The varying effects of warm-water bathing therapies: partial bathing decreases exercise tolerance to levels similar to full-body bathing

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Abstract. [Purpose] The purpose of this study was to determine differences in postural sway and tolerance to exercise before and after full-body, forearm, and lower leg bathing in warm-water. [Subjects and Methods] Thirteen healthy, young adult males were subjected to full-body, forearm, and lower leg bathing at 41 °C for 10 minutes. [Results] The 2-point discrimination sense value and total trajectory length significantly decreased after bathing. [Conclusion] In summary, we found that warm-water bathing sharpens plantar sensation, and thus may help to prevent falls in the elderly. Even partial forearm and lower leg bathing increased exercise tolerance to levels similar to full-body bathing.

Key words: Warm-water bathing, Static balance, Exercise test

(This article was submitted Jun. 24, 2015, and was accepted Aug. 3, 2015)

INTRODUCTION

Murata¹⁾ demonstrated that stronger toe foot-gripping and sharper plantar sense decreased postural sway. Sakita et al.²⁾ showed that cooling the lower leg decreased plantar sense, increasing postural sway. However, to the best of our knowledge, no previous studies have investigated the effect of warm-water bathing, including full-body, forearm, and lower leg bathing, on postural sway. Furthermore, there are no studies on the effect of warm-water bathing on exercise tolerance. Here, we evaluated the effects of full-body, forearm, and lower leg bathing on vital reaction, 2-point discrimination sense, postural sway, and exercise tolerance.

SUBJECTS AND METHODS

We recruited thirteen healthy, young, male participants (13 males; mean age $\pm$ standard deviation (SD), 20.3 $\pm$ 1.3 years). Measurements were collected at room temperature (approximately 22 °C) and in bath water heated to 41 °C. Three bathing methods were used: full-body bathing, forearm bathing, and lower leg bathing. The bathing duration was 10 minutes. Each bathing method was implemented randomly on different dates. The vital reaction was measured during bathing by collecting the sublingual temperature (CM-210 Terumo Co., Ltd., Tokyo, Japan), heart rate (BSM-

2401 Nihon Kodan Co., Ltd., Tokyo, Japan), blood pressure, and respiratory rate. Each measurement was collected during rest before bathing (pre-bath) and at 10 minutes after the bath was completed (post-bath). In order to assess the heat insulation state, the sublingual temperature was also measured 30 minutes post-bath. The 2-point discrimination sense value and the postural sway were measured before bathing and at 30 minutes post-bath. The 2-point discrimination sense was measured at the thenar eminence on the side of the pivot leg and the hallux. To determine the postural sway, the participants were asked to stand on one leg (the pivot leg) for one minute. Sampling frequency was 30 Hz, above the force platform (PDM, zebris Medical GmbH, Isny, Germany). This test was performed three times, and the postural sway was calculated by averaging the total trajectory length of the three trials. The exercise test was performed before bathing and at 30 minutes post-bath using a bicycle ergometer. The metabolic equivalents (Mets) score was calculated based on the oxygen consumption measured using an oxygen consumption meter (AT-1100 Anima Co., Ltd., Tokyo, Japan).

This study was approved by the Clinical Review Board of the Faculty of Medicine at Kagoshima University (No. 284). All the participants signed a consent form after being informed of the study purpose and content, and all risks involved.

All statistical calculations were performed using SPSS 23 software. The Shapiro-Wilk test was used to evaluate the normal distribution of the data. The measurement time points and the bathing methods were analyzed using a 2-way repeated-measures ANOVA. Regarding our factors, we used Mauchly's test of sphericity to assess the degree of significance between the two levels. When interactions between three factor levels produced a p-value < 0.05 and

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Table 1. Two-way repeated measures ANOVA and multiple comparisons for each bathing method and their experimental variables

Experimental variables		Full-body bathing	Forearm bathing	Lower leg bathing
Sublingual temperature (°C)	Before bathing	36.6±0.3	36.6±0.3	36.7±0.1
	10 min after bathing	37.5±0.2 [#]	37.0±0.3 [#]	36.8±0.2 ^{#‡}
	30min after bathing	36.8±0.2	36.7±0.3	36.7±0.2
Heart rate (bpm)	Before bathing	77.2±7.2	75.4±8.2	73.9±9.1
	10 min after bathing	96.3±8.4 [#]	82.9±8.6 ^{#‡}	79.3±9.3 ^{#‡}
Systolic blood pressure (mmHg)	Before bathing	126.6±10.8	123.2±9.5	125.4±15.4
	10 min after bathing	114.5±8.8	125.0±16.1	123.3±14.3
Diastolic blood pressure (mmHg)	Before bathing	77.4±6.2	74.9±6.3	77.8±8.9
	10 min after bathing	55.7±5.4 [#]	73.6±8.6 ^{#‡}	78.7±10.8 ^{#‡}
Respiratory rate (Trial/min)	Before bathing	17.5±4.8	17.2±4.5	18.2±2.6
	10 min after bathing	17.54±5.6	18.9±3.0	19.9±4.0
2-point discrimination sense value for thenar eminence (mm)	Before bathing	8.0±2.4	8.6±2.8	7.9±2.0
	30 min after bathing	6.2±2.1 [#]	7.7±2.6 [#]	6.5±1.6 [#]
2-point discrimination sense value for hallex (mm)	Before bathing	7.9±2.4	8.2±2.3	8.1±2.2
	30 min after bathing	6.8±2.0 [#]	6.7±2.5 [#]	6.9±1.8 [#]
Total trajectory length (mm)	Before bathing	1131±218	1151±271	1183±202
	30 minutes after bathing	998±183 [#]	1011±224 [#]	982±149 [#]
MetS score for 25 W	Before bathing	2.4±2.1	2.3±0.4	2.3±0.3
	30 minutes after bathing	2.1±0.3 [#]	2.1±0.3 [#]	2.0±0.3 [#]

[#]Compared to pre-bath values (p<0.05)[‡]Compared to full-body bathing values (p<0.05)

a statistically significant result from the Mauchly's test of sphericity, we performed a Bonferroni's multiple comparison test. Bonferroni post hoc test correction was applied during the multiple comparison tests.

RESULTS

At the 10 minutes post-bath time point, the sublingual temperature was significantly increased compared with the pre-bath temperature under all bathing conditions. Compared to lower leg bathing, the full-body bathing significantly increased sublingual temperature by 0.9 °C (Table 1). Although the average sublingual temperature at 30 minutes post-bath was increased under all bathing conditions, the data were not statistically significant. The heart rate at 10 minutes post-bath was significantly increased ($p < 0.05$) compared with the pre-bath values under all bathing conditions. The heart rate was particularly heightened during full-body bathing, increasing by 19.1 bpm ($p < 0.05$), whereas forearm and lower leg bathing increased the rate 7.5 bpm ($p < 0.05$) and 5.4 bpm ($p < 0.05$), respectively. Systolic blood pressure decreased by 12.1 mmHg in full-body bathing compared with pre-bath measurements, although the difference between the pre-bath and 10 minutes post-bath values was not significant. Moreover, a significant decrease in diastolic blood pressure was observed when comparing pre-bath and 10 minutes post-bath values for full-body and forearm bathing. Full-body bathing demonstrated a more significant decrease in diastolic blood pressure than forearm bathing based on the p-value. The values dropped dramatically from 77.4 mmHg to 55.7 mmHg, a 21.7 mmHg decrease.

The respiratory rate was not significantly different

between pre-bath and 30 minutes post-bath. The 2-point discrimination sense significantly decreased 30 minutes post-bath compared with pre-bath values. Consequently, the 2-point discrimination results indicate that legs become sensitive after bathing. Meanwhile, the total trajectory length significantly decreased 30 minutes post-bath. The largest decrease was seen in lower leg bathing. The total trajectory length decreased from 1,183 mm to 982 mm, a 201 mm decrease. Thus, these results demonstrate that the postural sway decreases after warm-water bathing. During exercise tolerance assessments, the Mets score decreased by 0.3 Mets following full-body bathing, 0.2 Mets following forearm bathing, and 0.3 Mets following lower leg bathing.

DISCUSSION

We selected a 41 °C bathwater temperature based on the report by Horikiri³⁾ that suggested the optimal bathing temperature for people with cardiovascular disease is between 40 to 41 °C. Anything above that temperature range runs the risk of overloading the patients' hearts. In our study, full-body bathing induced potent vasodilation and produced the largest heart rate increase. This is consistent with Tanaka⁴⁾ who demonstrated that heart rate increases are induced by reflective sympathicotonia and inhibition of the vagus nerve due to vasodilation and decreased blood pressure. Our data showed that warm-water bathing increased 2-point discrimination sensitivity and decreased the total trajectory length of the postural sway, which led to static balance. In Tanaka's study^{5, 6)}, the older patients showed a significant decrease in the patient's sense of the toe compared with their younger counterparts. Similarly, static balance was less pronounced

among older adults than young adults⁷⁾. These results are consistent with Cho⁸⁾ who demonstrated that falls in post-stroke patients were associated with reduction in static balance. Ikeda⁹⁾ showed immediate improvement in standing balance among frail older patients with lumbar spinal canal stenosis following thermotherapy. Thus, strategic implementation of warm-water bathing to sharpen plantar sense in elderly patients may prevent potentially devastating falls.

Horikiri¹⁰⁾ argued that the increase in exercise tolerance observed following warm-water bathing can be attributed to a heat-induced improvement in overall blood flow, including coronary vessels, and enhanced musculoskeletal movement due to collagen softening. Furthermore, Kihara¹¹⁾ reported that improved expanded heart function may be an acute effect of body heating. Thus, our Mets score decrease, observed during the exercise tolerance test, might have resulted from diminished heart load caused by the heightened body temperature. The body temperature increase may have contributed to a decline in the heart preload and a decline in the heart afterload induced by telangiectasia function.

Initially we had assumed that full-body bathing would demonstrate larger impact on exercise tolerance. However, our decreased Mets values during forearm and lower leg bathing were similar to those of full-body bathing. Therefore, the results of our study demonstrated that even partial bathing, such as forearm bathing and lower leg bathing, can increase exercise tolerance to levels similar to full-body bathing.

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