Introduction

Previous studies have suggested that thermal stimulation enhances blood flow\textsuperscript{[1]}, increases skin temperature\textsuperscript{[2,3]}, and modulates gastrointestinal motility\textsuperscript{[4,5]}. It has been theorized that thermal-stimulation triggers the excitation of skin nociceptors such as C-fiber mechano-heat nociceptors that influence the skin’s peripheral vessels, resulting in reactions such as an increase in blood flow and a rise in skin temperature\textsuperscript{[5,6]}. Sato et al\textsuperscript{[6]} indicated that a neuroeffect response

Research Article

Difference between the effects of one-site and three-site abdominal hot-stone stimulation on the skin-temperature changes of the lower limbs

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OBJECTIVE: To determine whether any difference exists in the skin-temperature responses of the lower limbs to hot-stone application relative to one-site and three-site abdominal application.

METHODS: Twenty-five female students participated in experimental sessions after a random allocation: 14 participants received a hot-stone application on the umbilicus, superior-umbilicus, and inferior-umbilicus regions (hereafter referred to as the three-site stimulation group); and 11 participants received the hot-stone application on the umbilicus region only (hereafter referred to as the one-site stimulation group). Heated stones were applied for 9 min to participants in both groups. Four arbitrary frames (the lower leg, ankle, proximal foot, and distal foot regions) were created in order to observe and analyze the skin temperature of a lower limb using a thermograph. Observation periods were as follows: before hot-stone stimulation, immediately after stimulation, and 5, 10, 15, and 20 min after stimulation.

RESULTS: There was a significant offset interaction of distal foot skin temperature between the groups. The left-side distal foot skin temperature increased at 15 and 20 min following the three-site abdominal hot-stone stimulation. The right-side distal foot skin temperature increased immediately and at 5, 10, 15, and 20 min following the three-site abdominal hot-stone stimulation. No significant change in distal foot skin temperature was observed following the one-site stimulation.

CONCLUSION: Lower-limb skin temperature was altered following hot-stone stimulation applied to the abdomen, and the one-site stimulation and three-site stimulation yielded different distal foot skin-temperature reactions.

KEYWORDS: thermography; skin temperature; massage; hot-stone; pilot study

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occurs through different mechanisms, including central sensitization, peripheral sensitization, and the axon reflex, and that those response mechanisms are evoked by mechanical, chemical, or thermal stimulations. Sato et al\[^{[6]}\] further indicated, however, that skin nociceptors have high thresholds against mechanical, thermal, or chemical stimulation; thus, it is hard to excite these receptors without activating low-threshold sensory receptors. Kawakita et al\[^{[7]}\] indicated that the axon reflex induced by somatosensory stimulation, such as acupuncture and moxibustion, is related to the activation of the polymodal receptor.

Moxibustion, an acupuncture practice modality, is a form of thermal therapy that involves burning the herb moxa (Artemisia vulgaris, commonly called mugwort) over acupuncture points\[^{[8]}\]. Mori et al\[^{[9]}\] indicated that no difference existed in skin-temperature responses to indirect moxibustion relative to the duration of thermal stimulation. In another study\[^{[3]}\], however, they indicated that a difference does exist in skin-temperature responses to indirect moxibustion relative to one-point and three-point indirect moxibustion stimulation. Mori et al\[^{[2]}\] hypothesized that the increase in skin temperature following moxibustion stimulation observed in their study was elicited by the excitation of the thermal nociceptors via the autonomic nervous system.

Another thermal-stimulation therapy used in complementary and alternative medicine is hot-stone therapy. This treatment method involves placing heated basalt stones on certain areas of the body. The therapy has been incorporated as a part of massage-therapy practice; the massage therapist may hold the heated stone(s), apply massage oil as a lubricant, and then use them to administer massage treatment\[^{[10]}\].

Despite the frequent use of hot-stone therapy in the massage and spa industries worldwide\[^{[10]}\], few experimental and clinical studies on hot-stone therapy are available. In particular, to our knowledge, no study has examined skin-temperature response following hot-stone stimulation. In order to elucidate the effect of hot-stone stimulation on human skin temperature, we compared the effects of one-site and three-site abdominal hot-stone stimulation on skin-temperature changes of the lower limbs.

2 Methods

2.1 Participants

Thirty female participants were recruited for the study from July 12 to 26, 2012. An envelope method was used to randomly assign the participants to the three-site stimulation group (n=15) and the one-site stimulation group (n=15). This study adhered strictly to the principles of the Declaration of Helsinki. Before the study began, the participants were told about the purpose and procedure of the study, and all participants signed an informed-consent form. This study obtained the approval from the Research Ethics Committee of National University Corporation at the Tsukuba University of Technology, Japan.

2.2 Stimulation method

The stones used in this study were basalt (a natural stone available in the USA). Their size was as follows: (89.4 ± 2.5) mm on the major axis, (71.6 ± 1.1) mm on the minor axis, (320.7 ± 15.9) g in weight, and (134.4 ± 6.3) mL in volume.

The procedures were as follows: (1) The temperature of the electric pot was set to 62-63 °C; the stones were then placed in water in the pot and kept there for more than 30 min. (2) Immediately prior to stimulation, one or three basalt stones were removed from the pot. (3) The subject’s abdomen was covered with a towel, and the hot stone(s) were placed on the towel. (4) Another towel was placed over the stone(s).

For participants in the three-site stimulation group, hot stones were placed on the umbilicus, superior-umbilicus, and inferior-umbilicus regions for 9 min. For participants in the one-site stimulation group, a hot stone was placed on the umbilicus region only for 9 min.

2.3 Measurement methods

The participants were asked to expose their legs below the knees, lie on a table in a supine position, and then rest for 10 min. A thermograph (JTG-5310, JEOL Ltd., Tokyo, Japan) was used to obtain the skin temperature of the participants’ feet and lower legs. The experiments were conducted in a room with the temperature set at (26.1±0.3) °C and 50.8%±0.5% humidity, throughout the experimental sessions.

Thermographic images were then obtained at the following time periods: before (Pre) and immediately after (Post 0) the hot-stone application, as well as at 5 (Post 5), 10 (Post 10), 15 (Post 15), and 20 (Post 20) min afterward.

In order to analyze skin temperature, four arbitrary frames were made on each lower limb: the anterior aspect of the lower leg (hereafter referred to as lower leg), the anterior aspect of the ankle (hereafter referred to as ankle), the dorsal proximal aspect of the foot (hereafter referred to as proximal foot), and the dorsal distal aspect of the foot (hereafter referred to as distal foot). The exact locations of the frames, with anatomical landmarks, are shown in Figure 1.

2.4 Statistical analysis

Serial changes in skin temperature between the groups were analyzed via mixed-model two-way factorial analysis of variance. Serial changes in skin temperature within the group were analyzed via linear analysis using Bonferroni’s multiple-comparison tests. SPSS Advanced Models Ver. 15 was used as the statistical analysis software. The level of significance was set at $P < 0.05$. The values presented are mean ± standard deviation.
3 Results

3.1 Patient enrollment

One participant in the three-site stimulation group and four participants in the one-site stimulation group did not participate in the experimental sessions (due to sickness or no shows). A total of 14 participants in the three-site stimulation group and 11 participants in the one-site stimulation group participated in the experiments and the analysis was conducted based on those 25 participants (mean age (23.5 ± 0.7) years). See Figure 2.

3.2 Skin-temperature changes in the distal foot region

Skin-temperature responses before and after the hot-stone applications are summarized in Table 1. For the skin-temperature response on the left side, there was a significant offset interaction between the groups ($P = 0.048$). For the skin-temperature response on the right side, there was a significant offset interaction between the groups ($P = 0.013$). In the three-site stimulation group, the left-side skin temperature increased at Post 15 ($P = 0.013$) and Post 20 ($P = 0.001$), compared to the baseline. For the right side, skin temperature increased at Post 0 ($P = 0.037$), Post 5 ($P = 0.001$), Post 10 ($P = 0.001$), Post 15 ($P = 0.001$), and Post 20 ($P = 0.001$) compared to the baseline. No significant change was observed in skin temperature in the one-site stimulation group.

3.3 Skin-temperature changes in the proximal foot region

No significant interaction occurred between the groups. No significant change in skin temperature was observed within the three-site stimulation group. In the one-site stimulation group, the left-side skin temperature increased at Post 5 ($P = 0.049$), Post 10 ($P = 0.014$), Post 15 ($P = 0.022$), and Post 20 ($P = 0.017$) compared to the baseline. For the right side, skin temperature increased at Post 5
Skin-temperature changes in the ankle region

No significant interaction occurred between the groups. In the three-site stimulation group, the left-side skin temperature increased at Post 15 ($P = 0.008$) and Post 20 ($P = 0.006$), compared to the baseline. For the right side of the three-site stimulation group, no significant change within the group was observed in skin temperature. In the one-site stimulation group, the left-side skin temperature increased at Post 5 ($P = 0.047$), Post 10 ($P = 0.022$), Post 15 ($P = 0.006$), and Post 20 ($P = 0.007$), compared to the baseline. For the right side of the one-site stimulation group, the skin temperature increased at Post 5 ($P = 0.009$), Post 10 ($P = 0.003$), Post 15 ($P = 0.001$), and Post 20 ($P = 0.001$), compared to the baseline. See Table 1.

### Table 1 Skin-temperature responses after the hot-stone applications

<table>
<thead>
<tr>
<th>Skin temperature</th>
<th>Pre</th>
<th>Post 0</th>
<th>Post 5</th>
<th>Post 10</th>
<th>Post 15</th>
<th>Post 20</th>
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<tbody>
<tr>
<td>Dist Ft (L)</td>
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</tr>
<tr>
<td>Three-site</td>
<td>26.21±3.42</td>
<td>26.50±3.43</td>
<td>26.94±3.32</td>
<td>27.11±3.29</td>
<td>27.41±3.11$^*$</td>
<td>27.66±3.15$^{**}$</td>
</tr>
<tr>
<td>One-site</td>
<td>33.58±1.37</td>
<td>33.80±1.30</td>
<td>33.99±1.26</td>
<td>33.89±1.28</td>
<td>33.87±1.35</td>
<td>33.86±1.36</td>
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<tr>
<td>Dist Ft (R)</td>
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<tr>
<td>Three-site</td>
<td>25.76±3.16</td>
<td>26.37±3.35$^*$</td>
<td>26.64±3.28$^{**}$</td>
<td>26.79±3.25$^{**}$</td>
<td>26.89±3.01$^{**}$</td>
<td>27.11±2.95$^{**}$</td>
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<tr>
<td>One-site</td>
<td>33.47±1.30</td>
<td>33.81±1.10</td>
<td>33.96±1.12</td>
<td>33.86±1.23</td>
<td>33.80±1.29</td>
<td>33.77±1.37</td>
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<td>Prox Ft (L)</td>
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<tr>
<td>Three-site</td>
<td>29.54±2.46</td>
<td>29.57±2.42</td>
<td>29.66±2.40</td>
<td>29.60±2.43</td>
<td>29.74±2.30</td>
<td>29.83±2.33</td>
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<tr>
<td>One-site</td>
<td>33.43±0.78</td>
<td>33.74±0.96</td>
<td>33.82±0.93$^*$</td>
<td>33.87±0.94$^*$</td>
<td>33.85±0.93$^*$</td>
<td>33.86±0.92$^*$</td>
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<tr>
<td>Prox Ft (R)</td>
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<tr>
<td>Three-site</td>
<td>29.11±2.39</td>
<td>29.31±2.34</td>
<td>29.33±2.38</td>
<td>29.29±2.35</td>
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<td>One-site</td>
<td>33.25±0.79</td>
<td>33.60±0.82</td>
<td>33.72±0.79$^*$</td>
<td>33.79±0.80$^{**}$</td>
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<tr>
<td>Three-site</td>
<td>30.71±2.25</td>
<td>30.96±2.14</td>
<td>31.07±2.11</td>
<td>31.05±2.06</td>
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<td>One-site</td>
<td>33.45±0.46</td>
<td>33.72±0.55</td>
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<td>Three-site</td>
<td>30.33±2.17</td>
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<td>30.63±2.00</td>
<td>30.62±1.92</td>
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<tr>
<td>One-site</td>
<td>33.35±0.45</td>
<td>33.65±0.46</td>
<td>33.71±0.51$^{**}$</td>
<td>33.75±0.55$^{**}$</td>
<td>33.81±0.54$^{**}$</td>
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<tr>
<td>Three-site</td>
<td>32.09±0.86</td>
<td>32.37±0.71$^{**}$</td>
<td>32.47±0.65$^{**}$</td>
<td>32.51±0.69$^{**}$</td>
<td>32.53±0.65$^{**}$</td>
<td>32.54±0.63$^{**}$</td>
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<tr>
<td>One-site</td>
<td>33.16±0.42</td>
<td>33.35±0.38</td>
<td>33.37±0.36</td>
<td>33.42±0.37$^{**}$</td>
<td>33.47±0.39$^{**}$</td>
<td>33.45±0.42$^{**}$</td>
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<td>Low Lg (R)</td>
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<td></td>
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<tr>
<td>Three-site</td>
<td>32.07±0.95</td>
<td>32.38±0.79$^{**}$</td>
<td>32.46±0.74$^{**}$</td>
<td>32.49±0.75$^{**}$</td>
<td>32.51±0.71$^{**}$</td>
<td>32.56±0.67$^{**}$</td>
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<tr>
<td>One-site</td>
<td>33.24±0.37</td>
<td>33.45±0.36</td>
<td>33.48±0.37$^{**}$</td>
<td>33.52±0.40$^{**}$</td>
<td>33.59±0.43$^{**}$</td>
<td>33.58±0.46$^{**}$</td>
</tr>
</tbody>
</table>

$^*P < 0.05$, $^{**}P < 0.01$, vs Pre. Skin temperature was measured before (Pre) and immediately after (Post 0) the hot-stone application, as well as at 5 (Post 5), 10 (Post 10), 15 (Post 15), and 20 (Post 20) min afterward.

Dist Ft: distal foot; Prox Ft: proximal foot; Low Lg = lower leg; L: left side; R: right side.

3.4 Skin-temperature changes in the ankle region

No significant interaction occurred between the groups. In the three-site stimulation group, the left-side skin temperature increased at Post 15 ($P = 0.031$) and Post 20 ($P = 0.003$), compared to the baseline. For the right side of the three-site stimulation group, no significant change within the group was observed in skin temperature. In the one-site stimulation group, the left-side skin temperature increased at Post 5 ($P = 0.047$), Post 10 ($P = 0.022$), Post 15 ($P = 0.006$), and Post 20 ($P = 0.007$), compared to the baseline. For the right side of the one-site stimulation group, the skin temperature increased at Post 5 ($P = 0.009$), Post 10 ($P = 0.003$), Post 15 ($P = 0.001$), and Post 20 ($P = 0.001$), compared to the baseline. See Table 1.

3.5 Skin-temperature changes in the lower-leg region

No significant interaction occurred between the groups. In the three-site stimulation group, the left-side skin temperature increased at Post 0 ($P = 0.001$), Post 5 ($P = 0.001$), Post 10 ($P = 0.001$), Post 15 ($P = 0.001$), and Post 20 ($P = 0.001$), compared to the baseline. Right-side skin temperature increased at Post 0 ($P = 0.001$), Post 5 ($P = 0.001$), Post 10 ($P = 0.001$), Post 15 ($P = 0.001$), and Post 20 ($P = 0.001$), compared to the baseline. In the one-site stimulation group, the left-side skin temperature increased at Post 10 ($P = 0.009$), Post 15 ($P = 0.001$), and Post 20 ($P = 0.002$), compared to the baseline. Right-side skin
temperature increased at Post 5 ($P = 0.015$), Post 10 ($P = 0.003$), Post 15 ($P = 0.001$), and Post 20 ($P = 0.001$), compared to the baseline. No adverse event occurred during the study.

4 Discussion

In this study, we observed an increase in skin temperature on the lower limbs following both one- and three-site stimulation with hot-stone administration. In particular, a greater increase in the distal foot region’s skin temperature occurred in the three-site stimulation group.

Previously, thermal stimulation applied to the skin has yielded an increase in local skin temperature and blood-flow volume$^{[1-3]}$. Mori et al$^{[2]}$ reported that localized moxibustion stimulation to the cervical region (at the GV14 acupuncture point, located between the C7 and T1 spinous processes) increased skin temperature on the lower back; however, no differences manifested in the temperature curves and maximum temperatures with the use of two different thermal durations of indirect moxibustion.

In another study, Mori et al$^{[3]}$ compared indirect moxibustion applied to one location with indirect moxibustion applied to three locations, with the same duration of stimulation time. Their results showed that administrating moxibustion on three sites produced greater skin-temperature changes compared to the single-site application of moxibustion$^{[3]}$.

The result was similar to that of the current study, which showed a greater temperature response with three-site thermal stimulation with hot stones.

As indicated, a notable increase in the distal foot region’s skin temperature was observed with three-site stimulation. The greater influence observed distally is intriguing; we theorize that it could have resulted from the wider area of thermal stimulation applied on the abdomen, which enhanced blood flow in the pelvic region and influenced the peripheral blood flow of the foot.

In this study, we did not evaluate the clinical effect of hot-stone therapy. Therefore, based on our findings, we cannot assess the efficacy of hot-stone therapy in treating any diseases or conditions. However, the skin-temperature increase of the lower limbs and feet observed in this study should be highlighted as promising thermal-treatment options.

Decreased foot skin temperature is clinically observed in compromised peripheral circulation, which can be seen among individuals with certain health conditions such as arteriosclerosis or diabetes. Although “cold feet” without any underlying illness are rarely regarded as a health problem in conventional medicine, it is considered a clinically meaningful symptom in traditional East Asian medicine$^{[4]}$. “Cold feet” may be associated with various health issues, including certain types of constipation, diarrhea, abdominal pain, frequent urination, and dysmenorrhea. Practitioners may therapeutically address “cold feet” in an attempt to improve or prevent associated health problems.

In this study, no adverse events were observed. We were not able to locate any report regarding adverse events, such as burns, associated with hot-stone therapy. However, burn incidents have in rare cases been associated with moxibustion (7 cases out of 65 482 administrations)$^{[12]}$. When properly and safely performed, hot-stone therapy may be useful as a therapeutic modality. It may be also used to promote health and wellness.

In conclusion, lower-limb skin temperature was altered following hot-stone stimulation applied to the abdomen; as well, a difference was observed between one-site stimulation and three-site stimulation in the distal foot region’s skin-temperature response. Further studies are needed to evaluate the modality’s clinical usefulness.

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6 Conflict of interests

The authors have no conflict of interests to declare.

REFERENCES


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