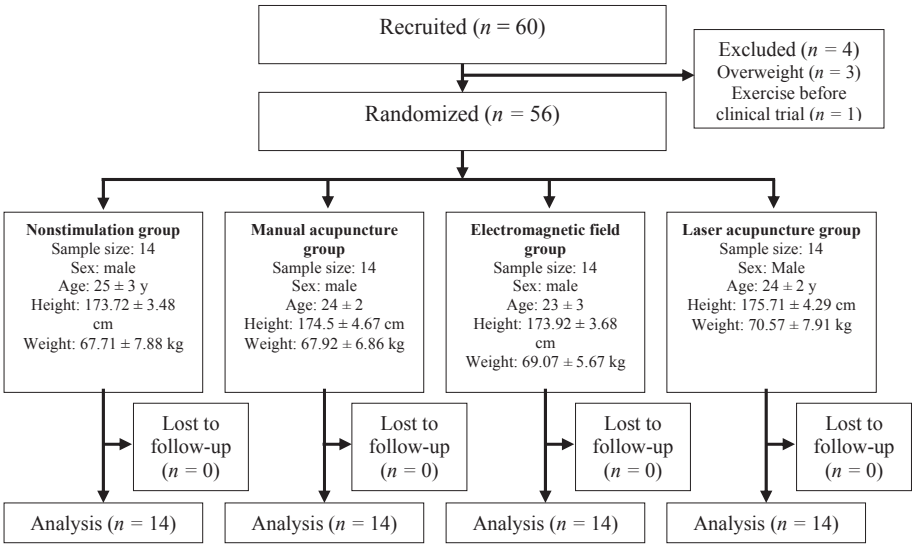

Figure 1 Participant flow diagram.

generate the electromagnetic field, we used a solenoid coil with a diameter of 15 mm and a height of 20 mm. As for the selection of the stimulation frequency, previous research on HRV showed that a frequency of 2 Hz was most frequently used [20]. Therefore, we chose a 2 Hz, 460-gauss (46 mT) for the PEMF stimulation method.

2.4. Heart rate variability measurement

Electrocardiograms (ECG) were performed using AD Instruments PowerLab/4SP equipment (Castle Hill, NSW, Australia). In the time-domain, the standard deviation of the R—R intervals and the mean square of successive R—R interval differences were calculated for each recording. In the frequency-domain, the powers of the low-frequency (LF; 0.04—0.15 Hz) and the high-frequency (HF; 0.15—0.4 Hz) components, as well as the LF/HF ratio, were calculated. To reduce the effects of noise and minimize the changes in the total powers of the LF and the HF components, we analyzed the normalized LF and HF components defined as

$$\text{LF or HF norm (nu)} = \frac{LF \text{ or } HF\ (ms^2)}{total\ power(ms^2) - VLF\ (ms^2)} \times 100.$$

where VLF is very low frequency.

2.5. Experimental procedure

For the experiments, all participants were allowed to rest comfortably in a quiet room with constant humidity (40%) and temperature (24°C). Each experiment lasted for 30 minutes. During the first 15 minutes, the patient was allowed to rest, after which the ECG was measured during a 15-minute period. All participants received the allocated stimulation for 20 minutes to 25 minutes. HRV was calculated by ECG data for 5 minutes before stimulation after stimulation to compare the change in ANS (Fig. 2).

2.6. Statistical analysis

HRV data are shown as means ± standard errors. The Wilcoxon signed rank test was used to compare the HRV values before and after treatment in the same group. A p value < 0.05 was considered statistically significant.

3. Results

3.1. The effect of stimulation methods on LF (nu)

Fig. 3 and Table 1 show each group's LF (nu) before and after stimulation. The nonstimulation group showed no significant difference after stimulation ($p > 0.05$). The electromagnetic and the manual acupuncture groups

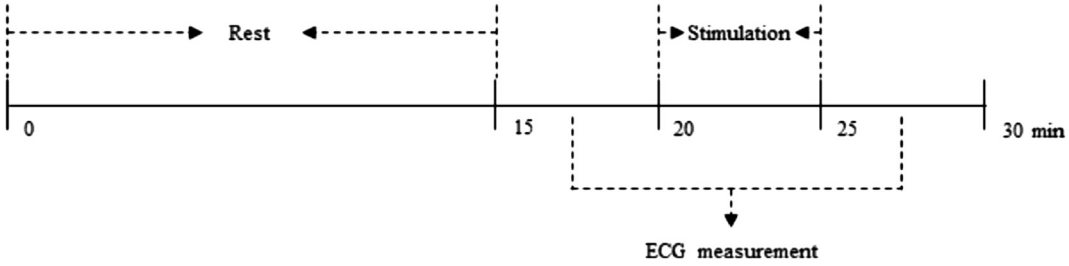

Figure 2 Experimental procedure. ECG = electrocardiogram.

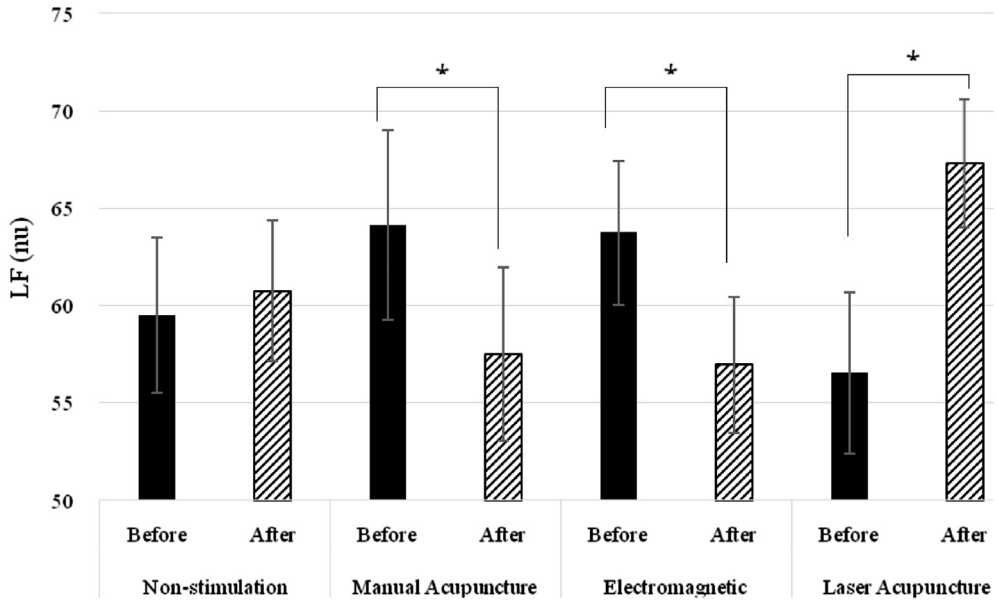

Figure 3 Variation in the low frequency [LF (nu)] before and after stimulation in the four groups. *The difference between the two indicated groups is statistically significant.

Table 1 Low frequency (nu) data for the four groups before and after stimulation.

Group	Before	After	p*
Nonstimulation	59.50 ± 3.99	60.76 ± 3.63	0.490
Electromagnetic field	63.73 ± 3.68	56.96 ± 3.51	0.013
Manual acupuncture	64.11 ± 4.87	57.51 ± 4.46	0.011
Laser acupuncture	56.53 ± 4.13	67.31 ± 3.27	0.006

*Statistical analysis: Wilcoxon signed ranks test.

showed a decreased LF (nu) after stimulation ($p < 0.05$). In contrast, the LF (nu) was increased after stimulation in the laser acupuncture group ($p < 0.05$).

3.2. The effect of stimulation methods on HF (nu)

The HF (nu) results are presented in Fig. 4 and Table 2. The HF (nu) of the nonstimulation group was slightly decreased, but the difference was not statistically significant ($p > 0.05$). The HF (nu) for both the electromagnetic and the manual acupuncture groups were increased after stimulation ($p < 0.05$). By contrast, the laser acupuncture

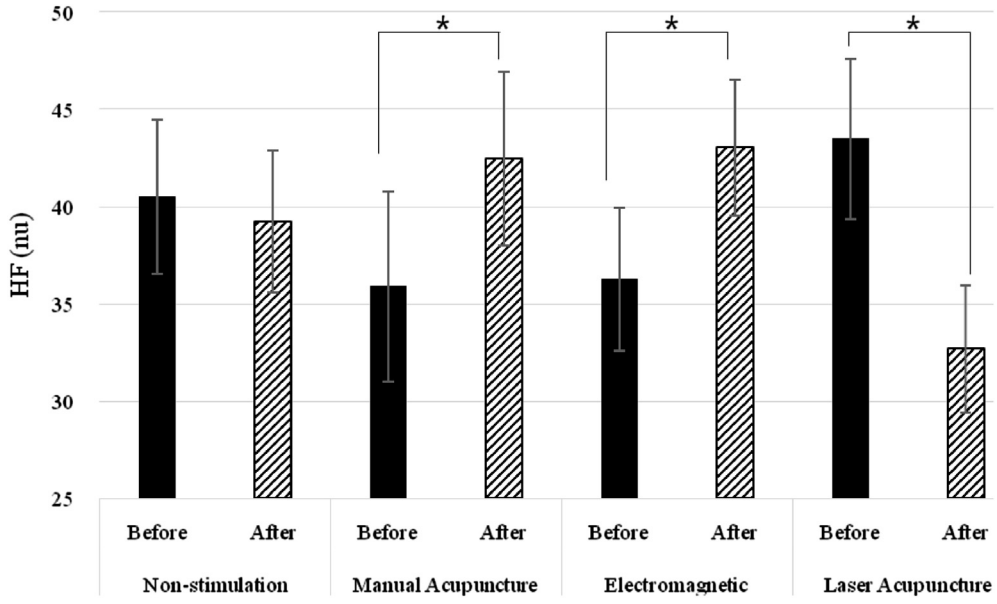

Figure 4 Variation in the high frequency [HF (nu)] before and after stimulation in the four groups. *The difference between the two indicated groups is statistically significant.

Table 2 High frequency (nu) data for the four groups before and after stimulation.

Group	Before	After	p*
Nonstimulation	40.51 ± 3.99	39.24 ± 3.63	0.490
Electromagnetic field	36.27 ± 3.68	43.04 ± 3.51	0.013
Manual acupuncture	35.89 ± 4.87	42.49 ± 4.46	0.011
Laser acupuncture	43.47 ± 4.13	32.69 ± 3.27	0.006

*Statistical analysis: Wilcoxon signed ranks test.

Table 3 Low frequency/high frequency ratios for the four groups before and after stimulation.

Group	Before	After	p*
Nonstimulation	2.06 ± 0.34	2.05 ± 0.32	0.778
Electromagnetic field	2.22 ± 0.37	1.54 ± 0.21	0.011
Manual acupuncture	2.38 ± 0.36	1.68 ± 0.25	0.026
Laser acupuncture	1.56 ± 0.23	2.71 ± 0.57	0.016

*Statistical analysis: Wilcoxon signed ranks test.

group showed a decrease in HF (nu) after stimulation ($p < 0.05$).

3.3. The effect of stimulation methods on LF/HF ratio

The results for the LF/HF ratio are shown in Fig. 5 and Table 3. The results for the LF/HF ratio were similar to those for the LF (nu). The nonstimulation group showed no significant difference ($p > 0.05$). The electromagnetic and the manual acupuncture groups showed similar decreases after stimulation ($p < 0.05$), and the laser acupuncture group showed an increase after stimulation ($p < 0.05$).

4. Discussion

To find the properties of the respective biological responses among the electromagnetic-field, manual acupuncture, and laser acupuncture methods, we stimulated BL15 by using each stimulation method under the same conditions and measured the HRV. The HRV is the one of the most convenient methods for analyzing the ANS, and it is widely used for analyzing the effect of acupuncture [21–23]. The HF component of the HRV is generally used as a marker of the parasympathetic nervous system (vagal modulation) whereas the LF component reflects the activity of the sympathetic and parasympathetic nervous systems. The LF/HF ratio can be used to confirm the global sympathovagal balance.

BL15 is the main acupoint for treating heart diseases, and a number of reports have demonstrated correlations between the HRV and stimulation at BL15 [14]. Acupuncture on BL15 has been found to stimulate activation of the parasympathetic nervous system. Also, manual acupuncture mediates effects throughout the central nervous system, including the medial prefrontal cortex, presupplementary motor area, and supplementary motor area. During manual acupuncture, those areas are deactivated, meaning an increase in parasympathetic nervous activity occurs [9]. In this study, the results of the manual acupuncture group are in accord with previous research as the value of HF (nu) was increased and the values of the LF (nu) and the LF/HF ratio were decreased after manual acupuncture had been applied.

The pattern of results for the electromagnetic-field group was identical to that for the manual acupuncture group: increased value of HF (nu), and decreased values of LF (nu) and the LF/HF ratio after stimulation. The influence on the ANS caused by exposure to an electromagnetic field is unclear. However, some research has reported that when

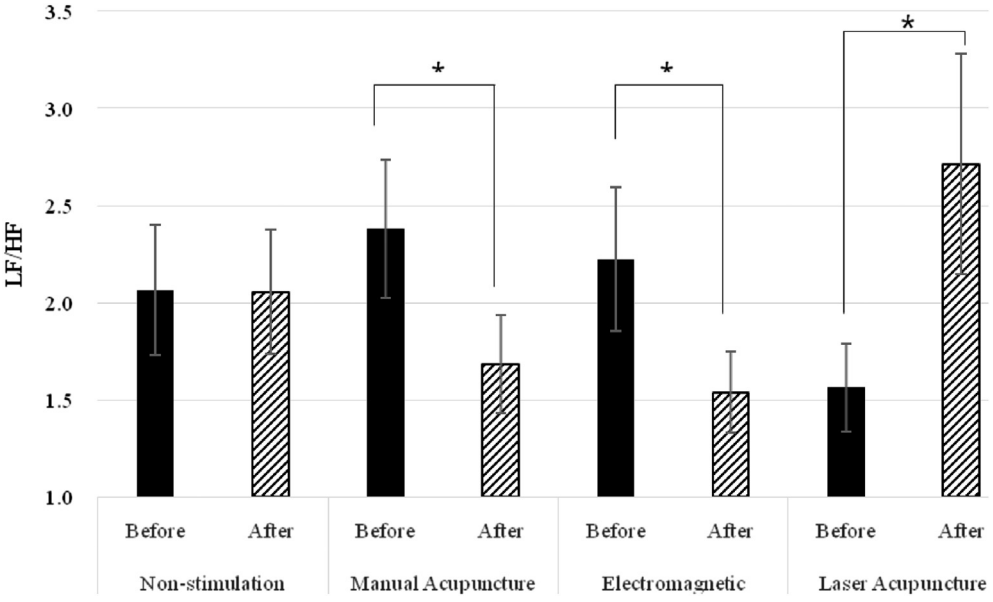

Figure 5 Variation in low frequency/high frequency (LF/HF) ratio before and after stimulation in the four groups. *The difference between the two indicated groups is statistically significant.

applied to the whole body at extremely LF, significant decreases in the resting heart rate (approximately 3—5 beats/min) and in the power of the LF band of the HRV occur [24,25]. In addition, electromagnetic acupuncture stimulation at BL15 has been found to cause a significant decrease in the pupil size, signifying activation of the parasympathetic nervous system [11]. We conducted local stimulation at BL15 by using an electromagnetic field and found that it caused effects similar to those of manual acupuncture.

The parasympathetic activation effect of manual acupuncture is supported by most previous research, but the influence of laser acupuncture is not well established. Some research has found that 830-nm laser acupuncture on PC6 increases vagal activity and suppresses cardiac sympathetic nerves [10]. On the contrary, another report showed that stimulating PC6 using 658-m laser acupuncture significantly increased the LF/HF ratio, suggesting activation of the sympathetic nervous system. However, 658-nm laser acupuncture at ST36, CV12, and BL21 was reported to induce no significant changes [18]. In our study, the laser acupuncture group had a different outcome in comparison with the manual acupuncture and the electromagnetic-field groups. The 660-nm laser acupuncture increased the LF (nu) and the LF/HF ratio, and decreased the HF (nu). In this case, determining whether the result of laser acupuncture was caused by the 660-nm laser acupuncture or by the stimulation of BL15 is difficult. Therefore, further studies are necessary to determine specific changes in the ANS related to the characteristics of an acupoint or a stimulation method.

In conclusion, we compared the responses of the ANS to manual acupuncture, electromagnetic-field, and laser acupuncture stimulations under the same conditions. We found that stimulation at BL15 using manual acupuncture and a PEMF (2 Hz and 460 gauss) caused identical patterns for the activation of the parasympathetic nervous system. However, the 660-nm laser acupuncture stimulation at BL15 activated the sympathetic nervous system. This result means that effects of stimulation at BL15 due to manual acupuncture and to PEMF are different from the effects of stimulation at BL15 due to laser acupuncture. Nevertheless, differentiating between the effects on the ANS of manual acupuncture, PEMF, and laser acupuncture stimulations at BL15 is not easy because those effects differ with parameters such as the acupoint used, the source of stimulation, and the intensity of stimulation. Thus, if the differences between the influences of acupuncture and other stimulation methods on the ANS are to be demonstrated, further studies are needed under the same experimental conditions.

Disclosure statement

The authors declare that they have no conflicts of interest and no financial interests related to the material of this manuscript.

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