Change in Autonomic Nerve Responses after Low-frequency Transcutaneous Electrical Nerve Stimulation

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Purpose: The purpose of this study was to examine changes in autonomic nerve responses after low-frequency transcutaneous electrical nerve stimulation (TENS).

Methods: Research subjects were 24 students who attend University. Subjects were divided into two groups: 1 = a low intensity group; 2 = a high intensity group. Electrodes were attached to the forearm of the dominant arm and electrical stimuli were administered for 15 minutes. Outcome measures were skin conduction velocity, skin temperature, blood flow, and pulse frequency, each of which was measured a total of 4 times. The data were analyzed using a repeated measures ANOVA.

Results: In changes in conduction velocity, the main effect of time variation (in black) was statistically significant. The interaction between time and group main effects was not statistically significant; nor was the difference between the groups. Results showed that skin conduction velocity changed without any relation to group.

Conclusions: Low frequency TENS selectively increases skin conduction velocity, which may be helpful for activating sudomotor function regardless of intensity.

Keyword: Transcutaneous electrical nerve stimulation, Autonomic nerve response, Skin conduction velocity, Skin temperature, Blood flow, Pulse frequency

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I. Introduction

The autonomic nervous system, which includes both sympathetic and parasympathetic divisions, carries out various physiologic functions which we normally cannot control through our intention to keep our body working properly and keep all systems in a suitable balance.[1]

Raja and Grabow[2] reported that numerous treatment modalities have been purported to be useful in the management of sympathetic dysfunction such as a complex regional pain syndrome (CRPS) and these include pharmacologic therapies, physiotherapy etc. For patients with autonomic nervous system dysfunction, the intensity of pain does not correspond to the amount of damage that they may have suffered or to any specific causes.[3] Additionally, there are few ways of treating, ways that have not proven to be effective, and which have made clinical doctors embarrassed.[3]

In connection with sympathetic dysfunction, physical therapy using electrical stimulation methods have been tried. Among electrical stimulation methods, transcutaneous electrical nerve stimulation (TENS) is a noninvasive method that can reduce side effects and dangers such as pain in the injection area, intravascular penetration, blocking failure and hematoma which might occur if an invasive method were used.[4] TENS is largely used in two types of processes accordingto the method of stimulating patients. First, low-frequency and intensity TENS is called conventional TENS and is based on pain control derived from gate control theory of Melzak and Wall.[5] Second, there is low-frequency and high intensity TENS which, like acupuncture, is based on pain control mediated by endogenous opioids.[6]

In physical therapy, electrical stimulation has been used extensively for pain control,[7] dysfunction control,[8] tissue repair,[9,10] and sympathetic nervous system modulation, such as for hypertension.[11]

Cramp et al[12] reported that low-frequency TENS increases blood flow compared with high-frequency TENS. TENS above the threshold for muscle contraction elicits a large increase in blood flow. However, a study of the application of TENS to healthy people, which was done by Wong and Jette,[13] showed a significant decrease in skin temperature on both sides by stimulating sympathetic nerve activity. Choi and Lee[14] reported that skin conductance was increased by high frequency-high intensity TENS but skin temperature, pulse rate, and respiration rate were not changed. Results of previous studies have varied with the nature of the electrical stimulation. In addition, there have not been many studies on the responses of sympathetic nerves as a function of the electrical stimulation.

Therefore, the purpose of this study was to characterize sympathetic nerve response as a function of different intensities, including low-frequency TENS which causes a relatively small muscle tetanus and discomfort. This study tested the hypothesis that variations in autonomic nerve responses could be due to the intensity of the electrical stimulation.

II. Methods

1. Subjects

All subjects were women attending university. The number of subjects required was calculated by a sample size calculation program. We assumed a program G power of 3.0, an effect size of 0.25, a significance level α=0.05, and a power ($\alpha-\beta$) of 80%. We determined that at least 24 subjects were needed. We selected subjects who did not show symptoms or indication of cardiovascular disease or sympathetic dysfunction, who had not required medical care for any physical problems within the previous month, and who had no musculoskeletal disease or neurologic trouble. All subjects provided informed consent.

The average age of subjects was 21.54±0.74 years; the average height was 161.92±3.82 cm the average weight was 55.00±6.77 kg. The 24 subjects were divided randomly into two groups of 12 each: group I received low frequency - low intensity stimuli; group II received low frequency - high intensity stimuli. There were no significant differences between the twogroups at baseline.

2. TENS interventions

To apply electrical stimuli, we used a pulsating current waveform that delivered 4 pulses per second (pps), with a pulse width of 250㎲(Endomed 482, Enraf, Netherlands). The maximum intrinsic signal strength for the two groups was set depending on the stimulus intensity group I (17.78±5.61 mA), group II (11.16±2.23 mA). An electrical stimulation electrode whose size was 5 cm × 5 cm and that had disposable self-adhesive areas, were attached to parts of each subject's dominant arm, based on the median nervous impulses passing the location of the mid-point. The duration of the electrical stimulation was set for 15 minutes in continuous mode.

3. Outcome measures

Temperature of the laboratory was 23~25°C; humidity was 50~70%. Subjects fasted for 3 hours prior to testing. Coffee and smoking were prohibited for the 3~4 hours prior to testing. Wearing compressive garments was forbidden

Before the experiment, subjects assumed a supine position and rested comfortably with their eyes closed. Electrodes were attached to the forearm and hand polished with alcohol. Electrodes were attached to the fingers to measure after 20 minutes. In addition, during the experiment, internal and external noise in the lab was controlled. Skin conduction velocity, skin temperature, blood flow and pulse frequency were measured. Sensors were attached at the end of the thumb and pulse and blood flow were measured. A second sensor was attached at the end of the finger to measure skin temperature. Sensors at the end of the ring finger were used to measure skin conduction velocity. Equipment used to measure the MP150 (Biopac, USA), skin conduction velocity, skin temperature and blood flow for 10 seconds at each time point were analyzed. A signal with a pulse frequency of 1 per minute was used. Measurements were taken before electrical stimulation, immediately after, and 5 minutes after. The effects of the stimulus were measured four times for 10 minutes each.

4. Statistical analysis

All data were analyzed by SPSS version 12.0 statistical programs.

Between group differences in general characteristics of subjects were analyzed using Mann-Whitney U tests. Repeated measure ANOVAs were used to compare between group differences as a function of time. Statistical significance was defined as $p<0.05$.

III. Results

1. Change in skin conduction velocity

In changes in conduction velocity, the main effect of time variation (in black) was statistically significant ($F_{3, 66}=7.40$, $p<0.05$). The interaction between time and group main effects was not statistically significant; nor was the difference between the groups (Table 1). Results showed that skin conduction velocity changed without any relation to group.

2. Change in skin temperature

In changes in skin temperature, differences in main effects and interactions were statistically significant in both groups (Table 2). Results showed that skin temperature was not changed after electrical stimulation.

3. Change in blood flow

In changes of blood flow, main effects and interactions were statistically significant differences for both groups (Table 3). Results showed that blood flow was not changed after electrical stimulation.

4. Change in pulse frequency

In changes in pulse frequency, differences in main effects and interactions were statistically significant in both groups (Table 4). Results showed that pulse frequency was not changed after electrical stimulation.

IV. Discussion

This study was designed to investigate changes in sympathetic nerve response as a function of different intensities, including low-frequency TENS which causes a relatively small muscle tetanus and discomfort.

In both groups, skin conduction velocity decreased immediately after the stimulus, began to increase after 10 minutes. Also, both groups were not statistically significant between the changing patterns. We found that TENS regardless of the stimulus strength increases temporarily a conduction velocity in skin, but its effects remain a short time.

In order to measure skin conduction velocity, galvanic skin responses (GSR) are used. GSR is a simple, useful and reproducible method of capturing autonomic nerve responses that depend on sweat gland function.[15] During a sympathetic response, eccrine glands in the skin produce ion-filled sweat, lowering the resistance of the skin and increasing conductivity.[16] Youn and Na[17] conducted a study of acupuncture. Skin joksamri conduction velocity after acupuncture was not significantly

Table 1. Change of skin conduction velocity (unit: micromho)

Group	Time				F		
	Pre	Post 15 min	Post 20 min	Post 25 min	time	group	time × group
I	0.30±0.06	0.38±0.07	0.35±0.09	0.32±0.10	7.40*	0.01	0.45
II	0.31±0.07	0.36±0.04	0.36±0.05	0.32±0.10			

All data are mean±SD
*p<0.05
I: low frequency - low intensity TENS
II: low frequency - high intensity TENS

Table 2. Change of skin temperature (unit: ℃)

Group	Time				F		
	Pre	Post 15 min	Post 20 min	Post 25 min	time	group	time × group
I	32.44±0.00	32.44±0.00	32.44±0.00	32.44±0.00	1.60	0.48	1.59
II	32.44±0.00	32.44±0.04	32.44±0.00	32.44±0.00			

All data are mean±SD
I: low frequency - low intensity TENS
II: low frequency - high intensity TENS

Table 3. Change of blood flow (unit: area, cm^2)

Group	Time				F		
	Pre	Post 15 min	Post 20 min	Post 25 min	time	group	time × group
I	2.48±0.61	2.46±0.02	2.49±0.07	2.47±0.00	0.97	1.76	0.82
II	2.46±0.00	2.46±0.01	2.47±0.01	2.46±0.13			

All data are mean±SD
I: low frequency - low intensity TENS
II: low frequency - high intensity TENS

Table 4. Change of pulse frequency (unit: beat per minute, BPM)

Group	Time				F		
	Pre	Post 15 min	Post 20 min	Post 25 min	time	group	time × group
I	78.33±16.40	75.67±17.15	80.25±24.60	83.83±32.66	1.04	2.55	0.58
II	65.50±7.33	70.25±10.80	68.17±19.10	71.08±14.42			

All data are mean±SD
I: low frequency - low intensity TENS
II: low frequency - high intensity TENS

different than before acupuncture. When compared with conduction velocity of the low frequency TENS group, acupuncture stimulated the skin to immediately increase conduction velocity. We found that TENS regardless of the stimulus strength improve a function of sweating by activating the sympathetic nervous system because of increase of sweating function by decrease of skin resistance.

Skin temperature, heart rate, and blood flow changes seen in both of the two groups showed no changes over time. These results are similar to previously reported results. Sherry et al[18] reported that there was no change in dorsal and plantar skin temperatures under the application of a 2 bps stimulus in burst mode to the common peroneal nerve and the tibial nerve for 5 minutes with the 3 different types of intensity: (1) under the threshold for muscle; (2) above the threshold for muscle contraction, (3) above the threshold for muscle contraction and 25% above the motor threshold. Cramp et al[19] reported no significant changes in the temperature of the forearms and fingers when a stimulus of 4 pps amount was applied to the right median nerve at various angles for 15 minutes. They reported that stimuli only above the threshold for muscle contraction significantly increased forearm blood flow. Reeves et al[20] reported that no significant change in pulse frequency of the middle fingers of the right and left hands of subjects when 100 pps and 4 pps were applied for 20 minutes at a strength under the threshold for muscle contraction. Scudds et al[21] reported no significant changes in temperature of the fingers irrespective of the frequency –that is, after 100 pps and 4 pps of electrical stimulation were applied to the ulnar border of the left hand and the web space between the first and second metacarpals with comfortable and endurable intensity for 30 minutes. In addition, the temperature of the fingers showed no significant changes, the reason for which was probably that wet fingers didn't get any electrical influences because of their long distance from the stimulated area. Accordingly, our results indicate that autonomic nerve changes were not detected, which might happen in the local area near the electrically stimulated point.

Park,[22] whose results are different from the study of ours, reported that the skin temperature of the second finger increased significantly when the stellate ganglion was stimulated through HVPC and TENS for 20 minutes with an intensity that did not cause muscle contraction. Worg and Jette[16] reported that the temperature of the fingers decreased significantly soon after each burst when high and low frequencies were applied to the forearms and to 4 acupuncture points at muscle contraction intensity for 25 minutes. In addition, Lin et al[23] reported that the blood flow of the finger decreased when 2 pps of electrical acupuncture stimulation was applied to the hoku point with muscle contraction intensity. As is shown above, changes in skin temperature, pulse frequency, and blood flow were shown in the electrically stimulated area such as the acupuncture point and the stellate ganglion and between the stimulated area and areas far away from it.

This study has some limitations. These include normal subject without autonomic nervous system dysfunction, gender, and age. Thus, in the future, studies investigating gender, age, and autonomic nervous system disorders will be needed.

V. Conclusion

We conclude that low-frequency TENS can cause skin conduction velocity to increase selectively irrespective of intensity, which may be temporarily helpful for the activation of sudomotor function. Also, we believe that the greater change in skin temperature, pulse frequency and blood flow can occur in the area nearer the electrically stimulated spot. Future studies should investigate the long term effects of TENS on skin conductance in subjects with known pathology.

Author Contributions

Research design: Lee JW
Acquisition of data: Park AR
Analysis and interpretation of data: Park AR, Lee JW
Drafting of the manuscript: Park AR, Lee JW
Research supervision: Hwang TY

References

1. Kang HS. Effect of exercise intensity on autonomic nerve system activity during acute exercise. Exercise science. 1998; 7(1):1-10.
2. Raja SN, Grabow TS. Complex regional pain syndrome I (reflex sympathetic dystrophy). Anesthesiology. 2002;96(5): 1254-60.
3. Moon JY, Kim YC, Park MJ et al. Cognitive assessment in complex regional pain syndrome patients. Korean J pain. 2009;22(1):28-32.
4. Park JW, Park SB, Han SH et al. The effect on electrocardiogram following transcutaneous electrical nerve stimulation on stellate ganglion region. Korean J Clin Geri. 2007;8(2):236-41.
5. Melzak R, Wall PD. Pain mechanisms: a new theory. Science. 1965;150(699):971-9.
6. Basbaum AI, Fields HL. Endogenous pain control mechanisms: review and hypothesis. Ann Neurol. 1978;4(5): 451-62.
7. Seo SK, Cho WS, Lee JW et al. Effects of auricle electric stimulation on pain, gait and balance in the old aged with knee joint disease. J Kor Soc Phys Ther. 2008;20(2):11-7.
8. Cho IS, Jang JS, Kim K et al. The effect of EMG-stim on upper limb function in chronic stroke patients. J Kor Soc Phys Ther. 2009;21(2):1-8.
9. Lee HM, Chae YW. Influence of microcurrent therapy I interleukin-1 expression in rheumatoid arthritis rats. J Kor Soc Phys Ther. 2009;21(2):103-8.
10. Oh HJ, Kim JW, Kim MS et al. The effect of microcurrent stimulation on histological structure of wound in rat. J Kor Soc Phys Ther. 2008;20(1):67-73.
11. Kim JH. The inhibition of hypertension-related response by 17β-estradiol and the increase of 17β-estradiol activity by electrical stimulation. J Kor Soc Phy Ther. 2009;21(2):109-16.
12. Cramp AF, Gilsenan C, Lowe AS et al. The effect of high- and low-frequency transcutaneous electrical nerve stimulation upon cutanoeus blood flow and skin temperature in healthy subjects. Clin Physiol. 200020(2):150-7.
13. Wong RA, Jette DU.Changes in sympathetic tone associated with different forms of transcutaneous electrical nerve stimulation in healthy subjects. Phys Ther. 198464(4):478-82.
14. Choi YR, Lee JW. Changes in sympathetic nervous system response of healthy adult women with changes in the stimulus intensity of high frequency transcutaneous electrical nerve stimulation. J Kor Soc Phys Ther. 2010;22(1):61-6.
15. Travainen MP, Koistinen AS, Valkonen-Korhonen M et al. Analysis of galvanic skin responses with principal components and clustering techniques. IEEE Trans Biomed Eng. 2001;48(10):1071-9.
16. Westeyn T, Presti P, Starnery T. ActionGSR: A combination galvanic skin response-accelerometer for physiological measurements in active environments. Wearable Computers, 2006 10th IEEE International Symposium on. 2006:129-30.
17. Youn DH, Na CS.Effect of acupuncture ST36 on skin temperature, galvanic skin response and heart rate in humans. The Korean Journal of Meridian & Acupoint. 2003;20(3): 29-34.
18. Sherry JE, Oehrlein KM, Hegge KS et al. Effect of burst-mode transcutaneous electrical nerve stimulation on peripheral vascular resistance. Phys Ther. 2001;81(6):1183-91.
19. Cramp FL, McCullough GR, Lowe AS et al. Transcutaneous electic nerve stimulation: The effect of intensity on local and distal cutaneous blood flow and skin temperature in healthy

subjects. Arch Phys Med Rehabil. 2002;83(1):5-9.

20. Reeves JL 2nd, Graff-Radford SB, Shipman D. The effect of transcutaneous electrical nerve stimulation on experimental pain and sympathetic nerve system response. Pain Med. 2004;5(2):150-61.
21. Scudds RJ, Helewa A. Scudds RA. The effect of transcutaneous electrical nerve stimulation on skin temperature in asymptomatic subjects. Pnys Ther. 1995;75(7):621-8.
22. Park RJ. The effects of transcutaneous electrical nerve stimulation and microampere electrical nerve stimulation on sympathetic tone in healthy subjects. J Kor Soc Phys Ther. 1997;9(1):51-7.
23. 23. Lin CF, Liao JM, Tsai SJ et al. Depressor effect on blood pressure and flow elicited by electroacupuncture in normal subjects. Auton Neurosci. 2003;107(1):60-4.