Comparison between Thermal Effects of Forearm and Lower-thigh Bathing — Effectiveness of bathing forearms as a partial bathing method —

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前腕浴と下腿浴の温熱効果の比較 —部分浴としての前腕浴の有効性—

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要 目

部分浴としての前腕浴と下腿浴、43℃、20分の深部体温、皮膚血流、循環動態等に及ぼす効果を比較検討した。

対象は、健常若年者23名（女性15名、男性8名、平均年齢20.5±1.4歳）である。

部分浴の方法は、椅子座位で充分な安静後に43℃の単純泉両前腕部の部分浴（前腕浴）を20分間行い、更に約4時間後に両下腿部の部分浴（下腿浴）を20分間行った。なお、前腕浴と下腿浴の施行はランダムにおこなった。測定項目は、皮膚血流量、表在温、舌下温、静脈血液ガス、心拍数、血圧、酸素消費量、主観的作業强度、入浴部表面積である。

結果、前腕浴と下腿浴の皮膚血流量は、前腕または大腿部では入浴前の測定値（以下control）から約2倍程度の増加であったが、皮膚温の差は指先と足趾の皮膚血流量が、controlの約4〜5倍にまで増加した。前腕浴と下腿浴の指先では、前腕浴が下腿浴よりやや優れている結果となった。表在温は足趾が前腕浴で31.5℃から35.7℃へ約4℃上昇した。舌下温は下腿浴より前腕浴が有意に約0.6℃も上昇した（p<0.01）。肘静脈血は、前腕浴が下腿浴よりp0.01では有意に上昇し、pCO2では有意に下降し、pHでは有意にアルカリ化を示した。平均血圧は、前腕浴で有意に低下した(p<0.01)が、下腿浴ではほとんど低下しなかった。心拍数の変化は、両群ともに約10拍有意に上昇し(p<0.01)、前腕浴の心拍数の上昇は、ほぼ全員で下腿浴の上昇より大きかった(p<0.01)。Mets数は、両群とも入浴20分目で約1.3Metsであったことから身体にかかる負担度は非常にわずかであった。入浴の温感については、下腿浴が前腕浴より有意に“熱い”という結果になった（p<0.05）。

以上より、前腕浴は、その面積、温感とも下腿浴よりも小さいにも拘らず、より大きな深部体温上昇とそれに基づく血管拡張と循環機能の促進がみられ、下腿浴よりも簡便で有効性の高い部分浴であると考える。

Key words :Partial bathing, 43℃, forearm, temperatures of deep body parts, hemodynamics
I INTRODUCTION

Thermal therapy makes use of physiological responses to heating, and it is classified into local and full-body heating or superficial and deep heating, depending on method(s) of application and properties of devices. Thermal therapy is further divided into wet and dry heating, depending on the presence of moisture (dampness) between the skin and a heating medium. Wet heating is known to have higher thermal efficacy, and it causes less damage to the skin compared to dry heating at the same temperature. Full-body bathing, which is practiced commonly in Japanese households and hot spring facilities, is a typical wet-heating thermal therapy, and its large heated area is associated with a great thermal effect. Additionally, a carbonated spring bath, an herbal bath, and a sand bath have been reported to have higher thermal effects.

Significant benefit of bathing and sauna therapy on cardiac failure was demonstrated by Tei, et al., and thermal therapy has been drawing much attention in recent years. The major thermal effects appear in vasodilation, but the mechanism of action of heating is yet to be revealed on the molecular basis. Recently, Ikeda, et al., reported the results of sauna therapy in mice, suggesting that thermal therapy improves endothelial function and prevents peripheral circulatory failure by increasing endothelial nitric oxide synthetase. Further, Orihara, et al., reported that thermal stimulation at 43°C significantly reduces the proliferation of smooth muscle cells and prevents restenosis following angioplasty, suggesting the physiological effects of thermal therapy.

At the same time, soothing and destressing effects of simpler heating therapy such as foot bath have been noted, and this type of partial bathing has been increasingly seen in households and hot spring facilities. However, no reports have been made for the thermal effects of dipping fingers and forearms in a hot water bath. The effects from this type of partial bathing were thought to depend on the amount of heat delivered into the body via the skin capillaries. For this reason, smoother heat transfer was expected in the fingers and forearms, since they are located higher in the body and closer to the heart compared to the legs. Accordingly, we decided to compare the thermal effects after taking a foot bath (lower-thigh bathing) and a forearm bath.

II PARTICIPANTS AND METHODS

The total of 23 healthy volunteers, 15 healthy women and 8 healthy men, mean age 20.5 ± 1.4 years (18-23 years old), participated in this study. Participants changed their clothes and wore a patient gown and a bathrobe at a room temperature (25 ± 1°C), and put on the measuring instrument that appears in the following description. They sat on a chair quietly for 15-20 min until blood pressure (BP) and heart rate (HR) stabilized, and subsequently, baseline measurements (control) and blood were taken. In the sitting position, they dipped the hands and forearms, 1/2 distal from the elbow joint (forearm bathing), and used a lift to dip the feet and lower thighs, 1/2 distal from the knee joint (lower-thigh bathing), into a hot water bath that was kept constantly at 43°C with a thermo regulator (Iwaki, CTR-320,) for 20 min each. Immediately after each 20-min bathing, they removed moisture, wore bathrobes, and sat. They were monitored for 30 min thereafter. Forearm and lower-thigh bathing were performed randomly at approximately 4-hour intervals. Participants were in-
formed of the study methods and signed informed consent forms prior to the initiation of the study.

Study items measured and analyzed were skin blood flow; skin surface and sublingual temperatures; venous blood gases; HR, BP, and oxygen consumption; rating of perceived exertion (RPE); and the bathed surface area.

Measuring devices and methods.

Skin blood flow of the following body parts were measured using a laser Doppler flow meter (Advance, Co., Ltd., ALF-2100): the mid part of the flexor surface of the upper arm, the palmer surface of the forefinger, abdomen (near the navel), the mid part of the anterior region of the thigh, and the dorsal surface of the great toe. Two to 3 measurements were taken for each body part, and the results were averaged. Skin surface temperatures of the forehead, abdomen, and the dorsal surface of the great toe were taken using a radiation thermometer (Konica Minolta Holdings, Inc., HT-7). Sublingual temperatures were continuously taken by fixing the sensor of an electronic thermistor (Terumo Corporation, CTM-303) under the tongue. Blood gas analysis was performed on venous blood using a 1306 Gas Analyzer (Instrumentation Laboratory). HR and BP were measured using an automated sphygmomanometer (Parama-Tech, Co., Ltd., GP-303S), and average BP was calculated using the formula: (minimum BP + pulse pressure/3). Oxygen consumption was measured by AT3000 (Anima) using the breath-by-breath method, and METs were calculated on the sitting position at rest. The degree of thermal comfort, such as moderate ("somewhat strong") and intense ("strong,") were expressed using Borg's12) RPE, which allows quantitation of feelings. Since the bathed surface areas for the forearms and lower thighs are important indicators of thermal effects, these areas were measured by two different methods. For the first method, a thin layer of a watercolor was applied on the area to be bathed, and the entire surface was wrapped around a thin Japanese paper. The paper was later removed and the area with the color was measured. For the second method, the areas actually heated by forearm and lower-thigh bathing were dipped into the liquid paraffin that was heated to 55

Table 1 Changes in skin surface temperature after forearm bathing and lower-thigh bathing

<table>
<thead>
<tr>
<th>Method</th>
<th>Part measured</th>
<th>Control(A)</th>
<th>Immediately after 20 min of bathing(B)</th>
<th>Difference between A and B</th>
<th>30 min after bathing(C)</th>
<th>Difference between A and C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forearm bathing</td>
<td>Forehead</td>
<td>35.6±.58</td>
<td>35.0±.98**</td>
<td>-0.6**</td>
<td>35.4±.47**</td>
<td>-0.2**</td>
</tr>
<tr>
<td></td>
<td>Abdomen</td>
<td>35.3±.8</td>
<td>34.0±.97**</td>
<td>-1.3**</td>
<td>35.2±.85</td>
<td>-0.1</td>
</tr>
<tr>
<td></td>
<td>Dorsal surface of great toe</td>
<td>31.5±2.9</td>
<td>35.7±.79**</td>
<td>+4.2**</td>
<td>34.8±1.2**</td>
<td>+3.3**</td>
</tr>
<tr>
<td>Lower-thigh bathing</td>
<td>Forehead</td>
<td>35.7±.39</td>
<td>35.1±.72**</td>
<td>-0.6**</td>
<td>35.6±.49</td>
<td>-0.1</td>
</tr>
<tr>
<td></td>
<td>Abdomen</td>
<td>35.0±1.0</td>
<td>34.8±1.0</td>
<td>-0.2</td>
<td>35.5±.96</td>
<td>+0.5</td>
</tr>
<tr>
<td></td>
<td>Dorsal surface of great toe</td>
<td>31.5±2.9</td>
<td>----</td>
<td>---</td>
<td>35.1±1.1**</td>
<td>+3.6**</td>
</tr>
</tbody>
</table>

Data are presented as mean ± S.D.
* P<0.05, ** P<0.01 compared to control
°C for approximately 2 seconds, and the mass of the paraffin hardened on the skin was measured by an electric balance, BA310S (Sartorius). These processes were repeated three times, and the mean mass was calculated. All statistical analysis was performed using a paired t-test except for Borg’s index, which was analyzed by a non-parametric test.

III RESULTS

1. Changes in skin blood flow

Fig. 1 shows changes in skin blood flow in various body parts immediately after forearm and lower-thigh bathing. After forearm bathing and lower-thigh bathing, the flow in the forearms and thighs increased up to 10mL/min/100g or approximately 1.2-1.8 times of control; however, the flow in the toes and fingertips increased more than 20mL/min/100g or approximately 4-5 times of control. In other words, results suggested that skin blood flow in the unbathed toes and unbathed fingers significantly increased after forearm bathing and lower-thigh bathing, respectively. When forearm and lower-thigh bathing were compared, the blood flow increase after forearm bathing was slightly superior in all body parts assessed.

2. Changes in skin surface temperatures

We assessed which body part would benefit from great thermal effects after partial bathing (Table 1). Skin surface temperatures of the central body parts (forehead and abdomen) significantly decreased at 1% significance level, and those of the dorsal surface of the great toes significantly increased at 1% significance level. Although the toes are located the furthest from the
forearms that had been heated, temperature changes observed were the greatest, approximately \(4 \degree C\) (from \(31.5 \degree C\) to \(35.7 \degree C\)). At 30 min after the bathing, the temperature of the toes was \(34.8 \degree C\), which was approximately \(3 \degree C\) higher than control. Sufficient insulation effect was maintained for 30 min after the bathing.

3. Changes in sublingual temperatures

To assess the effects of partial bathing on deeper body temperature, we observed changes in sublingual temperatures at a 10 min interval, up to 30 min after forearm and lower-thigh bathing (Fig. 2). The sublingual temperature (36.6 \degree C, baseline) significantly increased to 37.0 \degree C after 10 min of forearm bathing (\(+0.45 \degree C, p < 0.01\)) and after 20 min, to 37.2 \degree C (approx. \(+0.6 \degree C, p < 0.01\)). Sublingual temperatures kept increasing with continuous bathing. Additionally, sublingual temperatures taken after 10 min and 20 min of forearm bathing were significantly higher than those of lower-thigh bathing (\(p < 0.01\)). Further, high sublingual temperatures were maintained after bathing in both bathing groups, and even 30 min after bathing, they were still significantly higher than those of control (\(p < 0.01\)).

4. Changes in blood gases

Venous blood gases were analyzed before and after 20 min of forearm and lower-thigh bathing. Fig. 3 shows results obtained for both bathing groups. After forearm bathing, \(pO_2\) and \(pCO_2\) significantly increased and decreased, respectively, and blood \(pH\) showed significant alkalinization compared to lower-thigh bathing. Further, \(pO_2\) in venous blood significantly increased from \(34.7 \pm 11.7\) mmHg (control) to \(75.1 \pm 5.7\) mmHg after 20 min of forearm bathing (\(p < 0.01\)), and visual observation indicated that the venous blood was in brighter red. \(pCO_2\) was \(50.0 \pm 5.1\) mmHg initially, and it significantly decreased to \(41.2 \pm 2.5\) mmHg (\(p < 0.01\)). \(pH\) significantly alkalinized to \(7.41 \pm 0.02\).

![Fig. 3 Changes in partial pressure of gases mixed in venous blood and pH after forearm bathing (●—●) and lower-thigh bathing (■—■). Data are presented as mean ± S.D. **p<0.01 compared to control ††p<0.01 forearm bathing forearm compared lower-thigh dipping](image-url)
5. Changes in BP, HR, and METs

Mean BP, HR, and METs obtained immediately after 20 min of forearm and lower-thigh bathing are shown in Fig. 4. While mean BP after forearm bathing significantly decreased by 7.5 mmHg, from 83.0 ± 7.2 mmHg to 75.5 ± 8.1 mmHg (p < 0.01), mean BP after lower-thigh bathing decreased only slightly, from 82.1 ± 6.2 mmHg to 81.7 ± 7.1 mmHg. HR increased by approximately 10 bpm in both groups (p < 0.01), but the increase in almost all participants in the forearm bathing group was higher (p < 0.01). METs in both groups were around 1.3 after 20 min of bathing, i.e., less than 2, indicating that the burden of bathing on physical body was minimal in both groups.

6. Thermal comfort and the bathed surface area

Subjective level of thermal comfort that was evaluated at the beginning and after 20 min of for-
Thermal effects of forearm bathing

Table 2  Surface areas measured

<table>
<thead>
<tr>
<th></th>
<th>Forearm bathing (A)</th>
<th>Lower-thigh bathing (B)</th>
<th>B/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area coated with a Paper</td>
<td>511±86</td>
<td>851±181</td>
<td>1.6</td>
</tr>
<tr>
<td>Weight of paraffin (g)</td>
<td>23.9±4.9</td>
<td>35.9±8.1</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Data are presented as mean ± S.D.

arm and lower-thigh bathing are expressed in Borg’s index (RPE) (Fig.5). Thermal comfort in the forearm-bathing group was RPE 3-5 immediately after dipping their forearms, but that in the lower-thigh bathing group was RPE 5 or higher. Thermal comfort observed at the beginning of bathing the lower thighs was significantly more “hot” (p < 0.05). After 20 min of bathing, however, thermal comfort decreased down to RPE 4 in both groups.

Bathed surface area was measured, since the thermal effects exerted by forearm and lower-thigh bathing were thought to depend largely on this factor. As shown in Table 2, the method that used a Japanese paper indicated that the bathed surface area in the lower-thigh bathing group was approximately 1.6 times larger than that of the forearm-bathing group (851 ± 181 cm² vs. 511 ± 86 cm²). The method that used the mass of paraffin as an indicator showed approximately 1.5 times heavier bathed surface area in the lower-thigh bathing group compared to the forearm-bathing group (35.9 ± 8.1 g vs. 23.9 ± 4.9 g). In short, both methods indicated that the thermal stimulation was applied to 1.5-1.6 times larger surface areas in the lower-thigh bathing group compared to the forearm-bathing group.

IV DISCUSSION

Thermal effects of taking 20 min of 43°C forearm and lower-thigh baths were assessed in 23 healthy youths. For skin blood flow, not only the bathed fingertips but also unbathed toes showed a 4-5-time increase after forearm bathing. Similarly, bathed toes as well as unbathed fingertips had 4-5 times higher blood flow after lower-thigh bathing. These findings coincides with Lewis and Pickering13), who demonstrated that vasodilation following hand heating occurs due to decreased tension in the vasoconstrictor nerves, and that the greatest effects of the vasodilator nerves are found in the fingers followed by the toes. After forearm bathing, skin surface temperatures of the unbathed toes increased by 4°C due to increased skin blood flow. This phenomenon suggests that forearm bathing would be effective treatment for diseases that accompany symptoms such as poor peripheral circulation. Expected outcomes of the increased blood flow in the peripheral body parts include delivery of O₂ and nutrients and removal of waste products (CO₂, lactic acid, etc.) and inflammatory/algogenic substances (kinin, thromboxane, leukotriene, PAF, etc.)14-18).

With respect to sublingual temperatures, which indicate temperatures of deep parts of physical body, Tanaka et al.19) reported 0.7-1.0°C increase after taking a full-body bath at 41-42°C for 10 min. Sublingual temperatures taken in our study increased to a similar extent, 0.6 °C, after bathing the
forearms at 43°C for 20 min. It was, therefore, demonstrated that simple partial bathing, in the form of forearm bathing, has the thermal effect similar to full-body bathing.

This increase in temperatures of deep body was an extremely important finding, since it indicated a BP decrease and an HR increase associated with systemic vasodilation, i.e., lower burden to the heart, as well as higher cardiac output. Increased cardiac output leads to systemic delivery of O₂ and nutrient and excretion of CO₂, lactic acid, inflammation, and pain producing chemicals, which are the most beneficial effects of bathing (Tei, Tanaka, et al.). The O₂ increase, CO₂ decrease, and pH alkalinization that were noted in this study have been first reported by Tanaka, et al. in their full-body bathing study, which suggested improved metabolism in the tissue.

The increase in temperatures of deep body was significantly higher after forearm bathing compared to lower-thigh bathing, and this may have been associated with the degree of hemodynamic changes. However, the bathed surface area was smaller in the forearm group although thermal effects greatly depend on this factor. This seemingly contradicting result possibly stems from poor venous flow in the lower thighs with respect to heat delivery, when compared to arms.

BP decreased as a result of systemic vasodilation in relation to the temperature changes in deep body. Mean BP decreased by 7.5 mmHg after forearm bathing. As with findings from sublingual temperatures, the hypotensive effect of forearm bathing was similar to that of a 41°C full-body bath, considering that the reported BP decrease was 5-10 mmHg, which was measured after taking a full-body bath in a 41-42°C natural thermal spring for 10 min. In a past study, the hypotensive effect obtained after taking a bath in the evening was effective enough to withdraw antihypertensive drugs in mild to moderate hypertensive patients (Tei, et al.) Additionally, Nakatani, et al. reported good night sleep after taking a bath. These findings suggest hypotensive effects and good night sleep associated with a forearm bathing at bedtime. Tei, et al. reported that after patients with cardiac failure were assisted by an automated elevator to take a 41°C full-body bath in the recumbent position, METs increased to approximately 1.3, taking oxygen consumption into consideration. METs obtained in this study was also 1.3, showing that forearm bathing causes only slight burden on the physical body, and that it is unlikely to interfere with cardiopulmonary or other diseases. Unfavorable effects of hydrostatic pressure must be taken into consideration in full-body bathing, but forearm bathing is extremely safe because of no hydrostatic pressure. Partial bathing produces thermal effects with little burden on the physical body, and consequently, sick people whose physical conditions are not well enough to take a full-body bath can also benefit from the partial-bath therapeutic effects.

In this study, the temperature of partial bathing was set at 43°C, which was 2°C higher than for general full-body bathing, because the anticipated bathing areas were smaller. When thermal comfort in the forearm and lower-thigh bathing groups were compared, the forearms felt more comfortable and significantly easier to initiate the bathing. Iriki described that the area stimulated by thermal sensation controls the threshold of thermal comfort in bathing. Since the bathed surface area in the lower-thigh bathing group was approximately 1.5 times larger than that in the forearm-bathing group, lower thighs could have felt more heat. For the relationship between the bathed surface ar-
Thermal effects of forearm bathing

Thermal effects of forearm bathing, despite smaller surface area in the forearm bathing, skin blood flow in the forearm bathing group was superior in all items, and sublingual temperatures taken in the forearm-bathing group were significantly higher. Nakayama\(^{22}\) reported that the highest amount of blood is supplied to the fingertips per unit volume, followed by the earlobes, hands, forehead, knees, and legs. The lower thermal effect observed in lower-thigh bathing was probably due to the least amount of blood supplied into the legs per unit area. In addition, the sitting position can deteriorate venous return, and the proximate location of the arms to the heart may be related to the increased heat delivery in the forearm bathing.

V Conclusion

- Twenty-three healthy youths dipped forearms into hot water at 43°C for 20 min, and after a sufficient interval, lower thighs were dipped under the same conditions.
- Skin blood flow and skin surface temperatures markedly increased in not only bathed areas but also unbathed areas in both forearm and lower-thigh bathing groups, but a larger increase was observed in the forearm bathing group. Sublingual temperatures in forearm and lower-thigh bathing groups increased by approximately 0.6°C and 0.4°C, respectively.
- Blood gas analysis of venous blood indicated that after forearm bathing, pO\(_2\) significantly increased and pCO\(_2\) significantly decreased. pH significantly alkalinized in the forearm bathing group.
- Mean BP significantly decreased in the forearm bathing group only. HR increased in both groups, but the increase in the forearm group was significantly higher. The METs increase was negligible in both groups, but thermal comfort expressed in Borg’s index was stronger in the lower-thigh bathing group.

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References


Summary

Effectiveness of taking a partial bath at 43 °C for 20 min was assessed with respect to forearms and lower thighs by comparing temperatures in deep body, skin blood flow, hemodynamics, and other parameters. Twenty-three healthy youths participated in this study (female: 15, male: 8, mean age: 20.5±1.4). Participants sat on a chair and took enough rest, and dipped both forearms into a 43 °C natural thermal spring for 20 min (forearm bathing). After approximately 4 hours, both lower thighs were dipped for 20 min (lower-thigh bathing). Forearm and lower-thigh bathing was taken randomly. Study items consisted of skin blood flow; skin surface and sublingual temperatures; venous blood gases; heart rate (HR), blood pressure (BP), and oxygen consumption; rating of perceived exertion (RPE); and bathed surface areas.

Following forearm and lower-thigh bathing, skin blood flow in the upper arms and thighs increased approximately twice compared to baseline levels (control). Skin blood flow in the bathed fingers and toes significantly increased by approximately 4-5 times. Furthermore, a similar significant increase was observed in the unbathed toes after forearm bathing and in the unbathed fingers after lower-thigh bathing. All measurements for forearm bathing showed slightly superior effects to those for lower-thigh bathing. For skin surface temperatures, temperatures in the toes increased approximately 4 °C, from 31.5 °C to 35.7 °C, after forearm bathing. Sublingual temperatures significantly increased by 0.6 °C after forearm bathing compared to lower-thigh bathing (p < 0.01). With regard to venous blood gases, after forearm bathing, the pO2 increase was significantly higher and the pCO2 decrease was significantly lower, and blood pH showed more alkalinization compared to lower-thigh bathing.

Average BP after forearm bathing significantly decreased (p < 0.01), but it hardly did after lower-thigh bathing. HR significantly increased by approximately 10 bpm in both groups (p < 0.01), but the HR increase of almost all participants in the forearm bathing group was higher (p < 0.01). METs in both bathing groups were approximately 1.3 after 20 min of bathing, which indicated that the burden of bathing on physical body was minimal. In terms of thermal comfort, participants felt lower-thigh bathing significantly more “hot” than forearm bathing (p < 0.05).

In summary, forearm bathing accompanied a larger temperature increase in deep body that was associated with vasodilation and facilitated hemodynamic functions, and it was indicated that forearm bathing is a simpler form of partial bathing with higher effectiveness compared to lower-thigh bathing.