



Original Article

Effects of half-body and foot baths on peripheral circulation in healthy adult males: a pilot study

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Abstract. [Purpose] This study aimed to clarify the optimal conditions of warm-water bathing required to improve peripheral circulation. [Participants and Methods] Ten healthy males experienced three warm-water bathing depths (half-body, low-leg, and foot) on different days. Peripheral circulation (earlobe blood flow), tympanic temperature, pulse rate, and blood pressure were measured during each session and compared among the bathing conditions. [Results] In half-body bathing, the relative blood flow of participants increased steeply to a level 2.7-fold higher than the baseline during bathing and rapidly decreased after that. Conversely, the relative blood flow gradually and continuously increased to a level 1.7-fold higher than that at the baseline during low-leg bathing and maintained a similar level after that. The blood flow did not markedly change throughout the experiment in foot bathing. The pulse rate during foot bathing and that during low-leg bathing did not change throughout the observation period, but that of half-body bathing increased considerably. [Conclusion] Rapid changes in pulse rate or blood pressure associated with bathing are considered risky. We suggest that low-leg bathing, rather than the usually adopted half-body bathing, is appropriate for improving peripheral circulation in terms of effectiveness and safety. **Key words:** Half-body bath, Foot bath, Peripheral circulation

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INTRODUCTION

Shoulder-deep full-body bathing is an essential lifestyle habit for Japanese people. Aside from cleansing the body, it promotes circulation, retains heat, and provides comfort due to its thermal effects. However, there are cases wherein full-body bathing becomes difficult due to illness, treatment, or a decline in the ability to perform daily activities associated with ageing. In patients with heart failure or coronary artery disease, sudden changes in blood pressure and heart rate during full-body baths may not only cause significant damage to cardiac function but also death in some cases^{1, 2)}. When bathing, vasodilation occurs due to the thermal effects of water, and blood moves to the periphery. In addition, the change in posture from a sitting position when bathing to a standing position after bathing may suddenly decrease hydrostatic pressure. The changes in peripheral circulation and hydrostatic pressure may reduce cardiac output and vascular resistance, resulting in a sudden decrease in blood pressure³⁾.

Waon therapy, wherein one enters a sauna at 60°C for 15 min, reportedly has similar thermal effects as those of half-body baths at 41°C for 10 min^{4, 5)}. One advantage of Waon therapy, which has already been proven in patients with advanced heart failure⁴⁾, is that the blood pressure does not change during treatment⁶⁾. Furthermore, long-term Waon therapy reduces mortality and readmission rates⁷⁾. However, Waon therapy requires a sauna; therefore, it cannot be performed anywhere. Hence, an appropriate treatment performed in any hospital without a sauna or in ordinary households is desired.

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Half-body baths result in less hydrostatic pressure changes than full-body baths, and partial bathing requires little consideration. Half-body baths involve bathing in xiphoid process-deep water. Conversely, partial bathing involves submerging only a part of the body, such as the hands or feet. Foot baths are widely performed to maintain the cleanliness of the feet. In recent years, several reports have focused on the effects of body baths on the cardiovascular system. Hu et al.⁸⁾ reported that the cardio-ankle vascular index, which is an index of arterial stiffness, immediately improved in healthy participants after a 30-min knee-level leg bath at 43°C. Yoon et al.⁹⁾ reported that a 30-min lower thigh bath at 40°C improved the coronary flow reserve in patients with coronary artery disease. Foot bathing is a generally safe activity in patients with acute coronary syndrome in the coronary care unit¹⁰⁾. However, conditions during baths (water temperature, duration, and depth) vary depending on the literature, and there are few reports that measured the differences in circulating blood volume between different water levels. Notably, increased peripheral circulation reduces cardiac load.

In this study, we aimed to measure the changes in peripheral circulation at three different water levels during baths (half-body, low-leg, and foot) and clarify the safe and convenient conditions for improving peripheral circulation.

PARTICIPANTS AND METHODS

Adult male volunteers were included in the study. A total of 10 out of 15 volunteers (age: 25.9 ± 3.1 years; height: 161.3 ± 31.2 cm; weight: 61.6 ± 7.4 kg) were able to complete the 3-day course of warm baths. The four volunteers who did not participate had a history of smoking, while one volunteer had difficulty adjusting to the 3-day schedule. None of the participants underwent regular thermal therapy, such as full- or half-body baths, foot bathing, or sauna. High-intensity exercise, caffeine, and alcohol consumption were prohibited 24 h prior to foot baths. The exclusion criteria were as follows: absolute and relative contraindications to hydrotherapy and hyperthermia, skin disorders on the lower limbs and trunk, habitual full- or half-body bathing, having a foot bath or sauna, respiratory or circulatory diseases, blood pressure $>140/80$ mmHg, smoking, regularly exercising, and difficulty coordinating a 3-day experimental schedule. In addition, the criteria for discontinuation and deviation were as follows: fever $\geq 37^\circ\text{C}$, complaints of poor physical condition, hypertension, hypotension, and a resting heart rate $\leq 50/\text{min}$ or $\geq 120/\text{min}$. This study was approved by the Ethics Committee of the Akita University (No. 2312) and was conducted in compliance with the Declaration of Helsinki and its amendments. Written consent was obtained from all participants.

Warm baths were prepared in an airconditioned environment at a temperature of 24°C – 26°C and humidity of 40%–60%. Baths started at 17:30 or 18:00. The participants bathed at three water depths (half-body bathing, low-leg bathing, and foot-bathing) on different days. The participants were in a sitting position for 5 min before and after bathing. For baths in xiphoid process-deep water, bathing was performed in a household bathtub at 41°C for 15 min while the participants were undressed⁹⁾. Participants entered and exited the bathtub straddling it within 10 seconds. Low-leg or foot-bathing was performed in a foot bath machine (Footbath KS-N1010: Nihon Deniken Co., Ltd. Tokyo, Japan) at 42°C for 20 min. The lower limbs were exposed by rolling up the pants to above the knees.

The measurement parameters were pulse rate, blood pressure, tympanic temperature, and peripheral circulation. Pulse rate and blood pressure were measured every minute before, during, and after warm baths using an electronic blood pressure monitor (Elemanno 2: Terumo, Tokyo, Japan). Tympanic temperature was measured every minute using an ear-type infrared thermometer (Mimitibion: Pigeon, Tokyo, Japan). Earlobe blood flow (EBF), which was used as an index of peripheral circulation, was measured in the earlobe using a wireless laser Doppler blood flow meter (Pocket LDF: JMS, Tokyo, Japan). The measured values were divided by the resting value to obtain the relative EBF. The mean value during a 3-min period before bathing was calculated and used as the baseline data. One-way analysis of variance (ANOVA) was used to compare changes in circulatory dynamics and blood flow ratios over time with the baseline, and a post-hoc test using the Bonferroni method was performed. In addition, ANOVA was used to compare blood pressure, pulse rate, tympanic temperature before bathing, and relative EBF 5 min after bathing between the different water levels. Tukey's method was used as a post-hoc test. SPSS version 22.0 (IBM Japan Inc, Tokyo, Japan) was used for all analyses, and $p < 0.05$ was considered significant.

RESULTS

Results are presented as mean \pm standard deviation. The baseline data for each parameter showed no significant differences (Table 1).

Table 2 shows the changes in haemodynamic parameters over time during and after bathing. The change in pulse rate at 1 min after bathing was significantly higher in participants who bathed in half-body bathing than those who bathed in foot-bathing ($p < 0.001$) and low-leg bathing ($p = 0.028$). The pulse rate of participants who bathed in half-body bathing (13.1 ± 15.3 bpm) significantly increased compared with that of participants who bathed in foot-bathing (-2.0 ± 3.8 bpm, $p = 0.007$) and low-leg bathing (-2.8 ± 7.7 bpm, $p = 0.004$). At 5 min after bathing, the pulse rate of participants who bathed in half-body bathing was higher than that of participants who bathed in foot-bathing, whereas it was not significantly different from that of participants who bathed in low-leg bathing (Table 2). This suggests that the pulse rate after a half-body bathing rapidly and significantly increases. There were no significant differences between the three bathing conditions in terms of systolic blood pressure, diastolic blood pressure, and tympanic temperature (Table 2).

Table 1. Baseline data of haemodynamic parameters

	Half-body	Low-leg	Foot
Pulse rate (bpm)	77.5 ± 11.1	71.9 ± 12.7	67.0 ± 11.0
Systolic blood pressure (mmHg)	114.9 ± 7.9	114.5 ± 7.2	110.4 ± 9.4
Diastolic blood pressure (mmHg)	77.1 ± 5.5	76.7 ± 5.1	70.9 ± 9.5
Tympanic temperature (°C)	36.3 ± 0.2	36.4 ± 0.4	36.6 ± 0.2

Table 2. Changes in haemodynamic parameters over time during and after bathing

	During bathing				After bathing	
	5 min	10 min	15 min	20 min	1 min	5 min
Pulse rate (bpm)						
Half-body bathing	70.2 ± 13.7	74.8 ± 14.6	80.8 ± 15.2	-	93.9 ± 17.5*	85.4 ± 12.7†
Foot bathing	66.5 ± 8.6	67.2 ± 10.6	69.0 ± 10.8	70.9 ± 11.2	68.9 ± 9.7	69.0 ± 12.3
Low-leg bathing	70.7 ± 10.5	75.5 ± 13.6	78.0 ± 12.7	80.5 ± 12.7	77.7 ± 10.0	72.4 ± 10.0
Systolic blood pressure (mmHg)						
Half-body bathing	109.2 ± 9.0	109.3 ± 10.8	111.1 ± 12.7	-	119.3 ± 15.1	116.7 ± 8.0
Foot bathing	109.7 ± 8.1	114.9 ± 8.0	110.4 ± 8.9	111.8 ± 8.3	110.2 ± 9.0	108.1 ± 10.4
Low-leg bathing	114.8 ± 6.2	113.0 ± 8.0	116.2 ± 8.6	112.5 ± 6.4	119.2 ± 9.5	116.0 ± 6.0
Diastolic blood pressure (mmHg)						
Half-body bathing	70.1 ± 8.7	69.5 ± 13.5	69.3 ± 13.2	-	84.0 ± 10.8	78.8 ± 5.8
Foot bathing	67.7 ± 8.6	72.1 ± 7.1	67.4 ± 9.4	71.6 ± 7.1	67.5 ± 9.9	71.1 ± 11.4
Low-leg bathing	74.4 ± 3.7	73.5 ± 9.6	73.9 ± 7.8	74.8 ± 7.2	71.6 ± 8.8	71.4 ± 10.7
Tympanic temperature (°C)						
Half-body bathing	36.2 ± 0.6	36.5 ± 0.6	36.6 ± 0.7	-	36.8 ± 0.7	36.6 ± 0.6
Foot bathing	36.5 ± 0.3	36.5 ± 0.2	36.5 ± 0.1	36.5 ± 0.2	36.5 ± 0.3	36.6 ± 0.2
Low-leg bathing	36.2 ± 0.4	36.1 ± 0.4	36.4 ± 0.4	36.4 ± 0.4	36.5 ± 0.4	36.6 ± 0.3

Data are presented as mean ± standard deviation.

*: p<0.05 Significant difference to the foot and the low-leg bathing.

†: p<0.05 Significant difference to the foot bathing.

The changes in relative EBF over time are shown in Fig. 1. The relative EBF of patients who bathed in half-body bathing was significantly higher than that at baseline (0 min). Data regarding EBF every 5 min are as follows: 5 min (1.9 ± 0.5, p=0.006); 10 min (2.5 ± 0.6, p<0.001); and 15 min (2.2 ± 0.9, p<0.001). In contrast, the relative EBF of patients who bathed in foot-bathing did not increase during bathing; however, that of patients who bathed in low-leg bathing gradually increased from that at baseline, albeit without significance. Data every 5 min are as follows: 5 min (1.3 ± 2.0, p=0.038); 10 min (1.5 ± 0.3, p=0.001); 15 min (1.6 ± 0.2, p<0.001); and 20 min (1.6 ± 0.3, p<0.001). Notably after bathing, the relative EBF of patients who bathed in low-leg bathing continued to remain high at 1 min (1.5 ± 0.2, p<0.001) and 5 min (1.7 ± 0.2, p<0.001). At 5 min after bathing, the relative EBF of patients who bathed in low-leg bathing (1.6 ± 0.1) was significantly higher than that of patients who bathed in half-body bathing (1.3 ± 0.4, p=0.046) and foot-bathing (1.2 ± 0.4, p=0.011). These data show that low-leg bathing improved peripheral circulation even after bathing.

DISCUSSION

In this study, we examined an effective foot-bathing method to improve peripheral circulation. A warm bath at 41°C for 10 min at the level of the xiphoid process had a thermal effect equivalent to that of the Waon therapy⁵⁾. We confirmed an increase in EBF in the swollen protuberance and middle of the lower leg. The effect was sustained even when bathing only in the middle of the lower leg, and the increase was greater than that of the full-body bathing in the swollen process. Skin blood flow increases approximately two-fold after high-intensity exercise¹¹⁾. In the present study, EBF increased 1.7-fold in low-leg bathing (the middle of the lower leg water), suggesting that it had a similar effect on improving peripheral circulation as high-intensity exercise.

Waon therapy has similar effects as those of full-body baths without being affected by changes in hydrostatic pressure. In fact, Waon therapy has already been used for patients with heart failure. Tei et al.¹²⁾ reported that Waon therapy improved haemodynamics, cardiac function, clinical symptoms, and vascular endothelial function in patients with heart failure. The

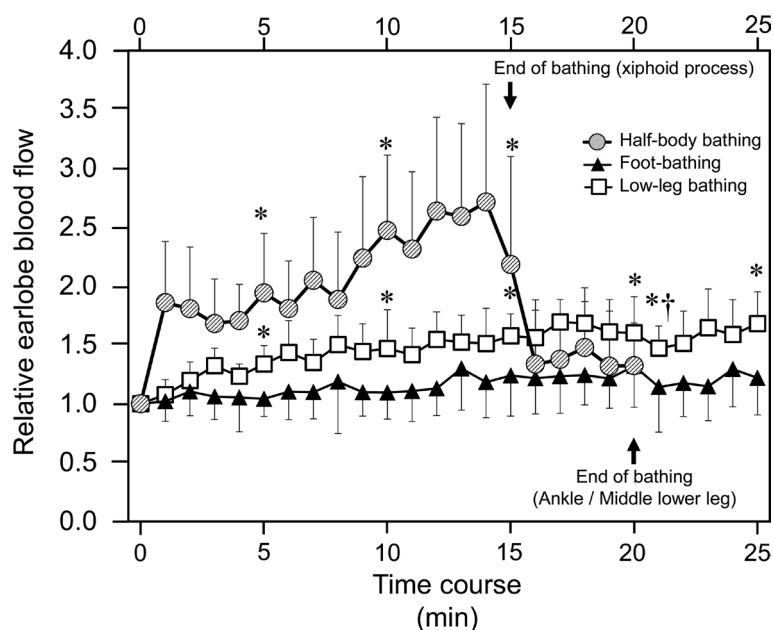


Fig. 1. Changes in peripheral circulation during and after bathing. Bathing time was 15 and 20 min in half-body bathing and foot-bathing or low-leg bathing, respectively. The relative earlobe blood flow (EBF) increased the most in half-body bathing (2.2 times that of the baseline), which rapidly dropped to levels comparable to that in foot-bathing. The relative EBF in low-leg bathing gradually increased and was maintained even after bathing (1.7 times that of the baseline).

*: $p < 0.05$ Significant difference to the baseline.

†: $p < 0.05$ Significant difference to half-body and foot-bathing.

immediate effect is a decrease in preload and afterload due to peripheral vasodilatation and an increase in cardiac output. These changes improved the clinical symptoms associated with peripheral circulatory disturbances in patients with heart failure¹³). In addition, undergoing regular Waon therapy increases peripheral vascular blood flow and endothelial nitric oxide synthase expression in the vascular endothelium by increasing shear stress¹⁴). As a result, vascular endothelial dilatation is improved, leading to a decrease in afterload, which in turn improves cardiac function¹⁴). Heat dissipation by partial bathing is achieved by increasing the blood flow outside the soaking area. An increase in blood flow to the earlobe, which is far from the soaking area, in a foot bath corresponds to an improvement in blood flow throughout the body; hence, a decrease in preload and afterload due to peripheral vasodilation can be expected¹²). This is a similar mechanism of action to that of full-body baths, such as those used in thermal therapy. Similar to the Waon therapy, it can be an alternative to full-body baths.

Half-body baths, defined as bathing in half-body bathing, are common practice in Japan because they can be easily performed at home. The half-body bath conditions used in this study are expected to have the same effect as Waon therapy^{4,5}). In our study, the relative EBF increased in two stages during half bathing. However, after bathing, the relative EBF suddenly decreased to near-baseline levels while the pulse rate rapidly increased. The rapid increase in EBF in the first half of the half-bath and the decrease after leaving the bath may reflect the hydrostatic pressure effect, while the thermal effect is reflected in the EBF after leaving the bath.

The change in EBF by foot bathing was gradual, while no changes in heart rate and blood pressure were observed. In a previous study, below-knee bathing at 41°C for 15 min¹⁵), lower leg bathing at 42°C for 15 min¹⁶), below-knee bathing at 43°C for 30 min⁸), and even foot bathing at 45°C for 15 min¹³) all revealed similar results with no considerable changes in blood pressure and heart rate compared to baseline. In contrast, a marked decrease in EBF and an increase in heart rate were observed in the half-bath immediately after exiting the bath. This change may be due to the hydrostatic pressure. Foot bathing is not affected by hydrostatic pressure; thus, it is a safe method with less fluctuation in circulatory dynamics.

The thermal effects of low-leg bathing promote sleep¹⁷) and relaxation¹⁵), relieve stress¹⁸), and reduce pain¹³). Low-leg bathing does not affect the hydrostatic pressure; thus, it is a safe method as it results in reduced fluctuations in circulatory dynamics. The low-leg bathing does not require any special equipment; thus, it can be performed at home or at the bedside. In addition, wearing or removing clothes is not required. Bathing with a water level 10 cm below the knee produces temperature-dependent changes in circulatory dynamics and the autonomic nervous system similar to those of full-body bathing¹⁹). Conversely, the relative EBF of patients who bathed in ankle-deep water did not change. Furthermore, focusing on peripheral circulation, it is optimal to take a foot bath at 42°C at the height of the middle of the lower leg for 20 min.

This study has limitations, including its preliminary design and small sample population. Its usefulness in patients with heart disease should be confirmed in future studies.

We observed an increase in blood flow in the earlobe, which was far from the heated area, even in a partial foot bath. We conclude that a 20-min foot bath at 42°C at the water level in the middle of the lower leg is the optimal setting for improving peripheral circulation in terms of effectiveness and safety.

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Conflict of interest

The authors have no conflicts of interest to disclose in relation to this work.

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