World Academy of Science, Engineering and Technology
International Journal of Biomedical and Biological Engineering
Vol:5, No:12, 2011

Effects of Combined Stimulation on the Autonomic Nervous System: A Pilot Study

Dae Won Lee, Ji Hyung Park, Sinae Eom, Syung Hyun Cho, Jong Soo Lee, Han Sung Kim

***Abstract*—**The autonomic nervous system has a regulatory structure that helps people adapt to changes in their environment by adjusting or modifying some functions in response to stress, and regulating involuntary function of human organs. The purpose of this study was to investigate the effect of combined stimulation, both far-infrared heating and chiropractic, on the autonomic nervous system activities using thermal image and heart rate variability. Six healthy subjects participated in this test. We compared the before and after autonomic nervous system activities through obtaining thermal image and photoplethysmogram signal. The thermal images showed that the combined stimulation changed subject's body temperature more highly and widely than before. The result of heart rate variability indicated that LF/HF ratio decreased. We concluded that combined stimulation activates autonomic nervous system, and expected other possibilities of this combined stimulation.

***Keywords*—**Far-infrared heating, Chiropractic, Autonomic nervous system, Heart rate variability

I. Introduction

THE autonomic nervous system (ANS) helps people adapt to changes in their environment. It adjusts or modifies some functions in response to internal or external stress. Also, it regulates involuntary function of human organs [1]. Especially, the ASN controls the behavior of the cardiovascular system which is tremendous in its complexity and importance to life [2]. The antagonistic nature of the parasympathetic and sympathetic branches of ANS allows rapid and essential changes in cardiac parameters (heart rate, contractility and stroke volume) in order to do physiologic balance which deliver metabolites and nutrients to tissues and organs that need them at any given time [1], [2]. For vitalization of the ASN, a number of medical devices have been developed with one or more functions. The Far-infrared heating, which is one of these functions, has many efficacies; increasing deep-seated body temperature, promoting the circulation of the blood by extension of the capillary vessel, revitalizing the metabolism, and improving regeneration ability of the tissue [3]. The chiropractic massage is a form of alternative medicine that emphasizes diagnosis, treatment, and prevention for mechanical disorders of the musculoskeletal system, especially the spine. Under the hypothesis, these disorders affect general health via the nervous system [4]. The massage affects the ASN, and it is possible to cure functional abnormality of organs [5]. Many researchers evaluated the effects of the stimulations for activation of the ASN. However, there have been few researches about the effects of these combined stimulations. Hence, the purpose of this study was to investigate the effects of combined stimulation, both far-infrared heating and chiropractic, on the ANS activities.

Dae Won Lee is with the Department of Biomedical Engineering, Yonsei University, Wonju, Republic of Korea (e-mail: kagenui@naver.com).
Ji Hyung Park is with the Department of Biomedical Engineering, Yonsei University, Wonju, Republic of Korea (e-mail: hyungpump@hanmail.net).
Sinae Eom is with the Department of Biomedical Engineering, Yonsei University, Wonju, Republic of Korea (e-mail: sinae0602@gmail.com).
Syung Hyun Cho is with the Nuga medical Co., Ltd, Wonju, Republic of Korea (e-mail : nugabest@nuga.kr)
Jong Soo Lee is with the Nuga medical Co., Ltd, Wonju, Republic of Korea (e-mail : oky7800@nuga.kr)
Han Sung Kim is with Department of Biomedical Engineering, Yonsei University,Wonju, 220-710, Republic of Korea (corresponding author to provide phone: +82-33-760-2913; fax: +82-33-760-2913; e-mail: hanskim@yonsei.ac.kr).

The activity of the ANS is able to be quantified by various physiological data, such as the peripheral blood circulation in finger tips and the nasal mucous membrane, the skin temperature at various sites of the body by means of infrared thermography, skin conductance, and heart frequency. These are indicators of the functional state of the ASN [6]. Especially, the electrocardiogram (ECG) and the photoplethysmogram (PPG) are used for quantification of the ANS [7]. Heart rate variability (HRV), which is one of estimations using the R-R interval, is able to measure and estimate the function of ANS through power spectrum analysis of extracted instant heart rate from PPG [7]. In this pilot study, for estimating combined stimulation on ANS, we used two parameters: HRV analysis from PPG signal and skin temperature using infrared thermography.

II. Method

Healthy 5 subjects ((mean(SD)) age: 27 years (±3), gender: male, body mass: 74 kg (±4.5), height: 170 cm (±6.3)) participated in the pilot study. With respect to regular physical activity, they were required not to have a sedentary lifestyle but also not to engage in regular physical activity, especially weightlifting exercises. The test procedure was given Fig, 1. PPG signals and the infrared images were obtained before and after the stimulation. PPG signal was not obtained during the test, because the massage would generate the motion artifact.

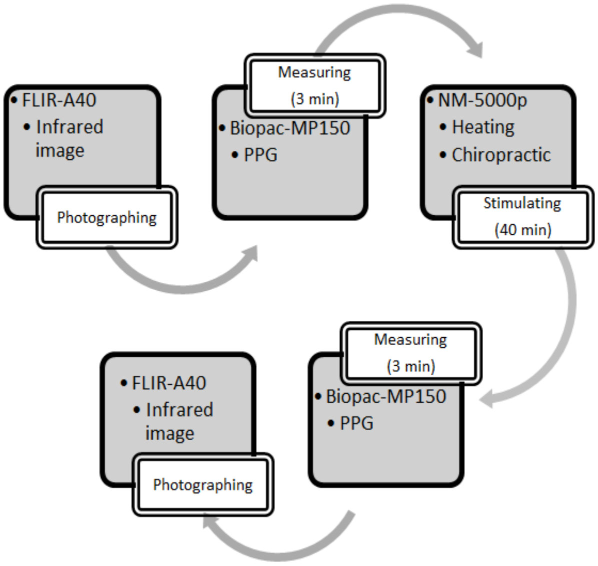


Fig. 1 Flow chart of procedures

A. Training

The subjects were exposed to far-infrared heating (40 ℃) and chiropractic massage by using NM-5000P (Nuga Best, Korea). In the machine, the rollers move along spine contour, based on the chiropractic. The internal infrared projector moves together with the rollers, and makes infrared heating like moxibustion. The subjects lied down on the machine in 40 minutes (Fig. 2). To avoid biorhythmic changes, all subjects were subjected to the same time of the day between 3 p.m. and 5 p.m.

B. Thermal imaging

Thermal images were obtained from an A40M (FLIR System, Sweden). The equipment is a line-scan imager producing images of 320×240 pixels at 16 bit dynamic resolution, with corrections for object emissivity and background temperature. Image processing and production were performed with ThermaCAM™ Researcher software (FLIR System, Sweden).

C. PPG signal collecting and processing

The MP150 data acquisition system (Biopac Systems, Inc, USA) was utilized to take the measurements. PPG signal was sampled at 200 Hz with gains of 100 and 10, PPG100C amplifier (Biopac Systems, Inc, USA), and set to comprise a low-pass filter of 10Hz and high-pass filter of 0.05 Hz. It was coupled with the TSD200 photoplethysmogram transducer, which is placed on the tip of the finger (Fig. 3). PPG Signal monitoring and R-R interval measurement were carried out by Acknowledge software (Biopac Systems, Inc, USA).

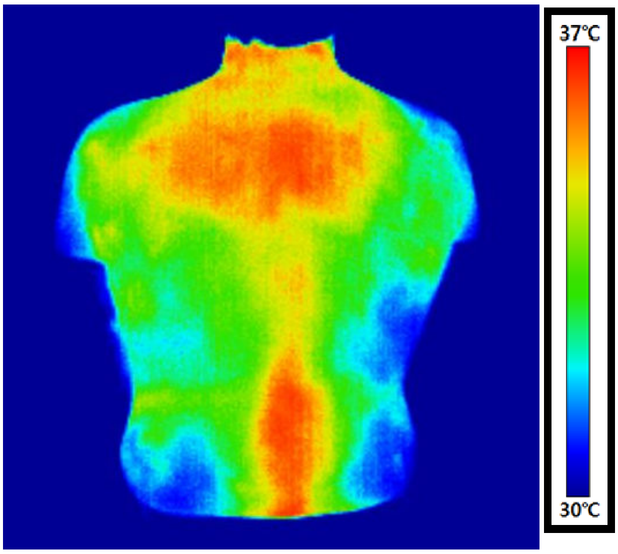
Fig. 2 Combined stimulation massager and subject

Fig. 3 Photoplethysmogram transducer

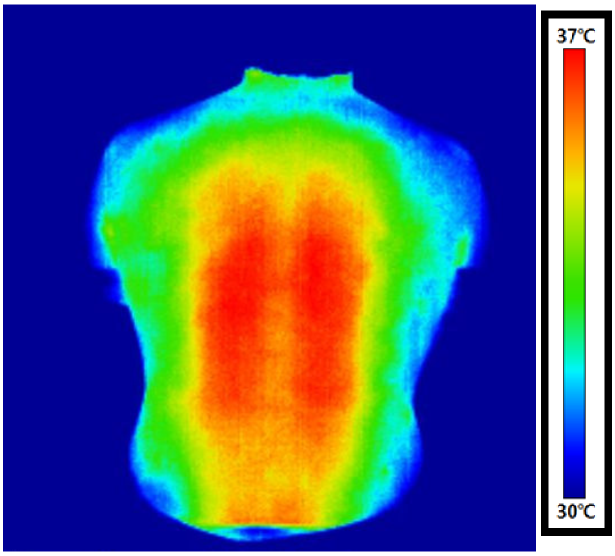
D. HRV Analysis

Among the HRV variables, in healthy subjects, the range of 0.04 – 0.15 Hz (low frequency, LF) is considered as markers of sympathetic nerve activity, also high frequency (HF) fluctuations in the range of 0.15 – 0.4 Hz is considered as markers of parasympathetic nerve activity. Thus, the LF/HF ratio is regarded as an index of ASN activity [8].

In the frequency-domain methods, a power spectrum density (PSD) estimate is calculated for the R-R interval series. In this study, the fast Fourier transform (FFT, 1024 point) and the auto-regressive model (AR model) were used for analysis by using Kubios HRV analysis software (Kuopio Univ, Finland)



(A)



(B)

Fig. 4 Thermal images of subject's back side (A) before stimulation, (B) after stimulation

which is based on Matlab(MathWorks, USA). The FFT is the most widely used nonparametric method for the calculation of PSD. This simple analysis uses the high processing speed without data pre-processing [9]. The AR method is the most frequently used model-based method, because estimation of the AR parameters can be done easily by solving linear equations [10].

E. Statistical Analysis

A t-test was carried out; between before and after stimulation. All data are expressed as the mean ± standard error of the mean (SEM). All statistical analyses were carried out using SPSS 17.0 (SPSS Inc., USA). The significance level was set at $p < 0.05$.

III. Result

In the thermal image for combined stimulation, the subjects' body temperature was increased by almost 4℃. The subjects' body heat which concentrated on the neck and shoulder spread widely after the stimulation (Fig. 4). The results of HRV analysis, both FFT and AR model frequency analysis, showed significant decrease of the LF/HF ratio (Fig. 5, $p < 0.05$) after the test. Especially, AR model demonstrated obvious alteration of LF/HF ratio (Table. I).

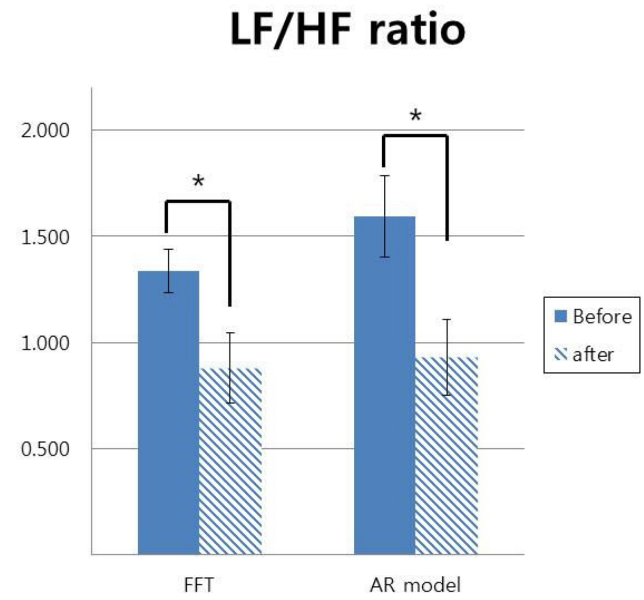


Fig. 5 Charges of the LF/HF ratio (* : $p < 0.05$)

TABLE I
Changes of HRV before and after stimulation

Parameter (mean(SD))	FFT		AR model	
	Before	After	Before	After
Low frequency (LF, %)	57.13 (1.93)	46.89 (4.12)	65.79 (2.85)	51.72 (4.41)
High frequency (HF, %)	42.87 (1.93)	53.11 (4.12)	34.21 (2.85)	48.28 (4.41)
LF / HF ratio	1.34	0.88	1.92	1.07

IV. Conclusion

This study is a pilot study for analyzing the efficacy of the stimulation which combined infrared heating and chiropractic massage on the ASN. All subjects' body temperature changed not only to spread more widely but also to increase more highly then before. That is to say, increased body temperature caused expansion of blood vessel for releasing body heat by the ASN. After stimulation, results of FFT and AR model indicated decreasing of LF/HF ratio (Table. 1). These results showed that LF value was decreased, but HF value was increased after stimulation significantly. In other words, the parasympathetic was activated by the stimulation. This activation was likely to make the subjects relaxed and refreshed. To find out effect of parasympathetic activated by the combined stimulation, further study needs subjective and objective methods such as survey, measurement, or analysis of other parameters. Also, it has to be performed to compare the results of the stimulated group and control group.

ACKNOWLEDGMENT

This research was supported by the Yonsei Medical Instrumentation Education Center in cooperation with Program in Gangwon-do Leading • Strategy Industry of the Nurturing and Training Talent.

REFERENCES

[1] Low P.A., "Clinical autonomic disorders", 3rd ed, Lippincott Williams & Wilkins, 2008, pp.11-12
[2] Kevin F. et al., "Handbook of cardiac anatomy, physiology, and devices", Springer Verlag, 2008, pp. 177-189
[3] Shojiro I., "Biological activities caused by far-infrared radiation", International Journal of Biometeorology, vol. 33, 1989, pp. 145-150
[4] Nelson C.F. et al., "Chiropractic as spine care: a model for the profession", Chiropractic Osteopathy, vol. 13, 2005, pp. 1-17
[5] Cauwenbergs P., "Vertebral subluxation and the anatomic relationship of the autonomic nervous system", Foundations of Chiropractic, Subluxation St Louis, 1995, pp. 235-266
[6] Suter B, Kistler A., "Demonstration of the effective of acupuncture on the autonomic nervous system by examination of the microcirculation", Research in Complementary Medicine, vol. 6, 1999, pp. 32-34
[7] Camm A. J., Malik M., Bigger J. T., Breithard G., "Heart rate variability: standards of measurement, physiological interpretation, and clinical use", European Heart Journal, vol. 17, 1996, pp.345-381
[8] Young-Chang P., "The Effect of Acupressure at the Extra 1 Point on Subjective and Autonomic Responses to Needle Insertion", Anesthesia and analgesia, vol. 107, 2008, pp.661-664
[9] Macor F., Fagard R., Vanhoof R., Staessen J., Thijs L., Amery A., "Power spectral analysis of short-term RR interval and blood pressure variability: Comparison of different methods and assessment of reproducibility", High Blood Pressure, vol. 3, 1994, pp.15–21
[10] Elif Derya U., Inan G., "Spectral analysis of internal carotid arterial Doppler signals using FFT, AR, MA, and ARMA methods", Computers in Biology and Medicine, vol. 34, 2004, pp. 293-306