Sympathetic nervous system responses to acupuncture and non-penetrating sham acupuncture in experimental forearm pain: a single-blind randomised descriptive study

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ABSTRACT

Objective To quantify the sympathetic nervous system response to acupuncture and non-penetrating sham acupuncture in volunteers with pain.

Methods A single-blind, randomised controlled study of 36 healthy adults with no recent participation in forearm strengthening or occupations involving repeated forceful wrist motion was carried out. A fatiguing wrist extension exercise protocol was completed to induce delayed onset muscle soreness. Group 1 received no treatment, group 2 a single session of acupuncture and group 3 a single session of sham acupuncture. Outcomes included skin conductance, skin temperature and perfusion measured for 20 min before treatment, during the 15 min treatment and for 10 min after treatment.

Results The acupuncture group showed a significant increase from baseline in ipsilateral perfusion (135%) and bilateral skin conductance (144 and 146%) and a significant decrease from baseline in bilateral distal skin temperature (98%). The acupuncture and sham acupuncture groups showed decreased ipsilateral proximal skin temperature.

Conclusions Acupuncture appears to activate the sympathetic nervous system, indicated by a bilateral increase in skin conductance and a bilateral decrease in distal skin temperature after needle insertion. The unilateral increase in perfusion near the needle site seen with acupuncture treatment may be due to local circulatory, rather than systemic, control.

INTRODUCTION

Acupuncture is a longstanding, popular treatment; however, its efficacy is controversial and the mechanism remains unclear.1–3 The sympathetic nervous system is believed to play a role in acupuncture analgesia, but there are few studies in this area and results are conflicting.1,4–6 Acupuncture is also thought to improve healing by enhancing local circulation, although again there are few studies in this area.7

A common reason for seeking acupuncture is pain. Measurement of changes in the sympathetic nervous system has been suggested as an objective measure of pain.6 When faced with a stressor like pain, the sympathetic nervous system responds with a predictable physiological pattern, including increased sweating, decreased skin circulation and increased skeletal muscle circulation.4,8 Consequently, increased skin conductivity (SC), decreased skin temperature (ST) and decreased skin perfusion can serve as indicators of sympathetic nervous system activation.4–6

It has been suggested that the sympathetic nervous system may play a role in pathological pain such as central and peripheral sensitisation, and may be involved in acupuncture analgesia; however, these possibilities have not been well studied.4,6,9 Acupuncture has been shown to reduce sympathetic nervous system activity as indicated by a longlasting increase in ST at the face, hands and
feet during and after a single session in normal participants.\textsuperscript{4} It has been suggested that the bilateral effect of acupuncture on ST is central in origin, but the effect may also be segmental.\textsuperscript{4} In contrast, acupuncture has also been shown to increase sympathetic nervous system activity as indicated by a short-term decrease in finger perfusion and an increase in cutaneous sympathetic nerve fascicle activity during a single session in normal participants.\textsuperscript{4} The differing reported treatment regimens make comparison of studies difficult.\textsuperscript{4,5}

It remains uncertain whether acupuncture consistently increases or decreases sympathetic nervous system activity. It is unclear if the response of the sympathetic nervous system to acupuncture is dependent on the acupuncture points used, the level of needle stimulation, the number of treatment sessions or whether or not the system is perturbed by pain.

The purpose of this study was to quantify the response of the sympathetic nervous system to acupuncture and non-penetrating sham acupuncture (S-ACU) in a system perturbed by experimental pain. We hypothesised that acupuncture would elicit greater sympathetic nervous system activation than S-ACU, indicated by increased SC and local ST as well as decreased skin perfusion and distal ST.

METHODS
A single-blind, randomised controlled descriptive study which adhered to the STRICTA guidelines and the recommendations of the practical guide for use of Streitberger needles was completed.\textsuperscript{10,11}

Participants
Eligible participants were aged 18–50 and recruited from the staff and students of the University of Manitoba. To ensure that forearm curls were a new exercise, only individuals with no participation in forearm strengthening or occupations involving repeated forceful wrist motion in the past 3 months were included. Exclusion criteria were pregnancy or lactation, bleeding disorders, alcohol or tobacco addiction and drugs affecting the nervous system.

All participants reviewed and signed a written information and consent form according to a protocol approved by the University of Manitoba Health Research Ethics Board. Participants were asked to refrain from taking analgesics or anti-inflammatory agents, or from participation in forearm exercises during the study. Participants were advised of the possibility of receiving acupuncture, or treatment with needles that do not pierce the skin, before the study.

A sample size calculation, completed before the study, indicated the inclusion of 12 participants in each group. Based on a previous study, we expected a 2°C difference in skin temperature between study groups, with a SD of 2°C.\textsuperscript{4}

**Trial procedures**
At the initial session, each participant completed an exercise protocol designed to elicit delayed-onset muscle soreness in the non-dominant forearm extensor muscles. Participants returned to the laboratory 48±2 h later for treatment and were randomly assigned to one of three groups using an online random numbers generator. Group 1, the control group, received no treatment; group 2, the acupuncture group, received acupuncture, and group 3, the sham group, received non-penetrating S-ACU.

**Exercise protocol**
Each participant sat in a chair with their non-dominant forearm resting on the armrest in 90° of elbow flexion and full pronation. Three sets of wrist curls were completed using a 5 lb (2¼ kg) dumbbell while keeping pace with a metronome set to 15 repetitions per minute, with 1 min of rest between sets. For the first two sets, participants were instructed to try to perform 75 repetitions, or to continue until they felt they ‘could not do one more repetition’. For the final set, participants were advised to continue until they felt they ‘could not do one more repetition’.

**Sympathetic nervous system monitoring**
Experiments were performed in a quiet room with an ambient temperature of 21–23°C. SC, ST and perfusion sensors were attached. SC values were measured with calibrated Flexicomp Infiniti SC-Flex/Pro SC sensors (Thought Technology, New York, USA) on bilateral index and ring fingers. ST (°C) was measured with calibrated Flexicomp Infiniti ST sensors (Thought Technology) proximally at each LI10 point and distally at the tip of each middle finger (see figure 1). Both skin temperature and SC were sampled at 32 Hz. A pillowcase was placed gently over participant’s fingers after the sensors were attached. Skin perfusion was measured in perfusion units (pu) with a calibrated laser Doppler perfusion metre linked to a PC where values were stored in Perisoft software (Perimed, Stockholm, Sweden). A perfusion sensor was placed at each LI10 point.

Figure 1 illustrates the experimental set-up. The sympathetic nervous system was monitored for a baseline period of 20 min, for the 15 min treatment period and for a 10 min recovery period after treatment.

**Acupuncture protocol**
LI4, LI10, LI11 and TE5 were used, selected based on Western medical acupuncture philosophy for their proximity to the forearm extensor muscles.\textsuperscript{12} The practitioner (KLP) was a licensed physiotherapist who treats upper limb conditions and is certified to carry out acupuncture with the College of Physiotherapists of Manitoba.

The practitioner located and marked all acupuncture points on all participants with a small plastic ring fixed...
Individuals in the control group rested comfortably for the entire treatment. Individuals in the acupuncture group received treatment with real penetrating needles (0.30 gauge, 30 mm length; Asiamed, Pullach, Germany) inserted to a depth of about 15 mm. Individuals in the S-ACU group received treatment with non-penetrating Streitberger needles (0.30 gauge, 30 mm length; Asiamed, Pullach, Germany) administered to appear to be inserted at a depth of about 15 mm (with 15 mm of the needle pressed up into the handle). The Streitberger protocol was used. The ring and tape at each acupuncture point served to hold the S-ACU needles in place.

The needles for both the acupuncture and S-ACU treatments were administered through the plastic ring and tape to make the two treatments appear as similar as possible.

Needles were not stimulated at the time of insertion. Participants were not asked whether they felt *de qi* sensation. All needles were left in place for 15 min and were stimulated manually by the practitioner at 5 and 10 min into the treatment. The practitioner stimulated acupuncture needles by grasping the handle and performing a piston motion (twisting while pulling up and down approximately 5 mm five times). The practitioner grasped the S-ACU needles at the junction of the shaft and handle while performing manual stimulation to prevent separation of the two parts. The practitioner took care to shield the participant’s view of needle insertion, stimulation and removal as well as removal of the rings and tape by holding one hand in front of the needle sites.

**Data analysis**

Perfusion recordings were visually inspected and any data points associated with obvious movement artefact were removed. The perfusion, SC, proximal ST (STP) and distal ST recordings were divided into 5 min intervals: baseline 0–5, 5–10, 10–15 and 15–20, treatment 0–5, 5–10, 10–15 and recovery 0–5, 5–10. The mean perfusion, SC, STP and distal ST values were calculated for each interval. Upon inspection of the raw data plots, the mean values for each group and variable were found to be representative. Thus, we feel confident in representing the data as mean±SD. The values from the baseline 15–20 interval were chosen as baseline values for comparison.

The changes in perfusion, SC and ST over time were determined using a Friedman repeated-measures analysis of variance (ANOVA) on ranks. Post hoc analysis for changes in perfusion, SC and ST over time were completed using Tukey’s test. At each individual time point, the differences between the control, acupuncture and S-ACU groups were determined using a Kruskal–Wallis one-way ANOVA on ranks. Post hoc analysis for differences between groups was completed using the Student–Newman–Keuls method. The significance level was set at p<0.05 for all analyses. The Sigma Stat programme (Systat Software, San Jose, USA) was used for the above statistical analyses.

In addition, to determine if gender or handedness affected the results, three-way repeated-measures ANOVA testing was performed for each of the outcome variables. This analysis was performed using SAS software V9.2 (SAS Institute Inc, Cary, USA).

**RESULTS**

Thirty-six healthy adults (29.8±5.0 years of age) (17 men, 19 women) (five left-hand, 31 right-hand dominant) participated. There were no significant differences in gender between the groups, but more people were left handed in the S-ACU group (p<0.05) (see online supplementary table S1). Neither gender nor handedness was associated with differences in SC, distal ST or proximal ST, ipsilateral or contralateral perfusion. For each of the three groups, SC was compared at all time points. For participants in the acupuncture group, SC increased at 5 min relative to baseline (p<0.05), and remained increased throughout treatment, only returning to baseline at the completion of the recovery period.
There was no difference in SC during treatment for the other groups (figure 2, online supplementary table S2).

Similarly, both ipsilateral and contralateral distal ST decreased for participants in the acupuncture group, but not the other groups. Distal ST decreased 5 min into the treatment, and remained below baseline throughout recovery ($p<0.05$). There was no significant change in either ipsilateral or contralateral distal ST for participants in the S-ACU or control groups (figure 3, online supplementary table S3).

There was a general trend towards lower proximal ST, both ipsilaterally and contralaterally, in all groups. For patients in the control arm, this was not statistically significant ipsilaterally, but was significant contralaterally (when comparing the baseline and the completion of the recovery period). In contrast, the proximal ST decreased at earlier time points in both the acupuncture and S-ACU groups. There was a decrease in proximal ST ipsilaterally at the end of the treatment period ($p<0.05$). Contralateral STP was also significantly lower at the completion of the recovery period in comparison with the baseline value for both of these groups ($p<0.05$) (figure 4, online supplementary table S4).

The final outcome measure reviewed was skin perfusion. Ipsilateral skin perfusion showed a dramatic increase 5 min after needle insertion in the acupuncture group (35% increase from baseline, $p<0.05$). This increase remained until the end of the recovery period, at which point it returned to baseline. There was no significant change in ipsilateral skin perfusion in either the control or S-ACU groups. There were modest changes in skin perfusion contralaterally, which were more pronounced in both the control and S-ACU groups ($p<0.05$, comparing the baseline value
with the final value) (figure 5, online supplementary table S5).

DISCUSSION

The primary objective of the study was to use skin perfusion, SC and ST measurements to evaluate the sympathetic nervous system response to acupuncture and S-ACU in healthy human participants with experimental muscle pain. The results show significantly increased ipsilateral perfusion and significantly increased bilateral SC in the acupuncture group. Significantly decreased bilateral distal ST was seen with acupuncture, while ipsilateral STP decreased significantly with both acupuncture and S-ACU, but not the control group.

The acupuncture group showed significantly increased ipsilateral local perfusion within 5 min of needle insertion, while no increase was seen on the contralateral side. This unilateral increase in local perfusion suggests that the changes are mediated locally, not systemically.

The acupuncture group showed significantly increased bilateral SC and reduced distal ST within 5 min of needle insertion. The increase in both ipsilateral and contralateral SC and decrease in both ipsilateral and contralateral ST suggests that the change is mediated systemically. Increased SC and decreased ST are suggestive of sympathetic nervous system activation. However, since the SC sensors and the distal temperature sensors were located on the same segment bilaterally, the possibility of segmental mediation cannot be ruled out.

On the contralateral arm, the control, acupuncture and S-ACU groups all showed significantly decreased proximal ST by the end of recovery. The S-ACU
group showed significantly decreased ipsilateral STP by the end of the treatment period and 5 min into recovery. Similarly, the acupuncture group showed significantly reduced ipsilateral proximal ST within 5 min of needle insertion and throughout recovery. The reduction of proximal ST in the acupuncture group was opposite to that expected given the significant increase in perfusion observed. It is possible that the temperature sensor was not placed close enough to the needle site to record any increase in proximal ST associated with the increased perfusion.

It appears that acupuncture causes activation of the sympathetic nervous system as indicated by the increased SC and decreased distal ST within 5 min of needle insertion. The unilateral increase in perfusion near the needle site appears to be due to local circulatory modulation.

Very few studies have investigated the sympathetic nervous system response to acupuncture in humans, specifically with experimental pain. In addition, it is difficult to compare the outcomes of studies since different protocols have been used. Our findings are in contrast to one study, which showed that acupuncture reduced sympathetic nervous system activity as indicated by increased ST at the face, hands and feet. The study included one acupuncture point (LI4) with a 15 min treatment in normal participants.4 Our study included four acupuncture points (LI4, TE5, LI10, LI11) with a 15 min treatment in participants with experimental pain. Possibly, the sympathetic nervous system responds differently to acupuncture in the presence of pain. The results of both studies suggest that the effect of acupuncture on ST is systemic in origin; however, the sites used for ST measurement do not allow the possibility of segmental participation to be excluded.

Our results are in keeping with another study, which showed that acupuncture temporarily increased sympathetic nervous system activity as indicated by increased activity in cutaneous sympathetic fascicles of the median nerve and decreased perfusion to the index finger.5 It is difficult to compare the outcomes of the two studies because the acupuncture protocols and perfusion sensor locations differed. Our study included four acupuncture points (LI4, TE5, LI10, LI11) with a 15 min treatment, whereas the other study included one acupuncture point (LI4) with a 2 min treatment.5 Furthermore, our study placed the bilateral perfusion sensors proximally near the elbow while a single perfusion sensor was placed on the contralateral index finger in the other study.

After removal of the plastic ring and tape, the skin was inspected and it was clear that there was no penetration in the S-ACU group. Although participants were advised of the possibility of receiving acupuncture or treatment with needles that do not pierce the skin, they were not asked to guess which type of needle they had received. This may be a limitation as information about the perception of whether or not they had received real or non-penetrating acupuncture might have provided information about participant expectations. It has been suggested that the muted effect noted with S-ACU might be due to participant expectation.14

CONCLUSIONS
The results of this study add to the scant body of studies investigating the sympathetic nervous system response to acupuncture. Acupuncture appears to activate the sympathetic nervous system as indicated by a bilateral increase in SC and a bilateral decrease in distal ST after needle insertion. The unilateral increase in perfusion near the needle site seen with acupuncture appears to be due to local, rather than systemic, circulatory control.

Further study into the response of the sympathetic nervous system to acupuncture is required to enhance understanding of acupuncture analgesia. To date, it is difficult to determine whether the effect of acupuncture on the sympathetic nervous system is central or segmental in origin. Thus, further study should include the placement of sensors at non-segmental locations.

Summary points

- Acupuncture’s effect on the sympathetic nervous system when pain is present is unknown.
- In experimental pain, our results suggest sympathetic activity increased during acupuncture.

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Contributors KLP performed the literature review, participated in study design, collected the data, administered the treatments, analysed the data and drafted the manuscript. Both authors (KLP and BLS) participated in study design, interpretation and discussion of the results and final manuscript preparation.

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