Another Understanding for Effects of Physical Stimuli on Modification of Autonomic Nerve System by Two Kinds of Stimuli on Feet

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Abstract

Background: In one series of studies, we observed the effects of acupuncture treatment (AT) on the autonomic nerve system (ANS). We experimented from various view-points. At last, we discovered a specific pattern for modifying ANS status, which showed that functions of the parasympathetic nerve increased while those of the sympathetic nerve decreased. To further study systematic modification of ANS balance, we focused on the lower body (feet). Moreover, two kinds of stimuli, tapping and vibration, were applied while measuring the value of finger floor distance (FFD) and heart rate (HR). Finally, the effects on ANS were discussed.

Methods: Twenty healthy subjects participated in this study, and they were divided into two groups; the tapping group and the vibration group. The former received 50 taps on the feet, and the latter received vibrations for two minutes. In order to indicate ANS status the effects of these stimuli were evaluated by FFD values and a kinetic record of changes in HR.

Results: Both groups showed improvement in FFD values, which was the same as the results for AT via modification of ANS. However, changes in HR showed a different pattern from AT; in this study sympathetic nerve dominantly showed an increase without a decrease in parasympathetic nerve.

Discussion and Conclusions: The reasons for differences in ANS modification may be found in the role, especially in an emergency, of the lower body. The lower body is heavy in skeletal muscles, which needs energy and blood to react during acute stress. The ANS, which controls blood distribution, may shift and concentrate system blood from the smooth muscles of the stomach (controlled by parasympathetic nerve) to the skeletal muscles of the legs and feet (controlled by sympathetic nerve). Thus, this study indicated that local stimuli of the foot induced systematic ANS modification.

Keywords: tapping, vibration, finger floor distance, heart rate, autonomic nerve system

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I  INTRODUCTION

In one series of studies, we observed the effects of acupuncture treatment (AT) on the autonomic nerve system (ANS). We conducted experiments with various ANS blockers while monitoring heart rate (HR), finger floor distance (FFD), pupillary constriction, and body temperature, and we found a specific pattern for changing the ANS\(^1\).

In bedside practice we proposed the following six pathways to explain the clinical mechanism; 1) The AT made small tissue damages and it enhanced innate immunity, 2) The AT induced local axon reflexes, it decreased stress in skeletal muscle, and it increased blood circulation, 3) deep AT (deep enough to needle into muscle) increased the SN function, 4) superficial AT (needleling through the skin 5 mm deep) increased PN functions, 5) The AT in the sitting position induced a comfortable SN dominance, and 6) The AT in the lying position decreased SN dominance.

Furthermore, we discovered the best combination of the following three factors to enhance the effect of AT; the position (sitting position), the period (expiratory period), and the depth (superficial depth). At that time, a specific pattern for changing of the ANS status was observed. There are two types of autonomic nerves. One is sympathetic nerve (SN) which is dominant when we suffer stress. The other is parasympathetic nerve (PN) which is dominant when we relax. They maintain our health by balancing each other like a seesaw. Our previous study showed that AT induces the function of the PN to increase while suppressing that of the SN. When the ANS function showed such a change, the resilience and homeostasis of the body were enhanced. We regarded this as the fundamental mechanism of AT\(^2\)-\(^4\).

We hypothesized that the lower body (legs and feet) might have a pathway (or switch) to control the balance of the ANS, increasing SN function without decreasing the PN function. To study this hypothesis, AT mechanism and examine each factor, we conducted the following experiments: 1) position (sitting vs lying), 2) respiration (expiratory vs inspiratory), and 3) depth (superficial vs deep). In a series of experiments, AT in the sitting position and the expiratory period increased whole body temperature\(^5\). At that time FFD values improved\(^6\), heart rate (HR) decreased, and pupila were constricted\(^7\). Our results of our study support our hypothesis of the mechanism.

For a further study of the systematic modification of ANS balance, we focused on the lower body (legs and feet). Moreover, two kinds of stimuli, tapping and vibration, were applied and we observed FFD and HR values. Then, the effects on ANS were discussed.

II  METHODS

1. Subjects

Twenty healthy university students participated in this study (n = 20; male = 16, female = 4) of age 19–53 (mean age 26.4 ± 2.2). They were randomly divided into two groups using the envelope allocation method. They have appropriate exercise and they are free from dependence of nicotine, drugs, sleep trouble, diabetes and autonomic imbalance. All subjects received an
explanation of the objective and details of this study, and written informed consents were obtained (Declaration of Helsinki). The study was approved by the institutional review board of Tsukuba University of Technology.

2. Experiments

Two experiments were conducted, and the protocol model is shown in Fig. 1. This study was conducted in a room of 26.0 ± 0.5°C, 50.0 ± 5.0% in room humidity, and subjects kept rest more than 30 minutes before the experiment. They had neither food, nor exercise, nor bath before the experiment.

i) **Experiment 1 (tapping)** Ten healthy subjects (n = 10; average age: 28.8 ± 4.1) participated, and took ten minutes rest sitting on chairs before the first FFD measurement. After measurement he or she rested in the same position for three minutes. In the tapping experiment, subjects were asked to put his or her dominant side foot on the opposite side thigh and that foot was tapped 50 times by the fists of the experimenter (50 times tapping/20 seconds). Then, subjects rested in a sitting position again for three minutes before the second FFD measurement.

ii) **Experiment 2 (vibration)** Ten healthy male subjects (average age: 23.9 ± 1.7) participated. Subjects put both feet on a vibratory device (Joy Foundation, Inc., Tokyo, Japan) and were given stimuli of vibrations for two minutes. The vibrations were made from a music CD, in the

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**Fig. 1** A. The entire protocol for this study  
B. Two kinds of stimuli, tapping and vibration
range between 20 and 150 Hz with the constant amplitude. The exclusion of everything else was the same as in Experiment 1. The dose of stimuli (50 times tapping or two minutes vibration) was determined referring to the methods of various previous studies and results of our precursor experiments (data not shown).

3. FFD values

FFD was measured twice (before and after the stimuli) within sight with a forward bending tester (W-35, Yagami Inc., Nagoya, Japan) from a standing position.

Subjects stood with their heels together (right toe tips and left toe tips were about 5 cm apart). They slowly bent forward with both hands held parallel touching the cursor of the tester. To obtain valid data the experimenter strictly confirmed subjects’ positions, if their knees were straight, and so on.

4. The pattern in ANS change

ANS function was observed by an electrocardiograph (ECG) device (MP36, BIOPAC Systems, Inc., CA, USA) during the study period. As our previous reports showed, an ECG record with a kind of up-slope pattern indicates an increase of SN function (and usually that of PN suppression). On the other hand, its sudden drop indicates PN increase (likewise, that of the SN was often decreased).

5. Statistical Analysis

The statistical significance of differences between values was tested with SPSS Advanced Models Version 15 using Mann-Whitney’s U test as well as Wilcoxon signed-rank test. P-values of less than 0.05 were considered to be statistically significant.

III RESULTS

There was no significant difference between the age of two groups (p=0.646).

1. Experiment 1 (tapping)

After the stimuli of tapping 50 times the absolute value of FFD improved prominently compared to before stimuli (−2.9 ± 2.6 to −5.9 ± 2.7 cm) (p = 0.011). Eight cases out of ten improved. (Fig. 2 A)

At the same time HR was also monitored. Case 1 showed an upward-sloping pattern, which indicates a typical increase of SN function. Case 2 showed a similar pattern, too. Such pattern was observed in seven cases while PN increase was found in only three cases out of ten. No case showed PN decrease. (Fig. 2 B)

2. Experiment 2 (vibration)

After stimuli of vibration the absolute value of FFD improved compared to before stimuli (4.9 ± 2.4 to 2.7 ± 2.3 cm) (p = 0.022) Thus, eight cases out of ten showed improvement after the stimuli. (Fig. 3 A)

In experiment 2, changes in HR showed two kinds of patterns. One pattern was the same as tapping, that is, Case 3 showed an upward sloping pattern indicating an increase of SN function. An interesting was found in Case 4, which showed a drop pattern like a split-fingered fastball.
It showed an increase of both PN function as well as SN. In short, Case 4 showed multiple increases of the SN/PN functions. In this experiment, eight cases showed patterns as for Case 4. (Fig. 3B) No case showed a decrease of PN function. (Fig. 4A)

IV DISCUSSION

Both kinds of stimuli, tapping and vibration on the feet, induced prominent improvements of FFD values. In our previous study, we reported that the best AT combination improved FFD values via ANS modification\(^6\). At that time our data showed an increase of PN function (SN function was suppressed)\(^4\). Then, it was thought that such modified function of ANS improved FFD values. In other words, it was understood to be a systematic response rather than a local one (such as lower body).

On the other hand, more than 70% of the results of this study showed SN function increase (including cases of multiple increases of SN/PN function). Moreover, no case showed a decrease
of PN function. (Fig. 4A) This was completely different from our previous study of AT. The reason for this difference may be found in the special uses of the foot. It may be considered that the lower body (legs and feet) has a very important role in acute emergencies.

For example, when a gazelle sees a charging lion, the gazelle’s brain detects a threat and orchestrates a physiologic response that enables the gazelle to flee. One more example might be found in a change of blood distribution. Such examples of stress responses enabling survival are seen throughout nature.

Another example may be found in childhood. Say a child would run out and play immediately after lunch, then he or she would get a stomachache. It may be explained that along with a change in ANS balance, blood distribution shifted from the smooth muscles of the stomach (controlled by PN) to the skeletal muscles of the legs and feet (controlled by SN).

An unbalance of the ANS, for example, an increase of SN function without changes in PN

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**Fig. 3**

A. The change of FFD value after vibration

B. Two typical patterns of HR change after vibration
function, would induce various problems such as palpitation or loss of motor function. To prevent such problems, the lower body (legs and feet) might have a pathway (or switch) to control the balance of the ANS. In other words, such a system, which increases SN function without decreasing the PN function is needed to survive by escaping from an emergency. Our study of stimuli of the feet might support the hypothesis mentioned above.

In the conventional model, when PN increases, SN decreases. However in this study, a new pattern of change of ANS status was observed in the stimuli of the lower body. This time SN function increased without a decrease of PN function. In this way, there might be two patterns

![Diagram showing the comparison between conventional and new patterns of ANS status change](image)

**Fig. 4**  A. Number of 10 cases
Patterns of HR change (each group n = 10).
SN: a single increase of SN function
PN: a single increase of PN function
SN (multiple): an increase of SN function including increase of PN
NC: no change
B. Two typical patterns of HR change (ANS modification)
for ANS change, one for promoting resilience and the other for maintaining the homeostasis of our bodies. (Fig. 4B) However, further study is needed to confirm this hypothesis from various points including questionnaire in a large scale study.

V CONCLUSION

Two kinds of stimuli, tapping and vibration, were applied to the foot to study systematic modification of ANS balance. 1) The FFD value improved after both stimuli. 2) Both stimuli induced ANS modification, increasing the function of both the SN and the PN, and 3) A hypothesis was proposed that there may be two patterns for ANS modification, promoting resilience and maintaining the homeostasis of our bodies. However, further study is needed from various points in a large scale study.

Conflict of Interest

None declared.

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Contributor statement

KN conceived the study. HM wrote the first draft and MW prepared final draft. KII, TM, KY and HK contributed in data collection. All authors critically edited drafts of this manuscript and approved the final manuscript.

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