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Association of habitual bathtub bathing with thermoregulatory responses in young men during hot- water immersion

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Abstract

Background

Heat acclimation enhances thermoregulatory functions such as sweating and skin vasodilation, contributing to improved heat dissipation. Such adaptations can be induced by repeated heat exposure, but whether habitual daily bathing confers similar physiological benefits remains unclear.

Objectives

This study aimed to investigate associations between habitual bathing frequency and thermoregulatory responses, including sweating and skin blood flow, in young Japanese men.

Methods

Thirty-two healthy young men participated in this cross-sectional study. Participants were categorized into a bathtub group (bathtub use ≥ 4 days/week) and a shower group (bathtub use ≤ 3 days/week). Physiological responses were measured during 20 min of hot-water immersion (~ 40°C) followed by recovery. Local sweat rate, skin blood flow, rectal temperature, and heart rate were continuously recorded. Associations were assessed using correlation analyses and linear mixed-effects models.

Results

The frequency of bathtub bathing correlated positively with both sweat rate and skin blood flow during immersion ($p < 0.05$), after adjusting for age, body mass index, smoking, alcohol drinking and exercise habits. The bathtub group exhibited significantly greater increases in forearm sweat rate and skin blood flow, with responses approximately 1.5–2.0-fold higher than those in the shower group. These differences were evident shortly after immersion and persisted throughout the bathing period.

Conclusions

Habitual bathtub bathing was associated with enhanced peripheral thermoregulatory responses, suggesting that more frequent bathing behavior may act as a form of passive heat acclimation. These findings provide insight into the potential role of lifestyle practices in improving heat tolerance in warming environments.

1. BACKGROUND AND OBJECTIVES

In recent years, global warming has led to a marked increase in heatstroke-related ambulance transports and deaths in Japan [1, 2], reflecting a growing public health problem that is straining medical resources. To prevent heatstroke, behavioral thermoregulation such as appropriate use of air conditioning and adequate hydration is needed [3, 4]. In addition, physiological heat acclimation enhances thermoregulatory functions such as sweating and skin vasodilation to efficiently dissipate internal heat [5, 6], and therefore has an important role to play. Acquiring heat acclimation during the hot season is thus a key physiological function for coping with increasingly warm global environments.

Heat acclimation develops naturally as seasonal acclimation from spring to summer [7] and can also be induced through exercise or passive heating, including repeated hot-water immersion (HWI) [8, 9]. Interventional studies have shown that both approaches increase sweat rates, lower the sweating threshold, and promote cutaneous vasodilation [5, 6]. In parallel, epidemiological studies have reported associations between habitual bathing in Japan and reduced cardiovascular disease and diabetes risks [10, 11]. Further, a study in Finland found associations between frequent sauna use and lower rates of both cardiovascular and all-cause mortality [12]. Although these associations may be influenced by lifestyle and socioeconomic factors, improvements in vascular functions have been proposed as a potential mechanism.

Taken together, interventional research highlights thermoregulatory improvements with heat exposure, whereas epidemiological studies suggest broader cardiovascular effects of habitual HWI. However, it remains unclear whether routine daily bathing, without any structured intervention, contributes to heat acclimation such as sweating and vascular responses.

In Japan, daily HWI has traditionally been common, supported by a public bath culture and the widespread availability of household bathtubs [13]. However, lifestyle changes, particularly among younger individuals, have been associated with increased variability in bathing practices, including bathtub bathing and shower use [14], resulting in substantial individual differences in bathing habits. To our knowledge, no previous study has directly examined the association between habitual daily bathing frequency and acute thermoregulatory responses during bathing. The present study therefore aimed to investigate whether habitual bathing frequency influences acute sweating and cutaneous vascular responses during hot-water immersion in young Japanese men. We hypothesized that individuals with more frequent bathing habits would exhibit greater sweating and vasodilatory responses, independent of confounding factors such as exercise habits. As a non-interventional study, this research may provide insight into whether everyday bathing behavior contributes to heat acclimation, with potential implications for public health in warming environments.

2. MATERIALS AND METHODS

Participants

Thirty-two healthy young men participated in this study. The study protocol was approved by the Ethics Committee for Experiments on Human Subjects at the Graduate School of Design, Kyushu University

(approval no. 459) and conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrolment.

Questionnaire

To assess the lifestyle of participants, current smoking (yes or no) and alcohol drinking habits (5 times/week, 3–4 times/week, 1–2 times/week, 1–2 times/month, or none), exercise habits ≥ 30 min/day (≥4 days/week, 2–3 days/week, 1 day/week, or none), and frequency of bathtub bathing (times/week) were collected by interview before the experiment.

Experimental protocol

The experiment was conducted from late March to mid-May 2022 in the bathroom of a climatic chamber at Kyushu University. Exercise, food and drink intake, and smoking were prohibited within 2 hours before the experiment. First, participants changed into shorts, then anthropometric measurements including height, body weight, and body fat percentage were recorded. Body weight and composition were measured using a body composition analyzer (InnerScan Dual RD-803L; TANITA, Tokyo, Japan). Body mass index (BMI) was calculated as the weight in kilograms divided by the square of the height in meters.

The experimental protocol is shown in Fig. 1. To prevent heat-related illness, the participant consumed 200 mL of water before the experiment began. The participant then entered a climatic chamber maintained at 28°C and 50% relative humidity, where measurement sensors were attached over approximately 30 min. At the start of the experiment, the participant remained seated at rest for 10 min for baseline measurements. The participant was then subsequently immersed for 20 min in hot water at approximately 40°C. Water temperature was allowed to vary naturally. During immersion, water level was adjusted to reach the axillae, and the participant was instructed to remain in a long-seated position and to enter and exit the bathtub as slowly as practicable. After exiting the bathtub, the participant returned to a seated position in the climatic chamber, where post-bathing measurements were continued for an additional 15 min.

A series of physiological and subjective variables was assessed during the experiment. Rectal temperature and skin temperatures at seven sites (forehead, abdomen, forearm, dorsal hand, thigh, lower leg, dorsal foot) were measured using thermistors (LT-ST08-12 or LT-ST08-21; Gram Corporation, Saitama, Japan) and recorded with a data logger (LT-8A; Gram Corporation). Local sweat rate on the forearm was measured using a wearable sweat sensor (SKW-1000; Skinos Corporation, Nagano, Japan). Skin blood flow was measured using a laser Doppler flowmeter (FLO-C1; OMEGAWAVE, Tokyo, Japan) taped to the right forearm; analog signals were digitized through an A/D conversion board at a sampling frequency of 1000 Hz. Heart rate (HR) was recorded using a memory-type heart rate monitor (ActiveTracer AC-301A; GMS Corporation, Tokyo, Japan).

Statistical analysis

To evaluate time-series differences associated with habitual bathing behavior, participants were categorized into two groups: a bathtub group bathing in a bathtub ≥ 4 days per week; and a shower group bathing in a bathtub ≤ 3 days per week. Questionnaire responses were dichotomized as follows: alcohol drinking (≥ 3–4 days/week) versus non-drinking (≤ 1–2 days/week or none); and exercise habit present (≥ 2–3 days/week) versus absent (≤ 1 day/week or none).

Physical characteristics and lifestyle habits were compared between groups using Student's *t*-tests or chi-square tests. Pearson's product–moment correlation and partial correlation analyses were conducted to examine relationships among measured variables. Age, BMI, current smoking, alcohol drinking, and exercise were adjusted in partial correlation analyses.

To assess time-series data, physiological measurements were compared between the bathtub group (≥ 4 days/week) and shower group (≤ 3 days/week), using a cutoff similar to that adopted in previous studies [10]. Physiological variables were analyzed using linear mixed-effects models to account for within-subject correlation and occasional missing observations. Group (bathtub vs. shower), time, and the interaction (group × time) were included as fixed effects, and participants were included as random effects with subject-specific intercepts. When a significant interaction was observed, post hoc simple main effect analyses were conducted to compare groups at each time point, with p-values adjusted for multiple comparisons using the simulation-based method.

All data are presented as mean and standard error (SE), and values of $p < 0.05$ were considered statistically significant. Analyses were performed using the SAS OnDemand for Academics (SAS Institute Inc., Cary, NC, USA), cloud-based statistical software environment.

3. RESULTS

Participant characteristics are presented in Table 1. No significant differences in physical characteristics or lifestyle habits were identified between the shower and bathtub groups.

Table 1
Participant characteristics (n = 32)

	Total (n = 32)	Shower (n = 20)	Bathtub (n = 12)	
	Mean (SE)			*p*-value
Age (years)	23.9 (0.7)	23.7 (0.5)	24.4 (1.8)	0.630
Height (cm)	173.0 (1.1)	171.8 (1.3)	175.0 (1.7)	0.164
Weight (kg)	62.5 (1.6)	60.5 (2.2)	65.8 (2.0)	0.116
BMI (kg/m^2)	20.8 (0.4)	20.4 (0.5)	21.5 (0.6)	0.213
Body fat (%)	17.8 (0.8)	18.1 (1.0)	17.3 (1.1)	0.601
	n (%)			
Current smoking (yes)	9 (28.1)	7 (35)	2 (16.7)	0.264
Alcohol drinking (≥ 3–4 days/week)	10 (31.3)	7 (35)	3 (25)	0.554
Exercise (≥ 2–3 days/week)	13 (40.6)	8 (40)	5 (41.7)	0.926

BMI, body mass index; SE, standard error.

At 5 min after the start of immersion, the number of days of bathtub bathing showed a significant and positive correlation with sweat rate ($r = 0.419$, $p = 0.017$; Fig. 1A) and blood flow ($r = 0.593$, $p < 0.001$; Fig. 1C). At 20 min after start of immersion, the number of days of bathtub bathing showed significant, positive correlations with sweat rate ($r = 0.547$, $p = 0.001$; Fig. 1B) and blood flow ($r = 0.429$, $p = 0.014$; Fig. 1D). These significant correlations remained after adjusting for covariates including age, BMI, current smoking, and alcohol drinking. At other time points, the number of days of bathtub bathing maintained significant positive correlations during immersion and for up to 10 min after exiting the bathtub.

However, no significant correlations were observed between the number of days of bathtub bathing and HR at any time point (Fig. 1E, 1F). Physical characteristics and other lifestyle habits were also not significantly associated with blood flow or sweat rate.

For forearm sweat rate (Fig. 2), significant main effects of condition ($p = 0.002$) and time ($p < 0.001$) were identified, as well as a significant condition × time interaction ($p = 0.003$). Post hoc analyses revealed that the bathtub group showed significantly higher sweat rates from 6 min to 32 min. In the bathtub group, sweat rate increased rapidly after the start of immersion and reached approximately twice the level of the shower group at around 5 min.

For forehead sweat rate (Fig. 3), a significant main effect of time ($p < 0.001$) and a significant condition × time interaction ($p = 0.005$) were identified. The main effect of condition was not significant ($p = 0.317$). Post hoc analyses revealed that the bathtub group showed significantly or marginally higher sweat rates at 7 and 8 min, respectively ($p < 0.05$ and $p < 0.1$, respectively). The differences were smaller compared with those in the forearm.

For forearm blood flow (Fig. 4), significant main effects of condition ($p = 0.003$) and time ($p < 0.001$) were apparent, as well as a significant condition × time interaction ($p = 0.038$). Post hoc analyses revealed that the bathtub group showed significantly higher blood flow than the shower group starting from 5 min after the start of immersion, with the difference maintained throughout the bathing period (5–35 min; $p < 0.05$). In the bathtub group, forearm blood flow also increased rapidly after the start of immersion and reached approximately twice the level of the shower group at around 5 min. Although data density decreased during the post-bathing rest period due to sensor detachments in several bathtub participants, the overall trend of enhanced vascular response remained.

For forearm skin temperature (Fig. 5), a significant main effect of time ($p < 0.001$) and a marginal interaction of condition × time ($p = 0.078$) were seen. Main effect of condition was not significant ($p = 0.3492$). Post hoc analyses revealed that the bathtub group showed marginally higher sweat rates at 12 and 16 min, respectively ($p < 0.1$).

No significant differences in rectal temperature (Fig. 6) or HR (Fig. 7) were observed at any time point.

4. DISCUSSION

Previous studies mainly employed short-term HWI interventions under controlled laboratory settings, whereas the present study focused on habitual bathing behaviors in daily life. This study demonstrated that habitual bathtub bathing was associated with higher sweating rate and greater skin blood flow, even after adjusting for relevant covariates (Figure 1). When analyzed as continuous variables, both the rate and magnitude of increase in sweating and skin blood flow were greater in the bathtub group, with responses approximately 1.5–2.0-fold higher than those in the shower group (Figures 2 and 4). Previous interventional studies have reported comparable physiological adaptations following repeated heat exposure combined with exercise [8, 15]. In this context, long-term daily bathing may induce similar adaptive responses. The present findings suggest that habitual bathing may function as a form of passive heat acclimation in daily life and may contribute to the prevention of heat-related illness.

The underlying physiological mechanisms may involve a reduction in the sweating threshold and enhanced vasodilatory capacity, as demonstrated in heat exposure interventions combined with exercise [5, 6]. In the present study, HR did not differ between groups, whereas skin blood flow was greater in the bathtub group, suggesting augmented peripheral vasodilation rather than increased cardiac strain. This interpretation is consistent with findings from sauna studies without exercise, in which Laukkanen et al. suggested improvements in vascular flexibility [12, 16]. Because vasodilation can secondarily contribute to blood pressure reduction, our findings are also in line with epidemiological evidence indicating that

habitual bathing is inversely associated with hypertension risk [11]. Repeated thermal exposure in daily life, together with the hydrostatic pressure of water immersion, may generate shear stress on the vascular wall, thereby promoting vascular adaptation and improved vascular compliance.

In addition, while sustained differences were observed in the forearm, the forehead sweat rate showed a significant group difference only during the early phase of bathing (at 7 min). Such site-specific variation may be attributed to the higher sweat gland density and lower sweating threshold of the forehead [17], resulting in a rapid increase in sweat rate in both groups. Given the inherently higher sweating capacity of the head region, adaptive differences associated with heat acclimation may be more readily detectable in peripheral limb regions. Such peripheral adaptations may play an important roles in improving whole-body heat dissipation and thermoregulatory efficiency.

In contrast, core temperature did not differ between the bathtub and shower groups, despite the higher heat adaptability suggested in the bathtub group. One possible explanation is that immersion limits effective evaporative heat loss, as a substantial portion of the body surface is immersed. In addition, the greater skin blood flow observed in the bathtub group may increase heat transfer from the warm water to the body, potentially offsetting the enhanced heat dissipation capacity. In line with this interpretation, forearm skin temperature tended to remain higher in the bathtub group. Under bathing conditions, increased skin blood flow may facilitate not only heat dissipation, but also heat transfer from warm water into the body. Consequently, skin temperature may remain relatively elevated despite enhanced sweating responses. Because this study was conducted during water immersion, the responses may differ under dry heat exposure in air. Future studies are therefore needed to clarify whether individuals with habitual bathtub bathing exhibit superior heat dissipation and smaller increases in core temperature under dry heat exposure in air, where evaporative cooling is not constrained by immersion.

Several limitations should be considered when interpreting the present findings. First, only healthy young men participated in this study, so the findings are not necessarily generalizable to women, older adults, or clinical populations. Second, because this study was conducted under water-immersion conditions, the observed responses may differ from thermoregulatory responses under dry heat exposure in air. Finally, because of the cross-sectional design, causal relationships cannot be established.

In conclusion, habitual bathtub bathing was associated with enhanced sweating and skin blood flow responses during HWI in young men. Repeated heat exposure through daily bathing may contribute to human heat adaptation.

Abbreviations

HWI = hot-water immersion

BMI = body mass index

HR = heart rate

SE = standard error

Declarations

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Authors' contributions

T.N., A.N., S.K., T.I. and K.A. conceived and designed the experiments. T.N., A.N. and R.M. conducted the physiological experiments and collected data. T.N., A.N., R.M. and K.A. wrote the paper. All authors read and approved the final manuscript.

Funding

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethics approval and consent to participate

This study was approved by the Ethics Committee for Experiments on Human Subjects at the Graduate School of Design, Kyushu University (approval no. 459). Each participant in this study was provided with detailed information about the research and confidentiality before written informed consent was obtained.

Consent for publication

Not applicable.

Competing interests

Takayuki Nishimura was provided with research funds from Rinnai Corporation.

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Figures

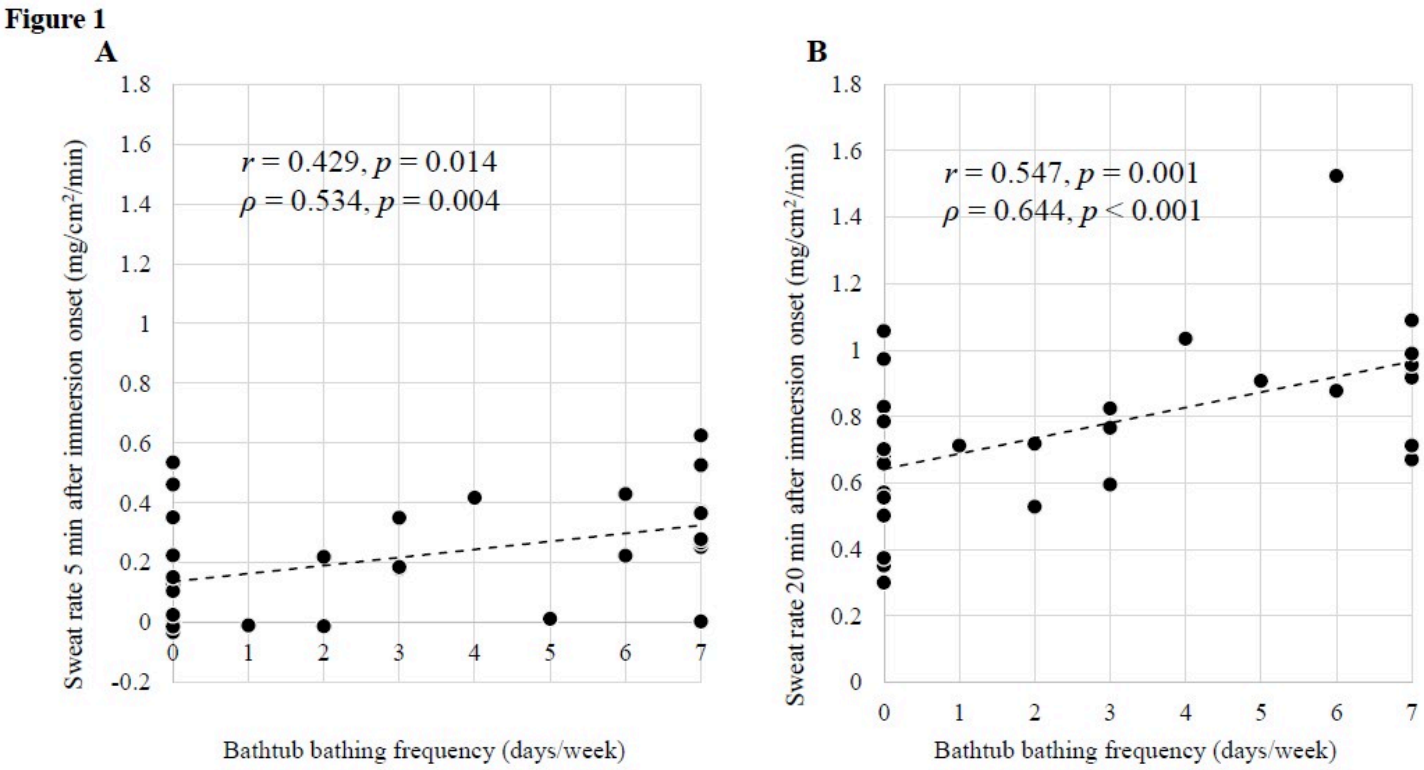


Figure 1

Correlation analysis between bathtub bathing frequency and blood flow, sweat rate, and heart rate

r, simple correlation coefficient; *ρ*, partial correlation coefficient adjusted for age, BMI, current smoking, alcohol drinking, and exercise habits.

Figure 2

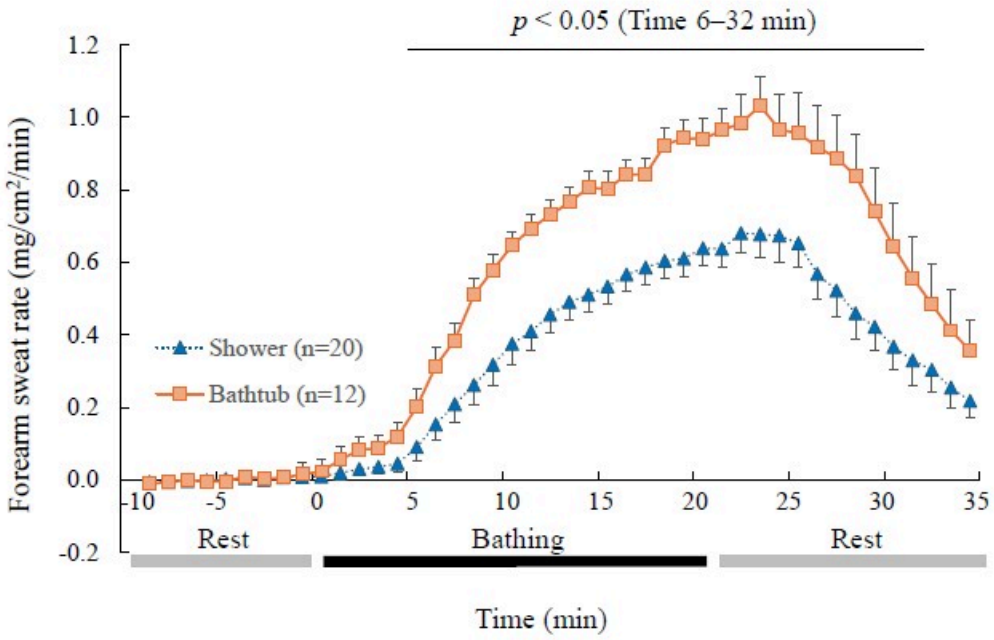


Figure 2

Time courses of forearm sweat rate for the two conditions

Values are shown as mean ± SE. Blue triangle, Shower group; orange square, Bathtub group.

Figure 3

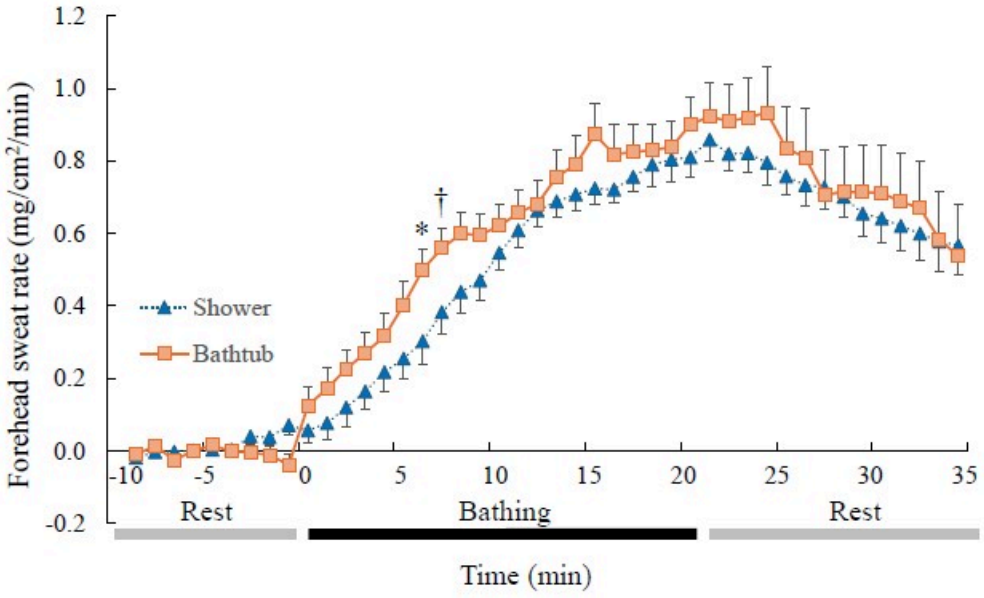


Figure 3

Time courses of forehead sweat rate for the two conditions

Values are shown as mean ± SE. Blue triangle, Shower group; orange square, Bathtub group.

* $p < 0.05$; † $p < 0.1$

Figure 4

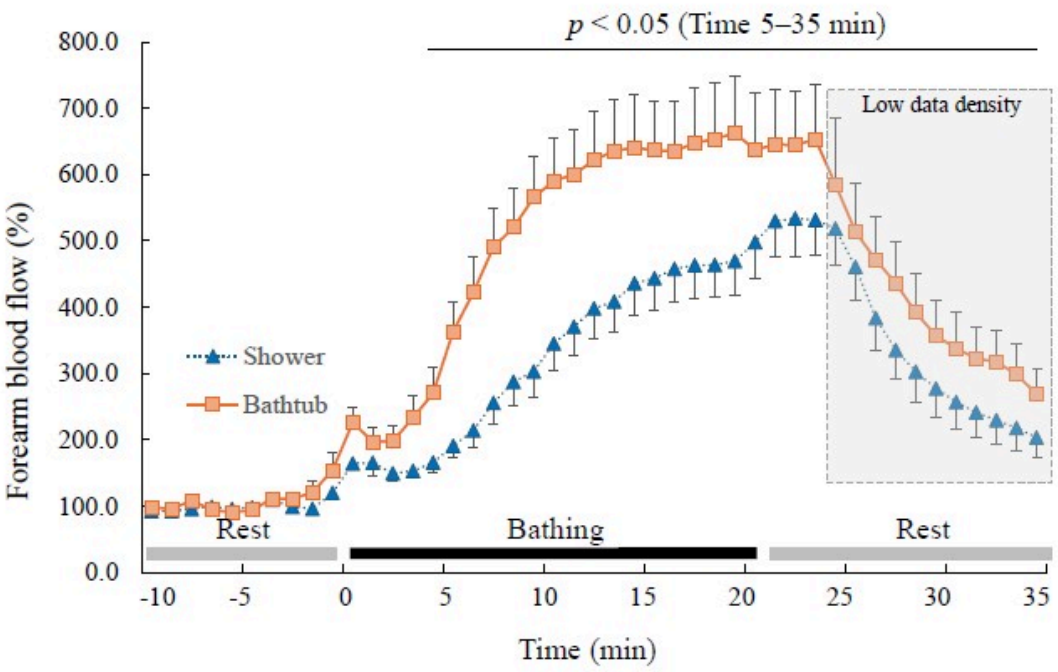


Figure 4

Time courses of forearm blood flow for the two conditions

Values are shown as mean ± SE. Blue triangle, Shower group; orange square, Bathtub group.

Figure 5

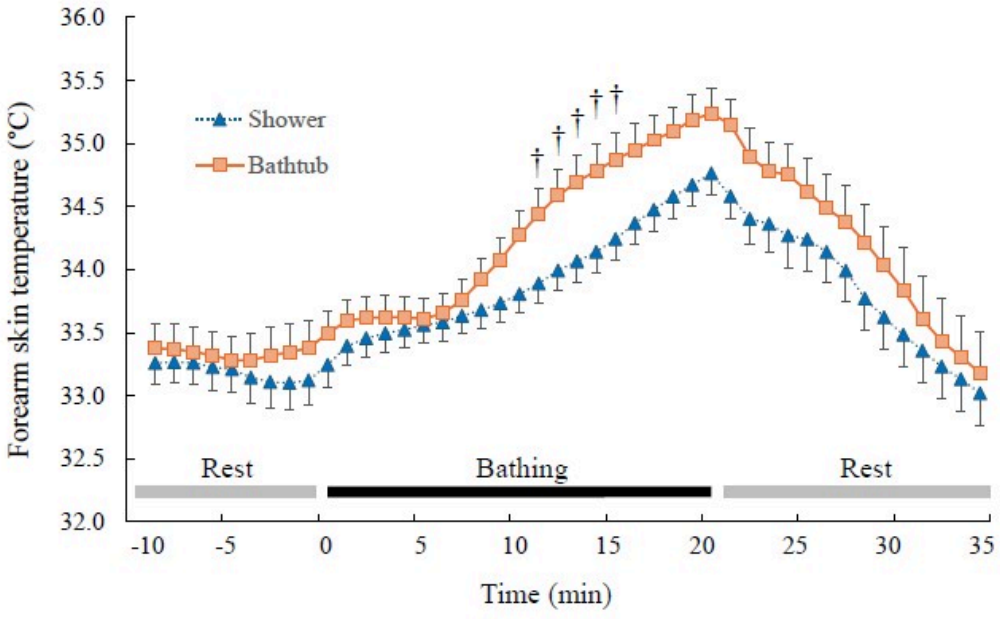


Figure 5

Time courses of forearm skin temperature for the two conditions

Values are shown as mean ± SE. Blue triangle, Shower group; orange square, Bathtub group.

† $p < 0.1$

Figure 6

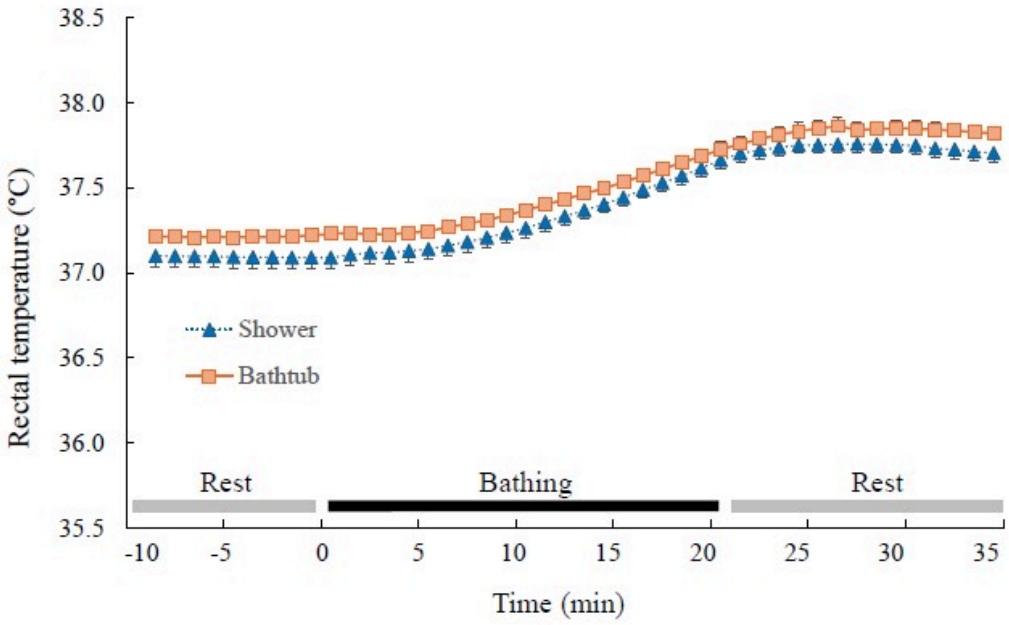


Figure 6

Time courses of rectal temperature for the two conditions

Values are shown as mean ± SE. Blue triangle, Shower group; orange square, Bathtub group.

Figure 7

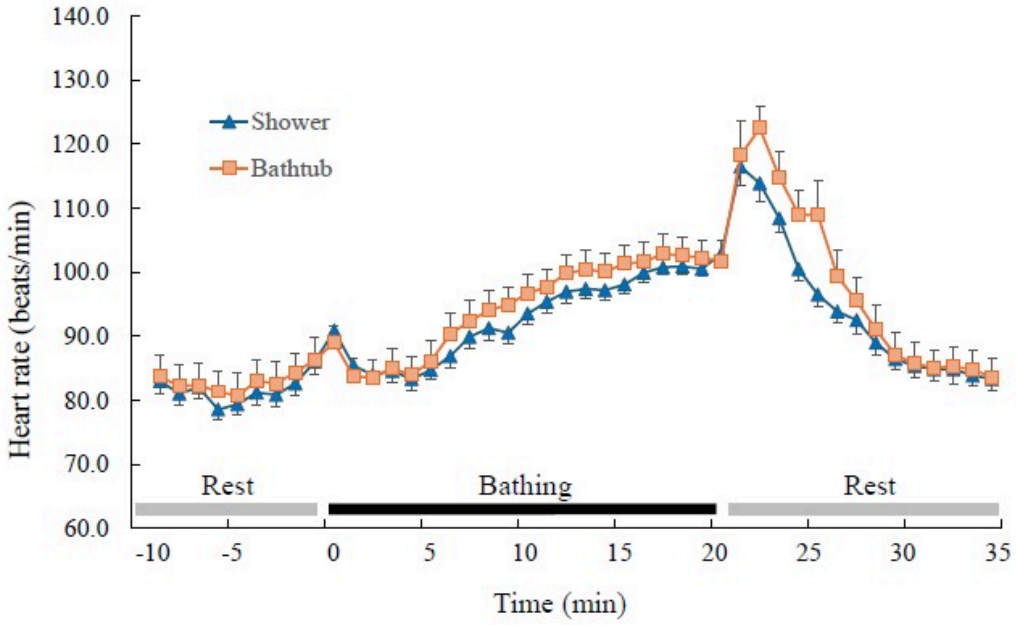


Figure 7

Time courses of heart rate for the two conditions

Values are shown as mean ± SE. Blue triangle, Shower group; orange square, Bathtub group.