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RESEARCH ARTICLE

Effect of Acupuncture Manipulations at LI4 or LI11 on Blood Flow and Skin Temperature

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Abstract
Acupuncture induces physiological changes, and patients have reported warm or cool sensations with "Burning Fire" (BF) or "Penetrating Cool" (PC) manipulations. This study aimed to evaluate whether these techniques had distinct effects on skin temperature and blood flow and to examine whether skin temperature correlated with blood flow. The participants were 25 healthy volunteers, each receiving acupuncture manipulations on points LI4 and LI11 bilaterally. Skin temperatures and blood flow were recorded continuously on both arms. The study found that acupuncture significantly increased skin temperature on the needling arm by 0.3514°C on average, but decreased it on the contralateral arm by 0.2201°C on average. Blood flow decreased significantly in both arms during needling (−3.4% and −5.97% for the ipsilateral and the contralateral sides, respectively), but the changes in skin temperature did not correlate with the changes in blood flow. Furthermore, these changes were not significantly different between acupuncture techniques and acupuncture points. In conclusion, acupuncture changes local skin temperature and blood flow independent of the manipulation technique. Moreover, blood flow may not be affected by the increased temperature on the needling arm. These results help to verify traditional Chinese medicine concepts and may help in establishing standards for acupuncture treatments.

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1. Introduction

Acupuncture originated in China more than 2000 years ago and has since then been considered an integral component of traditional Chinese medicine [1]. Over the past 30 years, more than 1500 randomized, controlled trials on the effects of acupuncture on humans have been performed and published in the English peer-reviewed literature alone. Although these studies have demonstrated the effectiveness of acupuncture for a number of clinical conditions [2,3], few have explored the physiological mechanisms underlying the basic practice of acupuncture—needle insertion and manipulation.

According to acupuncturists, tonifying and dispersing manipulations are important factors in determining the effectiveness of acupuncture [4]. Patients have often reported warm and cool sensations when either the "Burning Fire" (BF) or "Penetrating Cool" (PC) manipulations are used [5]. There are several different versions of the BF and PC techniques. In this study, a simple version was employed: for BF, the acupuncturist performs three quick, consecutively incremental needle insertions alternating with one slow, fuller withdrawal (Figure 1A); for PC, the acupuncturist does the reverse, performing three quick increments of needle withdrawal alternating with one slow, fuller insertion.

In western medicine, it is commonly known that body temperature is tightly regulated, which is achieved by a set of compensatory mechanisms. For example, heat generation rate is increased or heat removal rate is reduced when temperature is low and does the opposite when temperature is high [6]. Body heat is mostly generated in the internal organs during rest [7]; during exercise, the skeletal muscle generates an increased amount of heat with muscle contractions [7]. Heat removal rate is generally determined by the heat transfer rate from the core of the body to the body surface through blood vessels: vasoconstriction shrinks the superficial capillaries and directs blood away from the skin, thus preventing heat loss through the skin; vasodilation allows more blood to flow through the arteriole, thus venting the heat by convection and conduction through the superficial capillaries. Generally, vasoconstriction decreases the skin temperature while vasodilation increases it.

The study aims to test what effects the BF and PC techniques have on skin temperature and blood flow. It also examines if change of skin temperature correlated with blood flow changes. Through the study, we can verify the traditional concept of acupuncture theory from the scientific perspective. Eventually, consistent results might help to standardize acupuncture protocols for acupuncture treatment.

2. Materials and methods

The study population was comprised of 25 healthy volunteers (21 female and 4 male), aged 21—55 years [mean ± standard deviation (SD), 30.9 ± 8.7]. They were recruited through direct announcements in classrooms in the New England School of Acupuncture. The volunteers were screened to exclude chronic medical conditions such as hypertension, diabetes, and hypothyroidism. Those volunteers with movement disorders or physical tremors, taking blood thinner medicines, having chronic skin conditions, or being immune-compromised were also excluded from the study. Testing was performed in a practice room at the New England School of Acupuncture. The room temperature was maintained at 21.1°C. The study was reviewed and approved by the New England Institution's Review Board. Each volunteer read and signed an informed consent form prior to participation.

According to traditional Chinese medicine, acupuncture points LI4 (He Guo) and LI11 (Qu Chi) are common and useful points. LI4 is famous for pain reduction and LI11 is effective in reduction of fever (Figure 1B). The study chose these two points bilaterally to implement the acupuncture techniques. After volunteers arrived at the site, they were guided to lie on a treatment table. Each trial included four recordings, with the first recording started by randomly selecting LI4 or LI11 on the left or

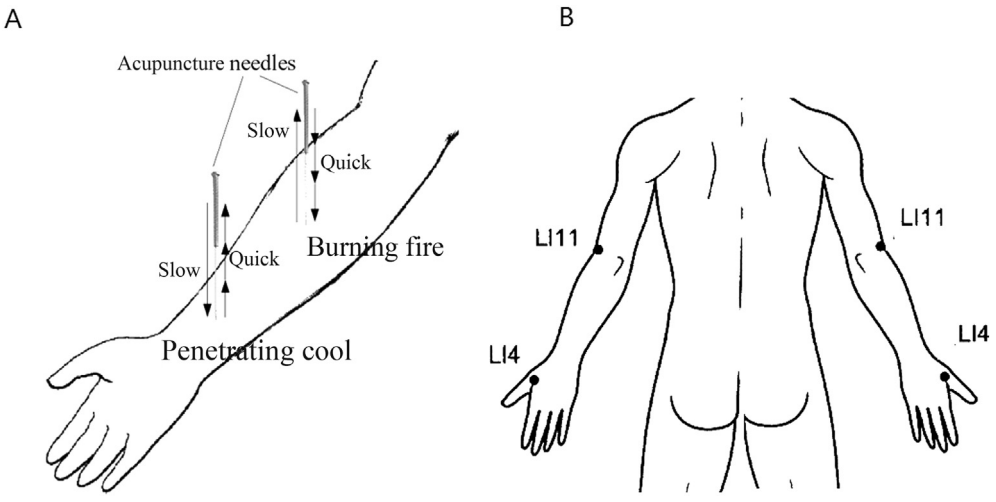

Figure 1 (A) Illustration of a simple version of BF and PC acupuncture techniques. (B) Illustration of the locations for LI4 (He Guo) and LI11 (Qu Chi) acupuncture points.

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right arm with BF or PC; after the first randomly selected combination, the other three recordings always switched to the other choice from the previous recording. Figure 2 (top panel) shows one scenario for a trial: the first recording was from randomly selected LI4 on the right arm, manipulated with PC; the second recording switched to LI11 on the left arm with BF technique; the third recording switched again for the point, arm, and technique and so forth for the fourth recording. Between each recording, the patient was given 5 minutes to rest. After the protocol was determined, two thermistor probes (MLT422/A, ADinstruments, Colorado Springs, CO 80906, USA) were used to measure skin temperatures in °C. One was attached to approximately 1 inch radial and distal away from the acupuncture site and the other symmetrically on the contralateral arm. Beat-to-beat volumetric changes of blood flow to the arms were monitored from the phalanx of both middle fingers with the photoelectric plethysmography (MLT1020PPG, ADinstruments). The blood flow was represented as an electric potential measurement directly correlated to the actual blood flow, with the unit of volt. All the sensors were connected to a data acquisition system (PowerLab, ADinstruments). After a licensed acupuncturist wiped the acupuncture point, 2 minutes or longer of stabilized baseline data were recorded before the needle insertion and manipulation [before acupuncture period (BAP), Figure 2]. Each session of manipulation lasted ~5 minutes, and was comprised of approximately 20–30 cycles of designated manipulations before the needle was removed [during acupuncture period (DAP)]. Another 2 minutes of data were collected before recording ended [after acupuncture period (AAP)]. The sampling frequency was 1 kHz.

Data analysis included mean and standard deviation calculation, analysis of mean difference, and matched pair test across groups. A value of $p = 0.05$ was considered statistically significant. Pearson correlations were calculated to assess the relationship between skin temperature and blood flow.

3. Results

Out of the 25 participants recruited in the study, one of them quit after two recordings (due to dizziness) and one volunteer quit after one recording (being intolerant to pain

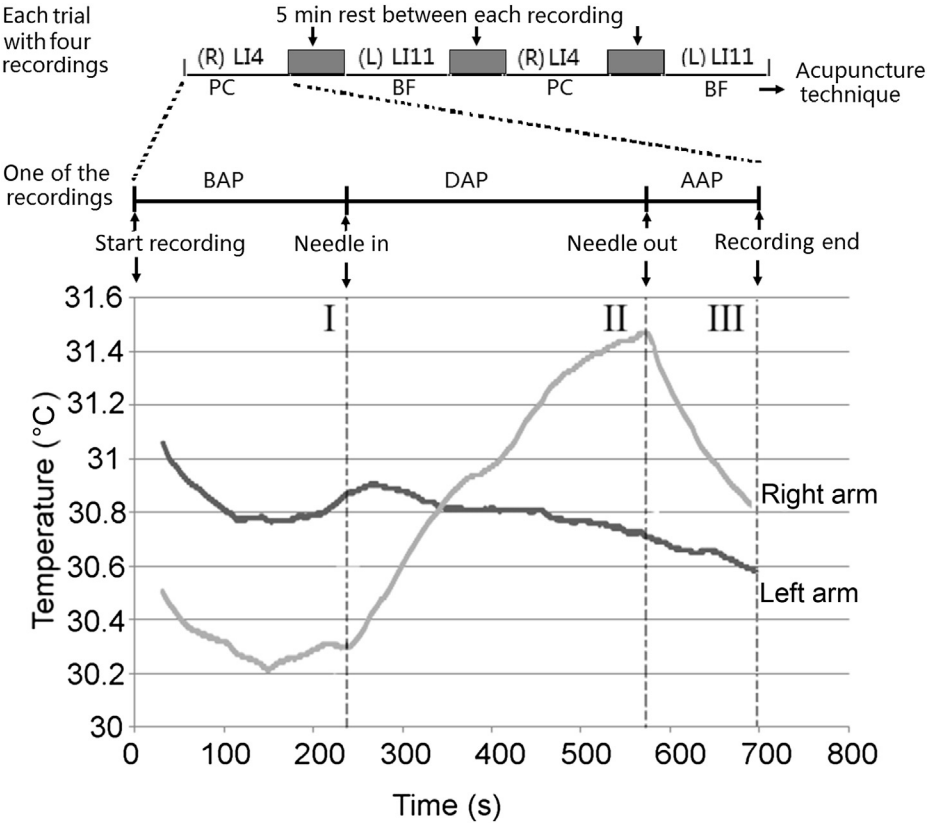

Figure 2 Illustration of experimental protocol. Each trial included four recordings with the first recording started by randomly selecting LI4 or LI11 on the left or right arm with BF or PC; after the first randomly selected combination, the other three recordings always switched to the other choice from the previous recording. Between each recording, the patient was given 5 minutes to rest. The time segment from the start of recording to the needle insertion was the before acupuncture period (BAP). The time segment between the insertion of needle to the needle removal was the during acupuncture period (DAP). The last segment for each recording spanned between the removal of needle to the time of stopping recording and was marked as the after acupuncture period (AAP). The figure also showed example traces of skin temperature changes with acupuncture manipulation (bottom panel).

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associated with acupuncture manipulation). In all, 95 sets of recordings were collected and analyzed.

Figure 2 (bottom panel) presents example traces of skin temperature of ipsilateral (right arm) and contralateral (left arm) sides when LI4 on the right arm was needled. The first vertical dot line (timing I) marks the time of needle insertion and manipulation; the second vertical dot line (timing II) indicates the time of stopping manipulation and needle removal; and the third vertical dot line (timing III) is the time when the recording stops. The figure reveals that skin temperature on the right arm increased significantly with the insertion and manipulation of the acupuncture needle, then quickly decreased after removal of the needle. Skin temperature slightly decreased on the contralateral (left) side. Figure 3A is an example trace of blood flow during the acupuncture manipulation. Figure 3B is the pulse flow magnitude calculated from the peak and trough of the pulsatile blood flow in Figure 3A [12,13].

Table 1 shows the mean values of the local skin temperature and pulse flow changes on the ipsilateral and contralateral arms before needles were inserted and with needles in. Temperature changes were calculated as the temperature differences between the temperatures at timing II and the temperatures at timing I (as illustrated in Figure 2). Pulse flow changes were computed as the differences of mean pulse flow during DAP and BAP. Also shown in the table are the p values from the matched pair comparison between groups of different manipulations. It can be seen that both the temperature and pulse flow changes were not significantly different between the BF and PC techniques for both LI4 and LI11 acupuncture points (all p values are > 0.05). We then grouped the data for different acupuncture manipulations and checked the effects of different acupuncture points on the temperature and pulse flow changes. The p values for the temperature and pulse flow changes were 0.0795 and 0.4469, respectively, showing no significant difference between different acupuncture points.

With no significant difference in skin temperature and pulse flow changes regarding the acupuncture points and manipulation types, the data were pooled to study the overall effects of acupuncture. The pooled data had skewness of 0.0768 and kurtosis of 0.2552. These numbers are relatively small, thus we can still consider the data had a normal distribution. Table 2 lists the skin temperature/pulse flow changes between DAP and BAP (DAP−BAP) and between AAP and DAP (AAP−DAP). The data demonstrate that skin temperatures were significantly increased ($\Delta T = 0.3514$, $p < 0.0001$) on the ipsilateral side of the needled arm while they were reduced ($\Delta T = -0.2201$, $p < 0.0001$) on the contralateral side. Pulse flows consistently decreased with acupuncture on both ipsilateral arms ($\Delta F = -0.005$, $p = 0.00131$) and contralateral arms ($\Delta F = -0.0074$, $p = 0.0006$). When the acupuncture needles were removed, skin temperature on the ipsilateral side started to decrease ($\Delta T = -0.4404$, $p < 0.0001$) and reached a level at the time of ending recording lower than the base temperature before acupuncture. The contralateral side further decreased, but at a smaller amount ($\Delta T = -0.1081$, $p < 0.0001$) compared with the ipsilateral side. Pulse flow on average rebounds back significantly with the removal of acupuncture needles for both ipsilateral ($\Delta F = 0.0039$, $p = 0.0247$) and contralateral arm ($\Delta F = 0.0044$, $p = 0.0137$).

Further, this study also studied the correlation between temperature and pulse flow during manipulation. The correlation coefficients were computed for each trial between skin temperature and pulse flow, which is 0.0169 ± 0.3818 for the ipsilateral arms and -0.009 ± 0.06282 for contralateral arms. The data showed that the skin temperature and blood flow do not correlate during acupuncture.

4. Discussion

Acupuncture manipulations, especially the two manipulations called BF and PC, are clinically important to traditional Chinese medicine, yet whether these manipulations can yield different physiological responses has not been confirmed and how they relate to hemodynamics has not been investigated in conventional medicine. This study

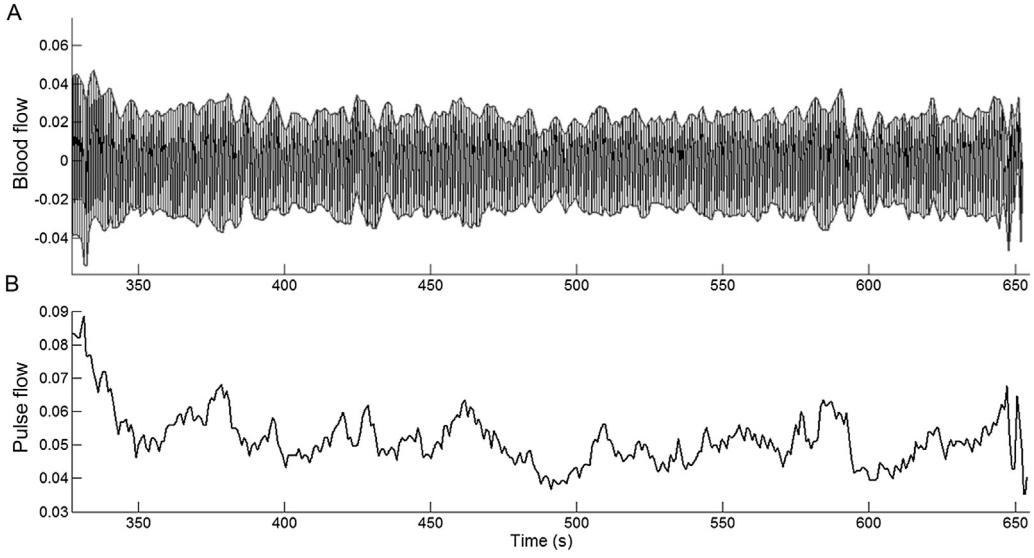

Figure 3 (A) Blood flow measured from the right arm. (B) Pulse flow calculated from blood flow.

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Table 1 Temperature (°C) and pulse flow changes with acupuncture with different manipulation technique (BF and PC) on different acupuncture points (LI4 and LI11). Matched-pair test with no significant difference between different manipulations.

		Temperature change (ΔT, °C)				Blood flow (ΔF, volt)			
		Ipsilateral		Contralateral		Ipsilateral		Contralateral	
LI4	BF (29)	0.3152	$p = 0.4840$	−0.241	$p = 0.7146$	−0.0061	$p = 0.9249$	−0.0078	$p = 0.7598$
	PC (19)	0.2395		−0.2716		−0.0067		−0.0094	
LI11	BF (19)	0.3635	$p = 0.5514$	−0.238	$p = 0.1938$	−0.005	$p = 0.6252$	−0.00267	$p = 0.3466$
	PC (28)	0.4283		−0.139		−0.00214		−0.00837	

Table 2 Skin temperature and pulse flow changes before and after acupuncture.

	Temperature changes (ΔT, °C)		Pulse flow changes (ΔF, volt)	
	Ipsilateral arm	Contralateral arm	Ipsilateral arm	Contralateral arm
DAP−BAP	0.35137 ($p < 0.0001$*)	−0.2201 ($p < 0.0001$*)	−0.005 ($p = 0.0131$*)	−0.0074 ($p = 0.0006$*)
AAP−DAP	−0.4404 ($p < 0.0001$*)	−0.1081 ($p < 0.0001$*)	0.0039 ($p = 0.0247$*)	0.00435 ($p = 0.0137$*)

AAP = after acupuncture period; BAP = before acupuncture period; DAP = during acupuncture period.
* indicates significant difference.

initiated the exploration of skin temperature and vascular response to these two acupuncture manipulations on the two acupuncture points of LI4 and LI11.

This study highlights the opposite changes of skin temperatures with acupuncture on ipsilateral and contralateral arms: skin temperatures were significantly elevated on the ipsilateral sides of acupuncture manipulations while they were decreased on the contralateral sides. Mean pulse flow decreases with acupuncture manipulations and slightly rebounds after the needles are removed on both arms. Pulse flow does not correlate with skin temperature during acupuncture manipulations.

The above results had several implications. First, different responses of skin temperatures on the ipsilateral and contralateral sides of the acupunctured arms implied that local physiological activities played important roles in response to acupuncture. Skeletal muscle contractions may be one of the mechanisms partly responsible for the increased skin temperature [8], but this is yet to be confirmed in future studies by recording electrical activities of the muscles through electromyography. Secondly, decreased average pulse flow after acupuncture manipulations implied that peripheral vasoconstrictions occurred during manipulations [9]. This may lead to the decreased skin temperature on the contralateral side with acupuncture manipulations. During the acupuncture manipulations, volunteers frequently reported pain sensation, which may interact with the autonomic nervous system, especially the sympathetic nerves, and lead to the vasoconstrictions [10]. When the acupuncture needles were removed, there was significant rebound of the pulse flow, but not to the baseline level before acupuncture manipulation. This further supports the study's hypothesis that pain induced during manipulation may constrict the vessels that might cause the lowered the skin temperature on the contralateral side of the needled arm.

The study also reveals that neither skin temperature nor pulse flow changes are significantly different with regard to which acupuncture techniques are being used (BF or PC) and which acupuncture points are being needled (LI4 or LI11). There are several possible explanations. Firstly, the simple version of BF and PC techniques are not strong enough to induce a distinct physiological response. A more sophisticated version of BF and PC includes multiple strong manipulations at each layer of tissue at different depths [5]. This simple version was chosen based on the consideration of volunteers' susceptibility to stronger pain sensation. Secondly, literally reported warm or cool sensations with BF or PC manipulations were never quantitatively documented in research, nor have these feelings been systematically surveyed among patients. Hence, it is not known whether these warm or cooling sensations are feelings from the core of the body or from particular regions of the peripheral tissues. The study only measured two points of skin temperature and thus is not able to fully explore the global or distal effects of BF and PC techniques. Future studies are required to quantify the effects of these two manipulation techniques and reveal the underlying mechanisms. Thirdly, the lack of variability between LI4 and LI11 may reside in the fact that both points are located on the same meridian.

When compared with past studies, the increased temperature on the ipsilateral side of acupuncture found in the present study is consistent with the study be Huang et al [11]. Acupuncture on ST36 of the right lower leg was found to increase the local skin temperature continuously until the needle was removed [11] In the paper, they did not measure the temperature on the contralateral side and no blood flow was recorded either. Kuo et al [12] observed increased blood flow at LI11 when needled on LI4 of the same forearm. The current study's observation is not consistent with that finding. There may be two possibilities. (1) The method in measuring the blood flow is different: in the study by Kuo et al [12], skin blood flow was measured by using laser Doppler flowmetry, while this study used photoelectric plethysmography. The laser Doppler flowmetry

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actually reflects the blood cell flux in the microscale vessels [13] whereas the photoelectric plethysmography shows the change of blood volume of the extremities [14,15]. Blood flow and flux readings might be different in response to similar acupuncture manipulations. (2) The measurement locations were different: in experiments by Kuo et al [12], they measured the blood flow at the LI11 while needling on LI4 on the same arm. In the present study, blood flow was measured from the phalanx of the middle fingers while needling on LI4 or LI11. The response of blood perfusion might depend on the relative location of measurement and acupuncture stimulation.

This study has a number of limitations. First, it involved a limited number of volunteers, having only two specific acupuncture points needled, and did not have sufficient power to evaluate the effects of gender, age, or ethnicity. Future studies may consider evaluating other acupuncture points and larger and more diverse cohorts. Second, the study only measured skin temperature on two points and cannot report the temperature changes on other parts of the body or the core temperature. Future studies will be needed to explore the use of a far infrared camera to record larger areas of skin temperature change or measure the core temperature. Third, blood flow was measured through photoelectric plethysmography, which is an only a surrogate marker of extremity perfusion and cannot be interpreted as a direct measurement. In addition, it could be affected by changes in blood pressure and venous pooling. Fourth, using a simple version of BF and PC does not show significant differences on skin temperature and blood flow. More sophisticated manipulations to induce warm and cool sensations exist and need to be explored in future studies. Fifth, all the measurements were conducted on healthy volunteers. How the skin temperature and blood flow change in patients with health conditions has not been investigated, which will be even more important to the clinic practice of acupuncture.

Despite these limitations, this study has a number of contributions. This is the first study that continuously measured the temperature and blood flow changes with high resolution during the acupuncture with two types of manipulation. With a large set of continuous data, signal processing and statistics analysis were able to be conducted to explore the underlying mechanisms associated with different acupuncture manipulation techniques.

Acknowledgments

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