J Acupunct Meridian Stud 2017;10(2):120—124

Available online at www.sciencedirect.com

Journal of Acupuncture and Meridian Studies

journal homepage: www.jams-kpi.com

RESEARCH ARTICLE

The Effect of Transcutaneous Electrical Nerve Stimulation of Sympathetic Ganglions and Acupuncture Points on Distal Blood Flow

Fahimeh Kamali [1], Hossein Mirkhani [2,3,*], Ahmadreza Nematollahi [1], Saeed Heidari [4], Elahesadat Moosavi [4], Marzieh Mohamadi [4]

[1] *Rehabilitation Science Research Center, Department of Physical Therapy, School of Rehabilitation Sciences, Shiraz University of Medical Sciences, Shiraz, Iran*
[2] *Department of Pharmacology, School of Medicine, Shiraz University of Medical Sciences, Shiraz, Iran*
[3] *Medical and Natural Products Chemistry Research Center, Shiraz University of Medical Sciences, Shiraz, Iran*
[4] *Student Research Committee, Department of Physical Therapy, School of Rehabilitation Sciences, Shiraz University of Medical Sciences, Shiraz, Iran*
Available online 12 January 2017

Received: Jul 4, 2016
Revised: Dec 21, 2016
Accepted: Jan 6, 2017

KEYWORDS
acupuncture;
blood circulation;
electrical stimulation;
sympathetic ganglia;
transcutaneous electrical nerve stimulation

Abstract
Transcutaneous electrical nerve stimulation (TENS) is a widely-practiced method to increase blood flow in clinical practice. The best location for stimulation to achieve optimal blood flow has not yet been determined. We compared the effect of TENS application at sympathetic ganglions and acupuncture points on blood flow in the foot of healthy individuals. Seventy-five healthy individuals were randomly assigned to three groups. The first group received cutaneous electrical stimulation at the thoracolumbar sympathetic ganglions. The second group received stimulation at acupuncture points. The third group received stimulation in the mid-calf area as a control group. Blood flow was recorded at time zero as baseline and every 3 minutes after baseline during stimulation, with a laser Doppler flow-meter. Individuals who received sympathetic ganglion stimulation showed significantly greater blood flow than those receiving acupuncture point stimulation or those in the control group ($p < 0.001$). Data analysis revealed that blood flow at different times during stimulation

* Corresponding author. Department of Pharmacology, School of Medicine, Shiraz University of Medical Sciences, Zand Boulevard, Shiraz 71348-53185, Iran.
E-mail: mirkhanh@sums.ac.ir (H. Mirkhani).

pISSN 2005-2901 eISSN 2093-8152
http://dx.doi.org/10.1016/j.jams.2017.01.003

increased significantly from time zero in each group. Therefore, the application of low-frequency TENS at the thoracolumbar sympathetic ganglions was more effective in increasing peripheral blood circulation than stimulation at acupuncture points.

1. Introduction

Electrical stimulation is the treatment of choice for complex and recalcitrant wounds, and has been proposed to diminish infection, expand cellular immunity, speed wound repair, increase skin perfusion, and improve venous flow. Electricity can be applied in different forms including direct current, alternating current, high-voltage pulsed current, low-intensity direct current, pulsed electromagnetic field, and transcutaneous electrical nerve stimulation (TENS) [1].

TENS is a widely practiced noninvasive treatment modality in clinical practice. Among the therapeutic applications of TENS are pain relief, temperature alteration, and blood flow increase [2]. The effects of TENS on blood flow has led researchers to evaluate the association between this modality and the peripheral vascular system [3,4]. Wong and Jette [5] reported that, in healthy people, blood flow was decreased by the application of three forms of TENS (high-frequency, low-frequency, and burst-mode). In contrast, Kaada [6] found that low-frequency and burst-mode TENS may increase blood flow in patients with diabetic polyneuropathy and Raynaud phenomenon. Both of these studies attributed circulatory changes to sympathetic activity. However, Chen et al [7] suggested that transient changes in blood flow caused by low- and high-frequency TENS may not be related to changes in sympathetic activity.

Another effective method to improve circulation is the use of acupuncture points. Acupuncture can regulate various biological functions, and may influence the level of blood cells and hormones, given that changes in blood composition affect blood fluidity [8]. Sandberg et al [9] reported increased circulation in skin and muscle after needle insertion in the tibialis anterior muscle of healthy persons. Inoue et al [10] demonstrated that electro-acupuncture at the sciatic and pudendal nerves and the lumbar nerve root induced temporary changes in blood flow in the sciatic nerve.

It is clear that stimulation applied to an organism impacts its endocrine and autonomic nervous systems. This impact may change cardiovascular function and result in blood flow alterations [11]. According to the best available knowledge, however, the best location of stimulation to achieve optimal blood flow has not yet been determined. We therefore decided to compare the effect of TENS application to sympathetic ganglions and acupuncture points on blood flow in the foot of healthy individuals.

2. Materials and methods

2.1. Participants

Seventy-five healthy adults (36 women and 39 men) aged 18–25 years provided their informed consent in writing and were entered into this experimental study (IRCT2016022126674N1). They were healthy with no sign of cardiovascular disease or autonomic nervous system disorders. Participants who were taking vasodilator drugs or who were smokers were excluded from the study. The participants were randomly assigned to one of three groups by a blocked randomization method. The first group received cutaneous electrical stimulation to the thoraco-lumbar sympathetic ganglions. The second group received stimulation to acupuncture points. The third group (control) received stimulation to the mid-calf area of the leg.

2.2. Procedure

All measurements were made in a temperature-controlled room at a physiotherapy clinic. The participants were asked to lie on the bed for 15 minutes in order to stabilize circulation and match their skin temperature with room temperature.

Blood flow in the left first toe was recorded with a laser Doppler flow-meter (AD Instruments, Sydney, NSW, Australia; Fig. 1). Then, low-frequency TENS (frequency 4 Hz, pulse duration 200 μs) was applied through surface electrodes with a Dynatron 438 device (Enraf, Rotterdam, the Netherlands) for 21 minutes. The first group received supramaximal stimulation to sympathetic ganglions in T12, L1, and L2, which innervate the lower extremity. The second group received supramaximal stimulation to acupuncture points ST36, GB34, and EX-LF10 (Fig. 2), which are responsible for blood flow increases. The third group received stimulation at the sensory threshold on the medial side of tibia in the mid-calf area. The intensity of stimulation was determined according to each participant's tolerance. Blood flow was recorded at time zero as baseline, and every 3 minutes after baseline during stimulation.

2.3. Statistical analysis

All data were analyzed with SPSS software (version 16; SPSS, Chicago, IL, USA), and the α and β levels were set at 0.05 and 0.2, respectively. The results of the Kolmogorov–Smirnov test showed a non-normal distribution of the data. Accordingly, we used two-way analysis of variance to compare mean perfusion between pairs of groups, and the *posthoc* Tukey test to compare perfusion in different times. This was followed by repeated measures analysis of variance to compare different times.

3. Results

Table 1 show the participants' demographic characteristics. There were no statistically significant differences in height,

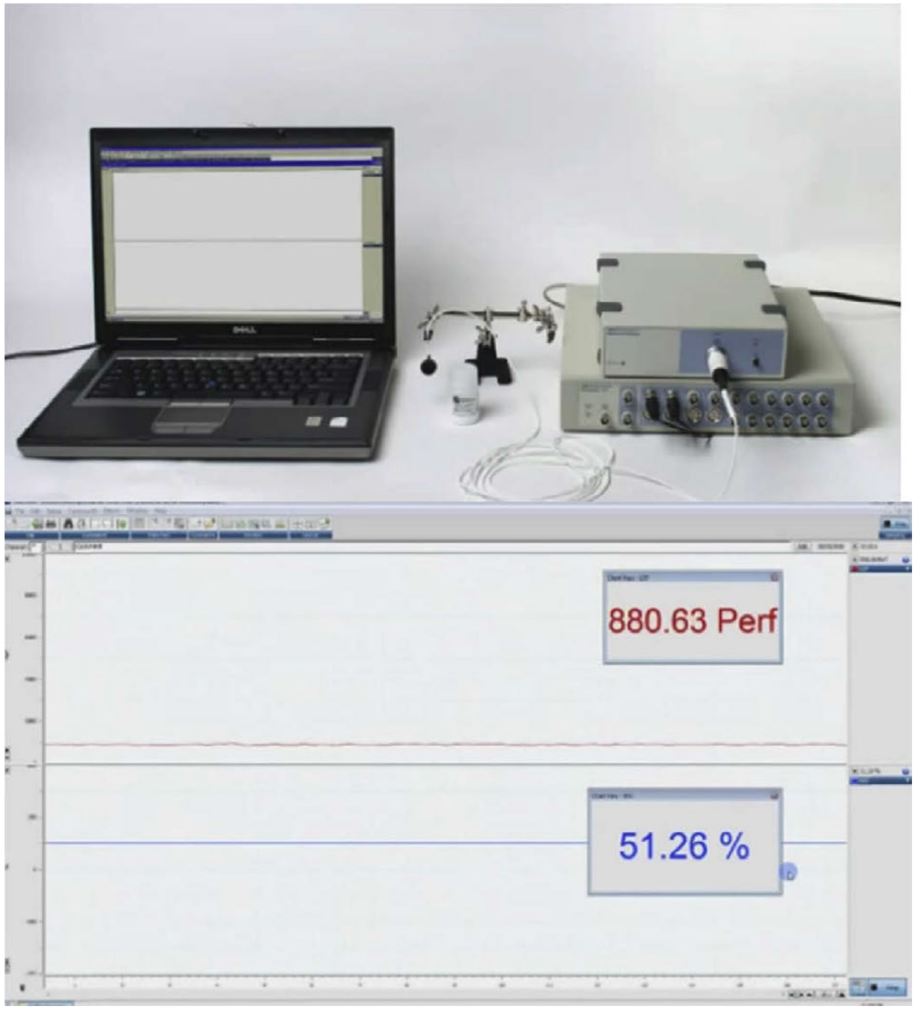

Figure 1 Laser Doppler flow-meter set-up.

weight, or sex distribution between the three groups ($p > 0.05$).

Two-way analysis of variance test revealed significant differences at different times ($F_{group1,\ 2} = 3.5$, $p < 0.001$; $F_{group1,\ 3} = 3.735$, $p < 0.001$; $F_{group2,\ 3} = 0.744$, $p = 0.635$). *Posthoc* comparisons with the Tukey test revealed differences between time 0 minutes and times 3 minutes, 6 minutes, 9 minutes, 12 minutes, 15 minutes, and 18 minutes, and also between time 21 minutes and times 12 minutes, 15 minutes, and 18 minutes.

Two-way analysis of variance revealed significant differences between groups ($F_{group1,\ 2} = 58.792$, $p < 0.001$; $F_{group1,\ 3} = 69.145$, $p < 0.000$; $F_{group2,\ 3} = 0.003$, $p = 0.957$). Individuals who received sympathetic ganglion stimulation had significantly greater blood flow than those who received acupuncture point stimulation or those in the control group, but individuals who received acupuncture point stimulation did not differ significantly from the control group (Table 2).

Repeated-measure analysis of variance revealed that blood flow at different times during stimulation increased significantly from time 0 in each group ($F_{group1,\ 2} = 2.162$, $p = 0.039$; $F_{group1,\ 3} = 2.833$, $p = 0.008$; $F_{group2,\ 3} = 0.193$, $p = 0.987$).

4. Discussion

To the best of our knowledge, this is the first study to compare the effect of low-frequency TENS application at the thoracolumbar sympathetic ganglions, acupuncture points, and mid-calf area on peripheral blood circulation. The results of this study show that low-frequency TENS at the sympathetic ganglions at the levels of T12, L1, and L2 may increase blood flow of the left first toe significantly more than TENS application at acupuncture points or the mid-calf area. Therefore, sympathetic ganglions may be the best site for stimulation intended to increase peripheral blood flow.

Previous studies that investigated vasoconstriction with electrical stimulation of cut nerves, and vasodilatation at the nerve section, found that sympathetic fibers exerted a tonic, vasoconstrictor effect [12,13]. It has been hypothesized [5,6,14—17] that the application of different intensities and frequencies of transcutaneous stimulation to peripheral nerves can increase or decrease postganglionic vasoconstrictor neuron activity. Sherry et al [18] noted that this influence of TENS was caused mainly by local mechanisms. They suggested that muscle accumulation of local metabolic vasodilator elements at the muscle pump along

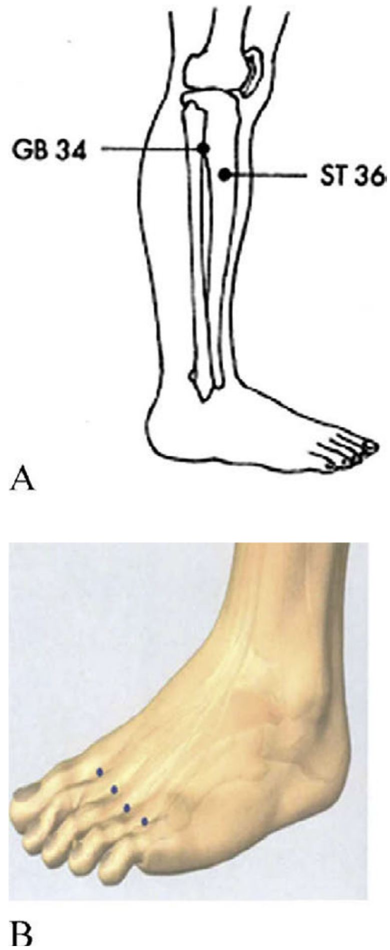

Figure 2 Acupuncture points. (A) ST 36 and GB 34; (B) EX-LF 10.

Table 1 Patient demographics at baseline.

		Group 1	Group 2	Group 3
Sex	Male	12	14	13
	Female	13	11	12
Height (m), mean		170.50	172.75	173
Weight (kg), mean		67.90	68.15	66.15

Group 1 = sympathetic ganglion group; Group 2 = acupuncture points group; Group 3 = control group.

with flow-induced expansion are the probable mechanisms underlying vasodilation [18]. The results of our study, however, do not support this explanation. When the intensity of low-frequency TENS is increased beyond the supramaximal threshold, there is a vasodilator influence with stimulation of the sympathetic ganglions.

Low-frequency TENS diminishes levels of epinephrine and norepinephrine [19,20]. Owing to this effect on the sympathetic nervous system, TENS at the ganglion region may attenuate the vascular response [21]. In accordance with our results, Vieira et al [21] reported that the acute application of TENS at the ganglion region induced vasodilator responses.

Table 2 Comparison of blood flow in different groups.

Group	Blood flow (perfusion units) (Mean ± standard deviation)	*p*
1 2	104.70 ± 24.45	<0.001
3	105.37 ± 24.45	<0.001
2 1	−104.70 ± 24.45	<0.001
3	0.066 ± 21.44	>0.95
3 1	105.37 ± 24.45	<0.001
2	−0.66 ± 21.44	>0.95

Group 1 = sympathetic ganglion group; Group 2 = acupuncture points group; Group 3 = control group.

It has been proven that neural mechanisms contribute to the vasodilatory effects of acupuncture stimulation [22]. Previous studies found that acupuncture stimulation may reduce sympathetic activity [23–25]. In the present study, the response to TENS applied at acupuncture points did not differ significantly in comparison to the control group—an unexpected finding. Our participants probably experienced no soreness or numbness after TENS application through surface electrodes at acupuncture points. Kuo et al [26] stated that the feeling of soreness and numbing (the *De-Qi* sensation) is necessary for the meridian system response and hence for increased blood flow. It is possible that the use of needle electrodes would have yielded different results in our participants. The effect of acupuncture point stimulation on blood flow is believed to reflect physiological effects and changes in blood composition—phenomena that may occur during a prolonged period [8]. If our intervention or assessment period had been longer time, we might have seen a significant difference between the responses to stimulation at acupuncture points versus other areas targeted for stimulation.

Hsiu et al [27] stated that acupuncture stimulation decreased the heart rate and dilated terminal vessels by decreasing sympathetic activity. However, they did not assess terminal circulation directly, and the vasodilatory effect of acupuncture was assessed only at the acupoint areas. Our results show that to improve peripheral circulation, the application of sympathetic ganglion stimulation was more effective than stimulation at acupuncture points.

Overall, the results of this study show that the application of low-frequency TENS at the thoraco-lumbar sympathetic ganglions improved peripheral blood circulation. This finding may be useful in situations such as fractures, when accessibility to distal sites is limited.

Conflicts of interest

The authors have received no benefits from industry to conduct this study.

Acknowledgments

The authors thank the staff of the Physiotherapy Clinic of the School of Rehabilitation Sciences, Shiraz University of Medical Sciences, for their assistance, and K. Shashok (AuthorAID in the Eastern Mediterranean) for improving the use of English in the manuscript. This manuscript was funded by Shiraz University of Medical Sciences (CT-90-56-37).

References

[1] Thakral G, LaFontaine J, Najafi B, Talal TK, Kim P, Lavery LA. Electrical stimulation to accelerate wound healing. *Diabet Foot Ankle*. 2013;4. http://dx.doi.org/10.3402/dfa.v4i0.22081.

[2] Machado A, Santana EF, Tacani PM, Liebano RE. The effects of transcutaneous electrical nerve stimulation on tissue repair: a literature review. *Can J Plast Surg*. 2012;20:237—240.

[3] Atalay C, Yilmaz KB. The effect of transcutaneous electrical nerve stimulation on postmastectomy skin flap necrosis. *Breast Cancer Res Treat*. 2009;117:611—614.

[4] Hallén K, Hrafnkelsdóttir T, Jern S, Biber B, Mannheimer C, DuttaRoy S. Transcutaneous electrical nerve stimulation induces vasodilation in healthy controls but not in refractory angina patients. *J Pain Symptom Manage*. 2010;40:95—101.

[5] Wong RA, Jette DU. Changes in sympathetic tone associated with different forms of transcutaneous electrical nerve stimulation in healthy subjects. *Phys Ther*. 1984;64:478—482.

[6] Kaada B. Vasodilation induced by transcutaneous nerve stimulation in peripheral ischemia (Raynaud's phenomenon and diabetic polyneuropathy). *Eur Heart J*. 1982;3:303—314.

[7] Chen CC, Johnson MI, McDonough S, Cramp F. The effect of transcutaneous electrical nerve stimulation on local and distal cutaneous blood flow following a prolonged heat stimulus in healthy subjects. *Clin Physiol Funct Imaging*. 2007;27: 154—161.

[8] Hisamitsu T, Ishikawa S. Changes in blood fluidity caused by electroacupuncture stimulation. *J Acupunct Meridian Stud*. 2014;7:180—185.

[9] Sandberg M, Lundeberg T, Lindberg LG, Gerdle B. Effects of acupuncture on skin and muscle blood flow in healthy subjects. *Eur J Appl Physiol*. 2003;90:114—119.

[10] Inoue M, Kitakoji H, Yano T, Ishizaki N, Itoi M, Katsumi Y. Acupuncture treatment for low back pain and lower limb symptoms—the relation between acupuncture or electroacupuncture stimulation and sciatic nerve blood flow. *Evid Based Complement Alternat Med*. 2008;5:133—143.

[11] Ishikawa S, Suga H, Fukushima M, Yoshida A, Yoshida Y, Sunagawa M, et al. Blood fluidity enhancement by electrical acupuncture stimulation is related to an adrenergic mechanism. *J Acupunct Meridian Stud*. 2012;5:21—28.

[12] Parati G, Esler M. The human sympathetic nervous system: its relevance in hypertension and heart failure. *Eur Heart J*. 2012;33:1058—1066.

[13] Linderoth B, Gunasekera L, Meyerson BA. Effects of sympathectomy on skin and muscle microcirculation during dorsal column stimulation: animal studies. *Neurosurgery*. 1991;29: 874—879.

[14] Owens S, Atkinson ER, Lees DE. Thermographic evidence of reduced sympathetic tone with transcutaneous nerve stimulation. *Anesthesiology*. 1979;50:62—64.

[15] Abram SE, Asiddao CB, Reynolds AC. Increased skin temperature during transcutaneous electrical stimulation. *Anesth Analg*. 1980;59:22—25.

[16] Cramp A, Gilsenan C, Lowe A, Walsh D. The effect of high-and low-frequency transcutaneous electrical nerve stimulation upon cutaneous blood flow and skin temperature in healthy subjects. *Clin Physiol*. 2000;20:150—157.

[17] Cosmo HS, Bornmyr Siv, Wikström Sven-Olof, Peter P. Effects of transcutaneous nerve stimulation on the microcirculation in chronic leg ulcers. *Scand J Plast Reconstr Surg Hand Surg*. 2000;34:61—64.

[18] Sherry JE, Oehrlein KM, Hegge KS, Morgan BJ. Effect of burst-mode transcutaneous electrical nerve stimulation on peripheral vascular resistance. *Phys Ther*. 2001;81:1183—1191.

[19] Mannheimer C, Emanuelsson H, Waagstein F. The effect of transcutaneous electrical nerve stimulation (TENS) on catecholamine metabolism during pacing-induced angina pectoris and the influence of naloxone. *Pain*. 1990;41:27—34.

[20] Emanuelsson H, Mannheimer C, Waagstein F, Wilhelmsson C. Catecholamine metabolism during pacing-induced angina pectoris and the effect of transcutaneous electrical nerve stimulation. *Am Heart J*. 1987;114:1360—1366.

[21] Vieira PJ, Ribeiro JP, Cipriano Jr G, Umpierre D, Cahalin LP, Moraes RS, et al. Effect of transcutaneous electrical nerve stimulation on muscle metaboreflex in healthy young and older subjects. *Eur J Appl Physiol*. 2012;112:1327—1334.

[22] Uchida S, Hotta H. Acupuncture affects regional blood flow in various organs. *J Evid Based Complement Altern Med*. 2008;5: 145—151.

[23] Knardahl S, Elam M, Olausson B, Wallin BG. Sympathetic nerve activity after acupuncture in humans. *Pain*. 1998;75:19—25.

[24] Ohsawa H, Okada K, Nishijo K, Sato Y. Neural mechanism of depressor responses of arterial pressure elicited by acupuncture-like stimulation to a hind limb in anesthetized rats. *J Auton Nerv Syst*. 1995;51:27—35.

[25] Middlekauff HR. Acupuncture in the treatment of heart failure. *Cardiol Rev*. 2004;12:171—173.

[26] Kuo TC, Lin CW, Ho FM. The soreness and numbness effect of acupuncture on skin blood flow. *Am J Chin Med*. 2004;32: 117—129.

[27] Hsiu H, Hsu WC, Hsu CL, Huang SM. Assessing the effects of acupuncture by comparing needling the *Hegu* acupoint and needling nearby nonacupoints by spectral analysis of microcirculatory laser Doppler signals. *J Evid Based Complement Altern Med*. 2011;2011:435928.