

Original

Effects of Acupuncture on Lower Limb Ischemia

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Objective: To investigate the efficacy of acupuncture treatment for lower limb ischemia.

Design: We quantitatively measured the effects of electro-pulsed acupuncture on cutaneous blood flow and oxygenation, by determining skin perfusion pressure (SPP) and transcutaneous oxygen tension (TcPO₂), respectively. The *Zusanli* and *Sanyinjiao* acupoints on the right leg were stimulated with electro-pulsed acupuncture at 1 Hz for 10 minutes, then SPP levels at 4 measurement points before and after, and TcPO₂ levels at those points before, during, and after treatment were measured. The control group (20 healthy volunteers, average 33.8 years old) received treatment once, while the patient group (9 patients with peripheral arterial disease [PAD], average 65.1 years old) received once-a-week acupuncture treatments and accompanying measurements for 4 weeks, and were also administered a set of questionnaire (VAS in pains and general conditions, KDQOL™, and the Medical Outcomes Study Short Form-36 Health Survey [SF-36]) on the first and final acupuncture treatment days.

Results: Blood flow and oxygenation were increased in peripheral areas in the control group. In the PAD patients, blood flow was significantly increased in the dorsum of the foot and ankle after the first and at all 4 points after the final treatment, whereas cutaneous oxygenation was not significantly increased. In addition, the patient group reported improvements in answers to the Physical Function of SF-36.

Conclusion: Our results indicate that acupuncture is effective as therapy for lower limb ischemia.

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Keywords: acupuncture, blood flow, blood oxygenation, diabetes, diabetes mellitus, electro-pulsed acupuncture, lower limb ischemia, peripheral arterial disease (PAD), skin perfusion pressure (SPP), transcutaneous oxygen tension (TcPO₂), Short Form-36 (SF-36)

INTRODUCTION

Improvement of limb circulation is a challenging problem when treating patients with peripheral arterial disease (PAD) and/or diabetic foot. Various approaches to increasing lower limb blood flow have been reported, including oral, local, and systemic prostaglandin¹⁾, angioplasty, and bone marrow mononuclear cell

transplantation²⁾, peripheral blood mononuclear cell transplantation³⁾, and peripheral blood stem cell transplantation⁴⁾. Unfortunately, even with combinations of those treatments, many patients with lower limb ischemia remain unable to avoid amputation.

Acupuncture has been shown to be effective in increasing blood flow, as documented by several different studies⁵⁻⁹⁾. The goal of the present study was to provide objective and quantitative data to support the use of electro-pulsed acupuncture for increasing cutaneous blood flow and oxygenation, as a potential treatment for lower limb ischemia. We applied

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electro-pulsed acupuncture to the *Zusanli* (ST36) and *Sanyinjiao* (SP6) acupoints, both of which are commonly used by acupuncture practitioners because of their effects to increase cutaneous blood flow in the lower limbs. Next, we measured the effects of the treatments on skin perfusion pressure (SPP) and transcutaneous oxygen tension (TcPO₂) in both healthy volunteers and PAD patients. To evaluate the qualitative aspects of the treatment in the patient group, a series of questionnaires was given.

MATERIALS AND METHODS

Ethical approval

The study was reviewed and approved by the Saitama Medical University Institutional Review Board.

Participants

The trial was conducted at Saitama Medical University from August 2006 to June 2007 for the control group and April to October 2007 for the patient group. We enlisted 20 healthy adults (10 males, 10 females; average age 33.8 years old) as the control group and 9 PAD patients (7 males, 2 females; average age 65.1 years old), each of whom were receiving hemodialysis therapy, as the patient group. We selected patients from those receiving hemodialysis, since PAD is more prevalent among them¹⁰. Table 1 shows the characteristics of the patient group.

Interventions

Using a 40 mm, No. 18 acupuncture needle (Seirin Corporation, Japan), the *Zusanli* (Leg Three Li; ST 36) and *Sanyinjiao* (Three Yin Crossing; SP 6) acupoints of the right leg were stimulated with electro-pulsed acupuncture for 10 minutes at 1 Hz. The *Zusanli* acupoint is located outside of the lower leg, a few inches below the kneecap on the tibialis anterior muscle, while the *Sanyinjiao* acupoint is 3 *cun* (the distance between the second and third knuckles) above the prominence of the medial malleolus, in a depression close to the medial crest of the tibia (Figure 1). A pulse generator (Suzuki Medical, Japan, Model PG-306) was used to provide the electric pulses. The control group received one acupuncture treatment, whereas the patient group received once-a-week treatments for 4 weeks (i.e. 5 times, 1 treatment at the beginning of the trial, and then 1 treatment every 7 days for the next 4 weeks). All acupuncture treatments were performed by one of the co-authors, Dr. Omata, a professional practitioner of acupuncture for 23 years.

Quantitative hemodynamic measurements

To avoid psychological effects, we chose two different

quantitative hemodynamic measurements considered to be unaffected by emotion or will. SPP and TcPO₂ were measured at 4 points before and after electro-pulsed acupuncture treatment, as follows: (a) the distal-dorsal point of the metatarsus of the first toe (first toe); (b) the proximal-dorsal point of the metatarsus of the first toe (dorsum of foot); (c) a point 5 cm proximal of the medial malleolus (ankle); and (d) a point 5 cm distal of the distal end of the knee cap on the medial face of the tibia (below knee) (Figure 1). The treatment room was kept at an average temperature of $24.7 \pm 1.7^\circ\text{C}$, with an average humidity of $57.6 \pm 11.4\%$. Figure 2 shows the sequence used for measuring.

(1) Measurement of SPP

Participants were placed in a supine position and the laser Doppler sensor of the SPP measurement apparatus (PAD 3000, Vasamedics, St. Paul, Minn., USA) was applied to the skin at one of the measuring points. A compression cuff was then applied to the test area over the Doppler sensor and inflated until the stable laser Doppler output value indicated near zero. Next, the cuff was deflated until the laser Doppler output increased for two consecutive pressure values. The pressure at which this first occurred was considered as the SPP value. Measurement of SPP was conducted for each measurement point, in the order of first toe, dorsum of foot, ankle, and below knee.

(2) Measurement of TcPO₂

Table 1. Characteristics of the PAD patient group

Patient	Gender	Age*	Fontaine Stage	Diabetes	Hemodialysis
1	M	69	IV	(+)	(+)
2	M	63	I	(-)	(+)
3	M	65	II	(+)	(+)
4	F	64	I	(-)	(+)
5	M	60	III	(+)	(+)
6	M	76	II	(+)	(+)
7	M	74	II	(+)	(+)
8	M	52	III	(+)	(+)
9	F	63	III	(+)	(+)

*Age is shown in years. M = male, F = female, (+) = present, (-) = not present.

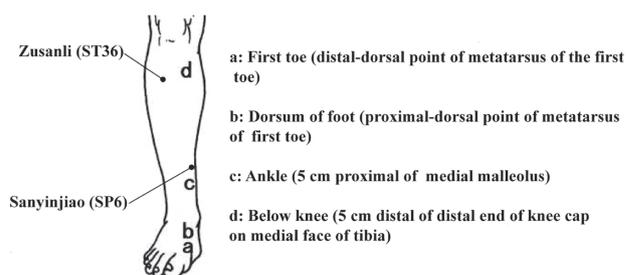


Fig. 1. Schematic view of the 2 acupoints of Zusanli (ST36) and Sanyinjiao (SP6) and 4 measurement points.

5 minutes after, and 10 minutes after beginning the 10-minute acupuncture treatment in the control group, and was analyzed using Fisher's least-significant-difference and multiple comparisons tests. The same protocol was used for the patient group for the first and final treatments. In addition, difference in TcPO₂ before the first and before the final treatment in the patient group was analyzed using a Wilcoxon signed-rank test.

A Wilcoxon signed-rank test was also used to compare the VAS, SF-36, and KDQOL™ scores obtained on the first acupuncture treatment day with those obtained on the final day. All statistical analyses were conducted using Microsoft Stat Excel 2006 for Windows® (Microsoft Corporation, Seattle, WA). We defined statistical significance at a confidence level of 95%.

RESULTS

Quantitative measurements – SPP and TcPO₂

Control group – SPP

Following the acupuncture treatment, SPP values in the control group were significantly increased in the first toe and ankle (Figure 3). Further, the increase in SPP value in the dorsum of the foot was just outside the 95% confidence level, whereas the change below the knee was not significant.

Control group – TcPO₂

The TcPO₂ values changed significantly in the first toe at 10 minutes after the start of the acupuncture therapy, as well as in the dorsum of the foot at both 5 and 10 minutes after the start in the control group (Figure 4).

Patient group – SPP

The effects of the initial acupuncture treatment in the patient group were somewhat different from those in the control group. Following the first treatment, the SPP values were significantly different for the dorsum of the foot and ankle in the patient group (Figure 5).

Thereafter, the patient group then received once-a-week treatments for 4 weeks (total of 5 treatments). The effects of the final acupuncture treatment were evaluated by comparing the SPP values before and after the final treatment. Those values were significantly increased at all 4 measurement points (Figure 6).

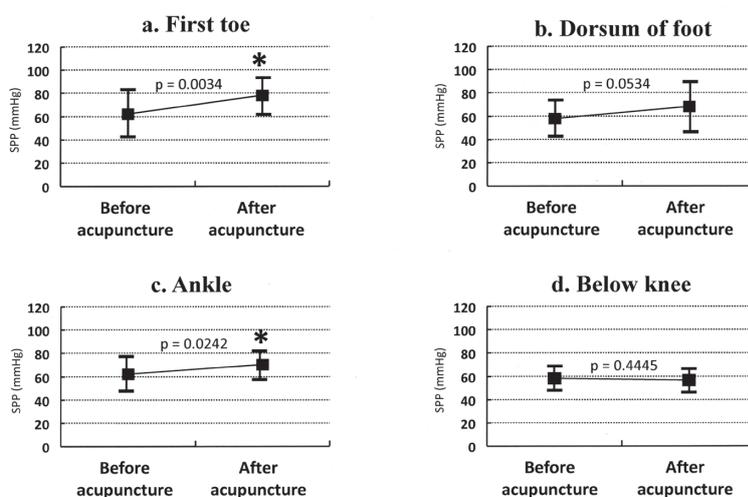
Patient group – TcPO₂

After the first acupuncture treatment, the TcPO₂ values showed no significant changes at any of the 4 measurement points. Those values on the final treatment day were also compared among before, just after insertion of the needles, 5 minutes after insertion, and 10 minutes after insertion. However, the TcPO₂ values did not change significantly at any of the measuring points on the final day.

Patient group – chronic effects on SPP and TcPO₂

To evaluate the chronic effects of acupuncture treatment, we compared the SPP and TcPO₂ values before the first treatment and before the final treatment (1 week after the fourth treatment) to determine whether there were sustained effects. However, neither the SPP nor TcPO₂ values showed a significant increase from the beginning of the 4-week period to the end of the 4-week period at any of the measurement points.

Qualitative measurements – VAS, KDQOL™, and SF-36



Wilcoxon signed-ranks test
n=20 mean ± S.D.
*p<0.05

Fig. 3. Control group. Changes in SPP before and after acupuncture treatment.

Although the average of both sets of VAS scores was decreased, neither showed statistical significance. The average score for physical difficulty decreased from 50.67 to 43.89 (p-value, 0.4008), while that for pain decreased from 48.78 to 40.11 (p-value, 0.3270). Among the 8 conditions addressed in the SF-36, only the physical functioning condition showed a significant increase after the fourth treatment, as the average score increased from 33.33 to 45.00 (p-value, 0.0284) (Figure 7). For the patient group, none of the 11 areas of the Kidney Disease Quality of Life (KDQOL™) study

showed a statistically significant change after the fourth treatment.

DISCUSSION

Acupuncture treatment has been reported to improve lower limb circulation, and a previous study of patients with collagen disease showed that the therapy raised cutaneous temperature and increased cutaneous blood flow, as shown by laser Doppler flowmetry results.⁵⁾ In addition, acupuncture treatment for healthy adults was found to increase the blood flow in the chorioretinal

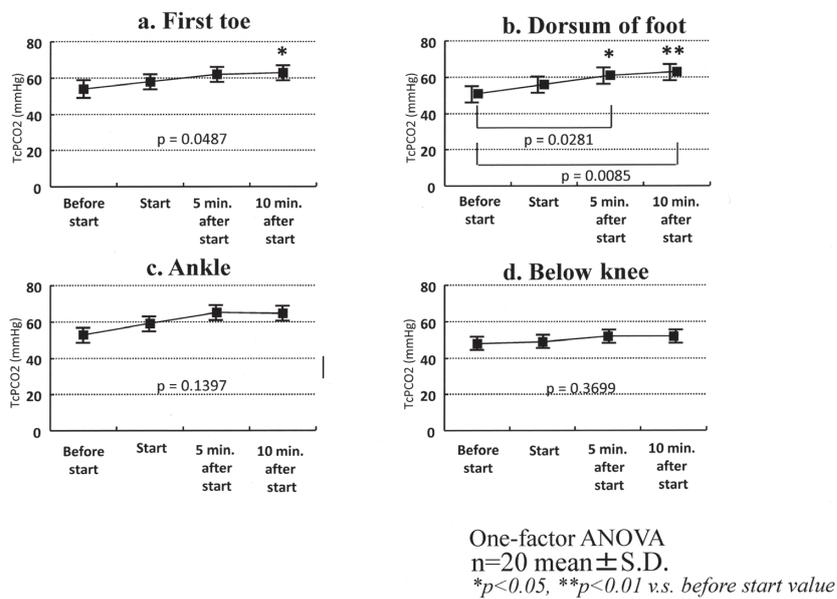


Fig. 4. Control group. Changes in TcPO2 before and after acupuncture treatment.

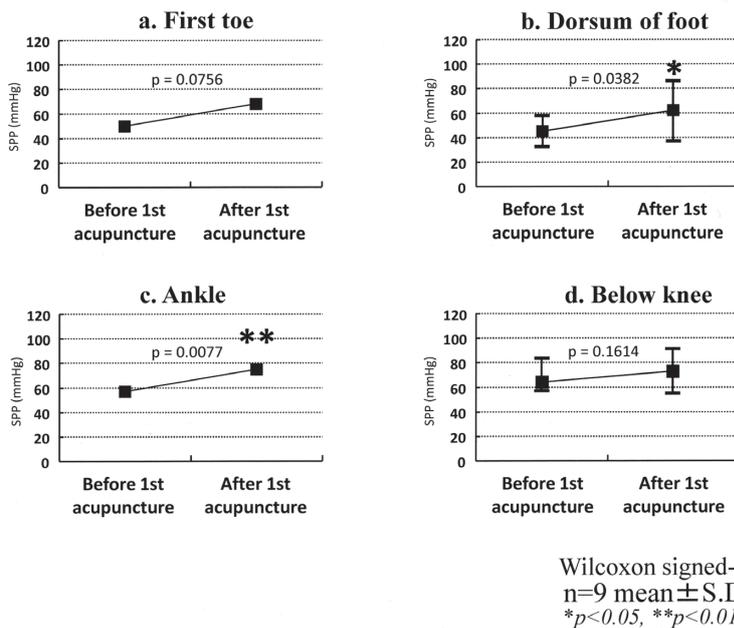


Fig. 5. Patient group. Changes in SPP before and after first acupuncture treatment.

area⁶⁾, while that in rats resulted in increases in permeability of the vascular wall and production of local free-radicals, as observed microscopically⁷⁾. Thus, effects of acupuncture on blood flow have been observed, with relative increases determined in a qualitative manner.

Other studies have taken a more clinical approach to the effects of acupuncture and acupressure on lower limb blood flow. Yasuno et al. revealed that PAD patients at Fontaine stage I and II experienced an easing of pain and numbness after acupuncture treatments⁸⁾. Also, Li et al. performed acupressure treatment for

Fontaine stage II PAD patients and observed increases in TcPO₂ levels in the lower limbs⁹⁾. However, neither study directly measured the effects of acupuncture/acupressure on cutaneous blood flow. In addition, other studies have suggested the microbiological effects of acupressure and acupuncture, though little has been proven¹³⁻¹⁶⁾.

The mechanism of the effects of acupuncture has been reported in a number of studies, as noted by Li et al⁹⁾. Acupuncture stimulation has been shown to be effective in regulating the autonomic nervous system¹⁷⁻¹⁹⁾. In addition, based on observations of the patients

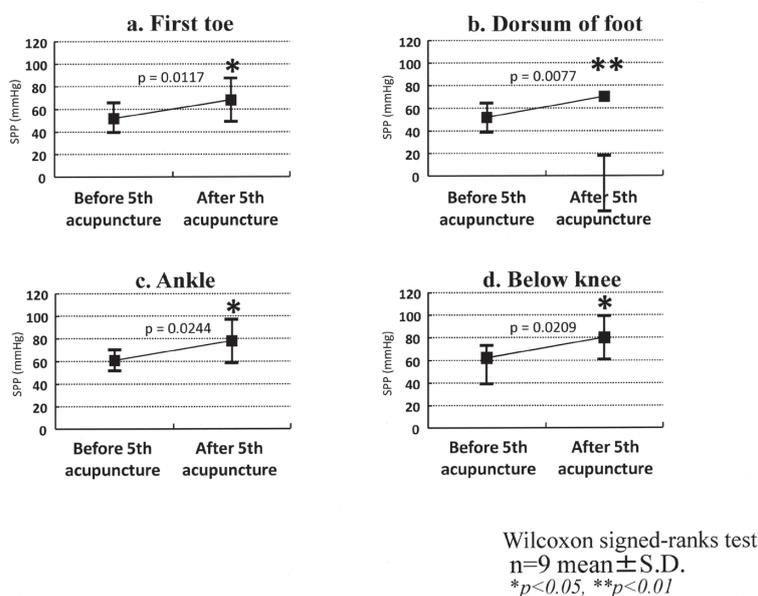


Fig. 6. Patient group. Changes in SPP before and after fifth (final) acupuncture treatment.

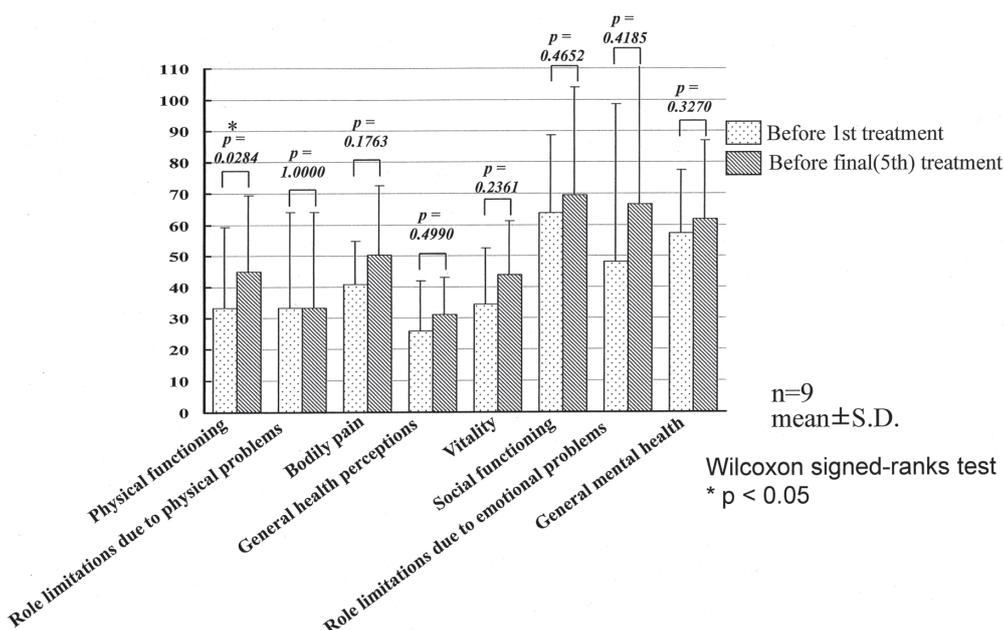


Fig. 7. Patient group. Changes in SF-36 scores after 4 weeks of acupuncture treatments.

undergoing sympathectomy treatments, vasoactive neuropeptides, such as calcitonin gene-related peptide (CGRP) and substance P (SP), are considered to take part in increased blood flow caused by acupuncture^{20,21}. Acupuncture may also relax the sphincter, allowing microvessels to drain tissue fluid, resulting in an increase in interstitial fluid and expansion of blood capillaries¹⁷. Based on these previous reports, Figure 8 shows a proposed schematic view of acupuncture related mechanisms lead to blood vessel dilation.

The results of the present study indicate that acupuncture stimulation to the *Zusanli* (Leg Three *Li*, ST36) and *Sanyinjiao* (Three *Yin* Crossing, SP6) acupoints in healthy adults increases SPP at more distal points of the legs. In the case of our PAD patients as well, the first acupuncture treatment increased SPP in the distal areas (the dorsum of foot and ankle). Four weeks later, after the patients had received four treatments, the effects of the fifth acupuncture treatment were greater than those of the first, as SPP was increased significantly at all 4 points of the lower leg and foot after the final treatment. This indicates that the efficacy of the acupuncture therapy was lower at first, whereas it increased with repeated treatments (Figure 9). These results showing increased SPP by acupuncture support previous studies in which

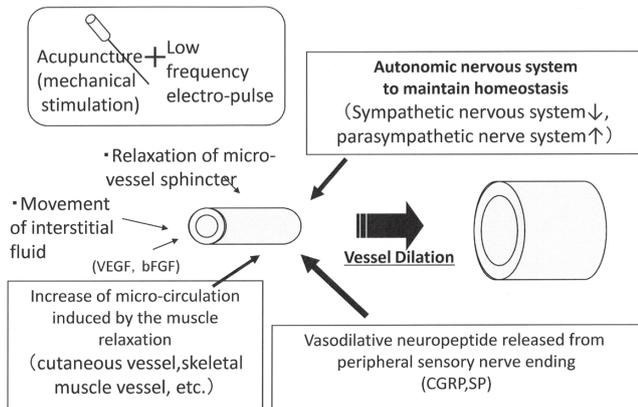


Fig. 8. Suggested mechanism for increasing blood flow through acupuncture. Acupuncture stimulation has been shown to be effective in regulating the autonomic nervous system¹⁷⁻¹⁹. In addition, based on observations of the patients undergoing sympathectomy treatments, vasoactive neuropeptides, such as calcitonin gene-related peptide (CGRP) and substance P (SP), are considered to take part in increased blood flow caused by acupuncture^{20,21}. Acupuncture may also relax the sphincter, allowing microvessels to drain tissue fluid, resulting in an increase in interstitial fluid and expansion of blood capillaries¹⁷.

acupuncture was shown to increase blood flow in the skin and chorioretinal area^{5,6}.

In contrast, there was no significant sustained increase in SPP after 4 weeks of acupuncture electro-therapy as compared with the initial SPP measurements, thus 4 weeks of once-weekly acupuncture treatments was not enough to maintain SPP at significantly high levels throughout the treatment interval period (1 week). One week after the fourth treatment (i.e. just before the final treatment), SPP was not increased significantly as compared with before the first treatment.

Increased cutaneous blood flow, which is determined by measuring increased SPP, provides more oxygen to cutaneous tissues, which is determined by measuring increased TcPO₂. The effects of acupuncture on TcPO₂ in healthy adults were shown to be greater at the distal measurement points (first toe and dorsum of foot). On the other hand, TcPO₂ values for the patient group did not increase significantly throughout the observation period (Figure 10). Deeper tissues, including muscle and bone, are more likely to be susceptible to hypoxia than superficial tissue, namely skin. Patients with PAD chronically suffer from hypoxia, while oxygen provided by increased cutaneous blood flow may be consumed not only by the skin, but also by such deeper tissues. Thus, it is possible that the

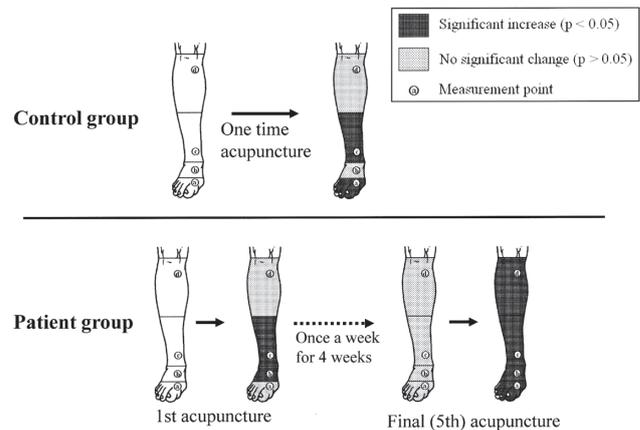


Fig. 9. Schematic view of SPP changes as a result of acupuncture treatments. SPP scores for the control group were increased at the points of the first toe and ankle, whereas those of the patient group were increased at the points of the dorsum of the foot and ankle after the first acupuncture treatment. Four weeks after the first treatment, that is 1 week after the fourth and just before the final treatment, SPP values for all 4 points showed no significant change from before the first treatment. In contrast, SPP was changed at all points after the final treatment.

increased blood flow seen in the patient group may have first provided oxygen to deeper tissues, while cutaneous tissue may not have received oxygen immediately by the increased blood flow. The control group consisted of healthy adults and deeper tissues of the lower limbs in those likely received sufficient oxygen prior to the acupuncture treatment. In such a condition, increased oxygen provided by increased cutaneous blood flow is not consumed by tissue with hypoxia and is measured as increased TcPO₂. This discrepancy in sensitivity between healthy adults and patients has been shown in previous studies. For example, Omata et al. observed the secretion of sweat in the palm areas as an indicator of peripheral sympathetic nerve system, and found that patients with collagen diseases secreted sweat for a longer period than healthy adults following acupuncture therapy⁵⁾.

Other factors of the blood flow of deeper tissue to influence cutaneous blood flow include the mechanical design of the SPP measurement apparatus and accompanying effects of the acupuncture therapy. Since SPP measurement requires the process of avascularization, the measurement value may reflect not only the cutaneous blood flow but also the blood flow in the deeper tissue. During the acupuncture treatment, muscles at the site of acupuncture point contract and this may also contribute the cutaneous blood flow to be influenced by the blood flow in the deeper tissue.

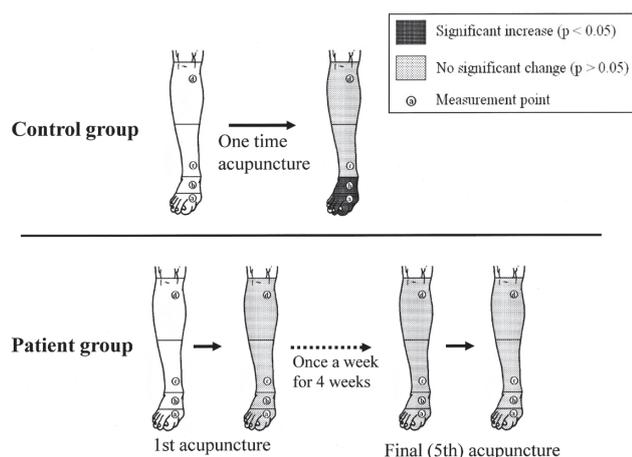


Fig. 10. Schematic view of TcPO₂ changes as a result of 10-minute acupuncture treatments. TcPO₂ in the control group was increased significantly at the points of the first toe and dorsum of the foot after 10 minutes of acupuncture treatment. In contrast, the patient group showed no significant increase in TcPO₂ at all 4 points throughout the 4 weeks of therapy.

We also evaluated qualitative changes in the patients as a result of the acupuncture therapy. Although the VAS scores and KDQOLTM study results did not show significant differences, the Physical Functioning category of the SF-36 had a significant improvement after 4 weeks of treatments. A high score in Physical Functioning indicates that the patient is able to perform all types of physical activities including the most vigorous without limitations due to health. Those who can perform the activities in this category are capable of doing most of the daily activities without someone's support. Questions asked in this category include those related to bathing, dressing, lifting and carrying groceries, climbing stairs, bending, kneeling, and walking moderate distances¹¹⁾. Each of these activities requires muscle movements and the muscles of the lower limbs plays a key role, especially in individuals suffering from lower limb ischemia. Acupuncture treatment increases blood flow to the lower limbs, which fuels such muscle movements. Thus, a quantitative improvement can be realized by patients in their daily activities, as reflected by qualitative results. This correspondence of quantitative to qualitative data is also seen in the study of Myers et al., in which absolute claudication time for PAD patients was correlated with physical functioning shown in the SF-36²²⁾. PAD patients desire improvements in such fundamental activities in everyday life and acupuncture therapy is one potential solution.

CONCLUSIONS

Acupuncture treatment applied to the *Zusanli* and *Sanyinjiao* acupoints resulted in increased blood flow in the lower limbs in both healthy adults and PAD patients, which in turn improved the activities of daily life for those patients. Our findings suggest that the acupuncture is effective as therapy for lower limb ischemia.

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AUTHOR DISCLOSURE STATEMENT

No competing financial interests exist.

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下肢血流障害に対する鍼治療の効果

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目的：下肢血流障害に対する鍼治療の効果を検証する。

デザイン：通電鍼刺激の皮膚血流および酸素化への効果を定量的に検証するため、皮膚還流圧 (SPP) および経皮酸素分圧 (TcPO₂) を測定した。右下肢の足三里穴および三陰交穴を 1Hz の通電鍼刺激によって 10 分間刺激し、右下肢の 4 計測点 (右第一中足骨遠位・足背・足関節・膝下) について SPP および TcPO₂ の変化を測定した。このうち SPP については通電鍼刺激前後の測定を行い、TcPO₂ については刺激前、刺激中、および刺激後の測定を行った。コントロール群 (20 人の健常者で平均年齢 33.8 歳) については通電鍼刺激および測定を 1 回のみ行った。患者群 (9 人の末梢動脈疾患患者 [PAD] で平均年齢 65.1 歳) は週 1 回の鍼治療を 4 週間、計 5 回受け、初回および 5 回目について SPP および TcPO₂ の測定を行った。患者群についてはさらに、初回および 5 回目の鍼治療開始前に一連のアンケート調査 (疼痛および全般について VAS score, KDQOLTM, 及び Medical Outcomes Study Short Form-36 Health Survey [SF-36]) を行った。

結果：鍼刺激により、コントロール群では皮膚血流および酸素化が末梢領域で上昇を認めた。PAD 患者群では初回鍼治療によって足背および足関節部での皮膚血流が上昇し、5 回目の鍼刺激によって 4 計測点すべての血流が上昇したが、患者群での酸素化の上昇は認めなかった。患者群では更に、SF-36 の身体機能について有為な改善を認めた。

結論：下肢血流障害に対する治療法として、鍼治療が有効であることが示された。

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