Spectral analysis of heart rate variability during trigger point acupuncture

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ABSTRACT

Objectives To clarify changes in the cardiovascular autonomic nervous system function due to trigger point acupuncture, we evaluated differences in responses between acupuncture at trigger points and those at other sites using spectral analysis of heart rate variability.

Methods Subjects were 35 healthy men. Before measurements began the subjects were assigned to a trigger point acupuncture or control group based on the presence/absence of referred pain on applying pressure to a taut band within the right tibialis anterior muscle. The measurements were conducted in a room with a temperature of 25°C, with subjects in a long sitting position after 10 min rest. Acupuncture needles were retained for 10 min at two sites on the right tibialis anterior muscle. ECG was performed simultaneously with measurements of blood pressure and the respiratory cycle. Based on the R–R interval on the ECG, frequency analysis was performed, low-frequency (LF) and high-frequency (HF) components were extracted and the ratio of LF to HF components (LF/HF) was evaluated.

Results The trigger point acupuncture group showed a transient decrease in heart rate and an increase in the HF component but no significant changes in LF/HF. In the control group, no significant changes were observed in heart rate, the HF component or LF/HF. There were no consistent changes in systolic or diastolic blood pressure in either group.

Conclusions These data suggest that acupuncture stimulation of trigger points of the tibialis anterior muscle transiently increases parasympathetic nerve activity.

INTRODUCTION

Noxious stimulation is known to increase sympathetic nerve activity.[1 2] Acupuncture is a form of noxious stimulation causing minor tissue injury and is therefore expected to increase sympathetic activity. However, in anaesthetised rats and humans, acupuncture has frequently been reported to induce a decrease in heart rate.[3–8] This is considered to require either an increase in parasympathetic activity or inhibition of sympathetic activity, or both. There are various theories regarding the neurological mechanism of this transient decrease in heart rate as a response to acupuncture.

Trigger points (TPs) are considered to be treatment points for chronic musculoskeletal pain such as that encountered in myofascial pain syndrome.[9–13] Few studies have examined changes in cardiovascular autonomic nervous system function induced by TP stimulation. Autonomic responses such as piloerection and perspiration occur around TPs,[9] and practitioners of acupuncture and moxibustion note that TP stimulation by compression or acupuncture frequently induces responses such as borborygmus, nasal congestion and saliva secretion, indicating increased parasympathetic nerve activity. Thus, it can be speculated that TPs markedly affect the autonomic nervous system and that the autonomic nervous system is involved in the effects of TP therapy.

Analysis of R–R interval variation on ECG was first used as a method to evaluate autonomic activity by Wheeler and Watkins.[14] They reported a decrease in or disappearance of respiratory sinus arrhythmia (measured in terms of R–R interval variation) in patients with diabetes-induced autonomic neuropathy. In the same year, Sayers[15] introduced spectral analysis using fast Fourier transformation (FFT) for the analysis of heart rate variability, suggesting the possibility of frequency analysis of heart rate variability. Spectral analysis of heart rate variability is a method of evaluating autonomic activity by frequency analysis of time series data on the R–R interval per unit of time using FFT to isolate the frequency components of cardiac sympathetic or parasympathetic activity. However, spectral analysis of heart rate variability is also affected by arrhythmias such as premature beats and by the respiratory rate. In particular, when the respiratory rate is ≤9/min, frequency components of cardiac sympathetic or parasympathetic activity cannot be isolated. The evaluation of autonomic activity using spectral analysis of heart rate variability is therefore complicated.

To clarify the effects of TP acupuncture on the autonomic nervous system, we compared changes in cardiac sympathetic and parasympathetic activities between TP acupuncture and acupuncture at other sites using spectral analysis of heart rate variability.

METHODS

Subjects

The subjects consisted of 35 healthy men aged 20–28 years with no history of cardiac disease or arrhythmia and not currently experiencing any psychological stressors such as examinations or relationship breakups. Before measurement we identified whether or not subjects experienced referred pain when points on a taut band within the right tibialis anterior muscle were pressed manually. On this basis, the subjects were assigned to one of two groups: (1) a TP acupuncture group; and (2) a control group. The TP acupuncture group consisted of subjects who had referred pain as described above, while the control group consisted of those who did not have such referred pain.

Measurements

ECG was performed with bipolar chest leads and time-series R–R interval data were recorded. Heart rate (beats/min) was calculated from the obtained R–R interval. Paced breathing was performed with a cycle of 2.5 s of inhalation followed by 2.5 s of exhalation using a metronome. Simultaneously, this respiratory cycle was confirmed based on rib cage movements using the chest impedance method.[16] Based on the obtained time series R–R interval data (sampled every 5 min), frequency analysis was performed with heart rate variability analysis software (HRV Module for chart, AD Instruments) using FFT. The low-frequency (LF; 0.04–0.15 Hz) and high-frequency (HF; 0.15–0.40 Hz) components were extracted. The HF component was evaluated as a parameter of cardiac parasympathetic activity and LF/HF as a parameter of cardiac sympathetic activity. For the HF component, to evaluate relative changes in cardiac sympathetic/parasympathetic activities we used normalised units (n.u.): the relative value of the HF power component in proportion to the total power minus the very LF component. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured at 5 min intervals using an automatic sphygmomanometer (HEM-7420; Omron).

Protocol

Measurement was performed at least 2 h after a meal and caffeinated beverage, between 15:00 and 19:00. Subjects adopted a long sitting position (sitting with the legs extended straight in front of the torso, with the hips flexed to 90°) in a room maintained at a temperature of 25°C, and measurement was initiated after a 10 min rest. Five minutes after the initiation of measurement, two acupuncture needles were inserted in the right tibialis anterior muscle and retained for 10 min (see detailed description below). The needles were then removed and the subjects remained in the long sitting position for 10 min (total measurement time 25 min).

Acupuncture stimulation

For acupuncture, stainless steel disposable needles (50×0.2 mm; Seirin, Japan) were used, with an insertion depth of about 15 mm. Previous studies have reported that acupuncture stimulation of acupuncture points on the limbs induces a decrease in heart rate.[4–8] Therefore, in this study we stimulated points in the tibialis anterior muscle. Two points on the right tibialis anterior muscle were stimulated, one approximately 50 mm below the lateral condyle of the tibia and the other 10 mm distal to this. TPs have been defined as 'sites that are present in rope-like indurations of muscle tissue and cause referred pain when stimulated by compression, needle insertion, or heating'.[17] We therefore identified as TPs those points that induced referred pain when a taut band within the right tibialis anterior muscle was pressed. In the TP acupuncture group, two acupuncture needles were inserted into TPs on the right tibialis anterior muscle, confirming the presence of referred pain, and the needles were retained for 10 min. In the control group, two acupuncture needles were inserted into similar sites in the tibialis anterior muscle (ie, a point at about 50 mm below the lateral tibial condyle and another 10 mm below this) that did not cause referred pain and were therefore not TPs, and the needles were retained for 10 min. The subjects used hand signals to indicate whether or not they experienced referred pain.

Statistical analysis

For statistical analysis, the Student t test was used to compare each parameter between the TP acupuncture and control groups. To compare time-series changes, repeated-measure analysis of variance was used and the multiple comparison test (Tukey's honestly significant difference test) was performed when significance was observed. p Values <0.05 were regarded as significant. All measurements are expressed as mean±SD.

RESULTS

Eighteen subjects were assigned to the TP acupuncture group (age 24.7±2.6 years) and 17 were assigned to the control group (age 24.5±2.6 years) prior to

Table 1 Comparison of the pre-stimulation value of each parameter

	TP group (n=18)	Control group (n=17)	p Value
Age (years)	24.7±2.6	24.5±2.6	0.825
HR (bpm)	67.6±8.8	66.1±8.5	0.605
SBP (mm Hg)	125.6±7.7	126.1±9.9	0.861
DBP (mm Hg)	76.6±8.4	74.0±8.3	0.491
HF (n.u.)	49.8±10.6	56.3±11.3	0.205
LF/HF	1.1±0.6	0.8±0.4	0.133

All values are mean±SD.
DBP, diastolic blood pressure; HF, high-frequency component; HR, heart rate; LF, low-frequency component; SBP, systolic blood pressure; TP, trigger point.

measurements. Before acupuncture stimulation no significant difference was observed between the two groups in heart rate, SBP or DBP. Spectral analysis also revealed no significant difference between the two groups in terms of HF component or LF/HF (table 1).

Changes in heart rate and blood pressure during acupuncture stimulation

In the TP acupuncture stimulation group the heart rate significantly decreased during acupuncture stimulation compared with the pre-stimulation value (pre-stimulation value: 67.6±8.8; first 5 min period of acupuncture stimulation: 64.4±8.9 $p<0.001$; last 5 min period of acupuncture stimulation: 65.2±8.9 $p=0.037$), and recovered to close to the pre-stimulation value after removal of the needle. In the control group, heart rate did not change significantly (pre-stimulation value vs first 5 min period during acupuncture stimulation: $p=0.151$). In addition, no consistent changes were observed in SBP or DBP in either group (figure 1).

Changes observed on spectral analysis during acupuncture stimulation

In the TP acupuncture stimulation group the HF component significantly increased during the first 5 min period of acupuncture stimulation compared with the pre-stimulation value ($p<0.001$), tended to remain

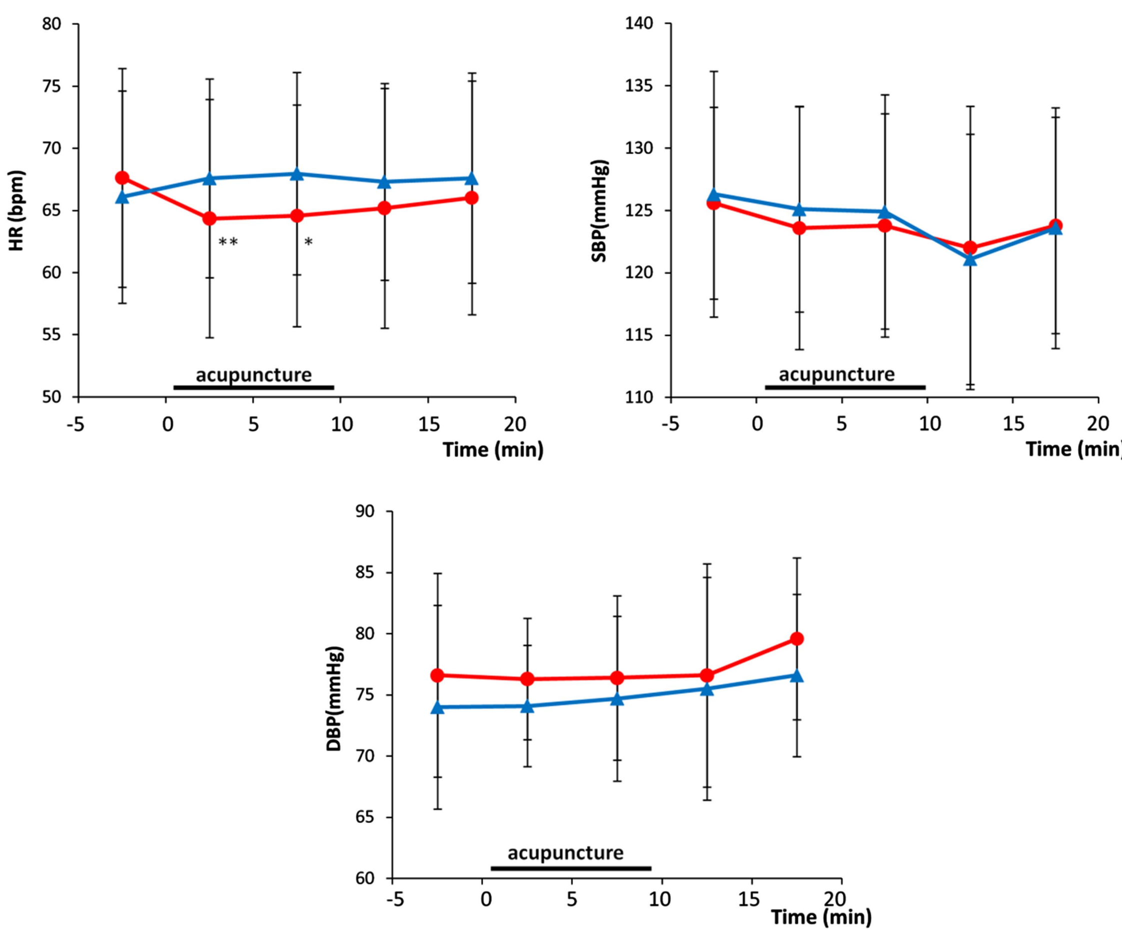

Figure 1 Changes in heart rate (HR) and diastolic blood pressure (DBP) and systolic blood pressure (SBP) in in the trigger point (TP) acupuncture stimulation group (circles) and the control group (triangles). In the TP acupuncture stimulation group the HR significantly decreased during acupuncture stimulation compared with the pre-stimulation value (first 5 min period during acupuncture stimulation: $^{**}p<0.001$; last 5 min period during acupuncture stimulation: $^{*}p=0.037$). No consistent changes were observed in SBP or DBP in either group ($p>0.05$).

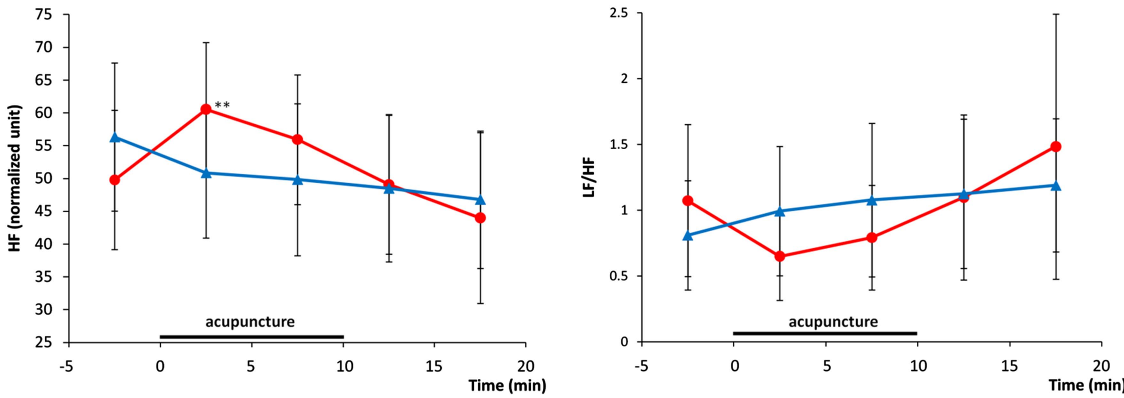

Figure 2 Changes in the high-frequency (HF) component and the ratio of low-frequency (LF) to HF components (LF/HF) in the trigger point (TP) acupuncture stimulation group (circles) and the control group (triangles). In each stimulation group the mean values of the HF component and LF/HF at 5 min intervals are shown. In the TP acupuncture group the HF significantly increased compared with the pre-stimulation value during the prior 5 min period of acupuncture stimulation and recovered to a value close to the pre-stimulation value after removal of the acupuncture needle (**p<0.001). LF/HF did not significantly change in either the TP acupuncture group or the control group (p>0.05).

elevated during the last 5 min period of stimulation (p=0.075) and recovered to close to the pre-stimulation value after removal of the needle. In the control group the HF component showed no significant changes (pre-stimulation vs first 5 min period of acupuncture stimulation: p=0.183; figure 2).

In the TP acupuncture stimulation group, LF/HF tended to decrease during the first 5 min period of stimulation, but this change was not significant (pre-stimulation vs first 5 min period of acupuncture stimulation: p=0.064). In the control group there were no significant changes in LF/HF (pre-stimulation vs first 5 min period of acupuncture stimulation: p=0.549).

DISCUSSION

Although noxious stimulation is anticipated to increase sympathetic activity, acupuncture stimulation decreases the heart rate. In the present study, changes in autonomic nervous activity were evaluated by spectral analysis of heart rate variability during acupuncture stimulation of TPs that are clinically considered to be associated with the autonomic nervous system, with acupuncture stimulation of non-TPs as a control. Spectral analysis showed a significant transient increase in the HF component in the TP acupuncture stimulation group, which did not occur in the control group. Taut bands in muscle are clinically considered to be treatment points. We therefore decided to needle a taut band as a control in the present study. The effects of needling in normal muscle tissue were not evaluated; however, the lack of any significant changes following stimulation of non-TPs in the present study suggests that no significant autonomic effects would be expected.

The results in the TP acupuncture group suggest a significant increase in parasympathetic activity and inhibition of sympathetic activity. However, an increase in sympathetic activity due to acupuncture similar to that observed in the control group may have occurred. LF/HF is a parameter of relative sympathetic activity and its decrease does not always represent inhibition of sympathetic activity. The interpretation of this parameter therefore requires caution. In the present study the TP acupuncture group showed an increase in the HF component but no significant changes in LF/HF. This constancy in LF/HF may in fact represent changes in both sympathetic and parasympathetic activity—that is, an increase in LF tending to balance out the increase in HF. The present findings are therefore similar to those of the studies by Bäcker *et al*[7] and Haker *et al*.[8] It is possible that a rise in parasympathetic activity surpassed any increase in sympathetic nerve activity due to acupuncture stimulation, resulting in the apparent inhibition of sympathetic activity evaluated in terms of LF/HF as a relative parameter. The LF component and LF/HF ratio have been reported as parameters of sympathetic activity on spectral analysis of heart rate variability, but their usefulness has not been confirmed and should be clarified by further studies.

The advantage of spectral analysis of heart rate variability is the non-invasive quantitative evaluation of cardiovascular autonomic function. However, heart rate variability reflects changes in various physiological functions such as thermoregulation, and is also affected by age and body position. In addition, the HF component, reflecting respiratory sinus arrhythmia, is also affected by the respiratory rate.[18 19] In the present study, no changes in the respiratory rate (as measured by the strain gauge method) were observed during acupuncture stimulation. Thus, the increase in the HF component during needle retention appears instead to represent a transient increase in parasympathetic activity due to TP acupuncture.

There are various theories regarding the neurological mechanism of a transient decrease in heart rate due to acupuncture stimulation.[3–8] Sugiyama *et al*[4] observed an increase in muscular sympathetic nerve activity (MSNA) and a simultaneous decrease in the heart rate during acupuncture using microneurography, suggesting enhancement of both parasympathetic nerve activity and MSNA. Nishijo *et al*[5] reported a decrease in heart rate due to acupuncture stimulation under administration of propranolol or atropine but disappearance of this response after administration of blockers of these drugs in humans, suggesting an increase in parasympathetic activity and inhibition of cardiac sympathetic activity. On the other hand, Uchida *et al*[6] found that the decrease in heart rate induced by acupuncture stimulation disappeared in anaesthetised rats that underwent spinal cord transection at C1, suggesting that the reflex centre is present in the brain. That study also found that acupuncture-induced inhibition of sympathetic activity was mediated by GABA receptors in the brainstem, resulting in a decrease in heart rate. The influence of anaesthesia on the autonomic nervous system and differences in the stimulation conditions have been suggested to be responsible for these differences in findings. In the present study, parasympathetic activity increased during TP acupuncture but no significant changes were observed in sympathetic activity. Studies examining the effect of TP stimulation by compression have also shown an increase in parasympathetic activity,[20 21] confirming that stimuli other than acupuncture also cause this response. These results suggest that TPs are sites causing an increase in parasympathetic activity when stimulated, and that this increase is not a response specific to the types of stimulus. In the present study the subjects were healthy volunteers. TPs in healthy volunteers who are not experiencing pain may be latent rather than active in nature.[9] Therefore, the results might have been different in patients with myofascial pain syndrome. Moreover, the design of the present study meant that subjects were preselected and assigned to groups rather than being randomised, which may have introduced bias.

A significant transient decrease in heart rate was observed in the TP acupuncture group. However, no consistent changes were observed in SBP or DBP. This might be explained by the transience of the changes in cardiac autonomic nervous function in response to TP acupuncture stimulation. Concerning the mechanism underlying TPs, the hypothesis integrating the motor endplate and energy crisis theories is widely known.[22] This integrated hypothesis states that excessive release of acetylcholine from the motor endplate induces excessive contraction of localised muscle fibres, compressing the blood vessels, and that the resulting relative oxygen insufficiency leads to an energy crisis, causing tissue injury. As a result, various sensitisers such as metabolites and inflammatory products are produced, sensitising nociceptors, causing pain. On the other hand, Kawakita *et al*[23 24] suggested the occurrence of polymodal receptor sensitisation and associated deep tissue oedema (polymodal receptor sensitisation hypothesis) based on results of observation in a delayed muscle pain model. Thus, various hypotheses have been proposed but the detailed mechanism of TP formation is still unclear. In each hypothesis, pain develops due to receptor sensitisation and stimulation of the sensitised area. Therefore, for pain relief to occur as a result of TP stimulation, receptor desensitisation or removal of stimulating factors such as taut bands, metabolites and inflammatory products is necessary. Since an increase in parasympathetic nerve activity increases peripheral blood flow,[25 26] accumulated metabolites and inflammatory products are circulated, reducing congestion. This is an important factor for relief of chronic pain by receptor desensitisation and removal of stimulating factors.[26 27] The present study suggests that the autonomic nervous system (particularly the parasympathetic component) is involved in the mechanism of relief of chronic motor pain such as myofascial pain syndrome by TP stimulation. In the future, experiments to evaluate the therapeutic effects of TP stimulation, measurements and evaluation of MSNA and muscle blood flow are necessary.

CONCLUSIONS

To clarify changes in cardiac autonomic nervous function due to TP acupuncture stimulation, we evaluated differences in responses between acupuncture stimulation of TPs and that of other sites using parameters of spectral analysis of heart rate variability. We found that acupuncture stimulation of sites other than TPs caused no significant changes. In contrast, acupuncture stimulation of TPs caused a transient decrease in heart rate and an increase in the HF component. These results suggest that TPs are sites that tend to cause an increase in parasympathetic activity when stimulated.

Summary points

- Acupuncture stimulation is known to differentially influence activity in the autonomic nervous system.
- Autonomic effects may be measured non-invasively by assessment of heart rate variability (fast Fourier transformation).
- In this study, needling at trigger points (but not taut bands in the absence of referred pain) in the tibialis anterior muscle produced a transient increase in parasympathetic activity.

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Contributors KK and SY conducted data acquisition and statistical analysis. KK and YK conducted data acquisition and wrote the paper.

Competing interests None.

Patient consent Obtained.

Ethics approval This study has been approved by the institutional review board of Kansai University of Health Sciences.

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