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Pilot Study on the Effect of Bathing Time on Thermal Sensation for Improved Sleep

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ABSTRACT

In Japan, cold sensitivity is a common complaint, particularly among women. However, because this condition is neither serious nor life-threatening, it is difficult to treat this issue or conduct research. Because a person's core temperature rises when eating or bathing, we investigated the effect of bathing time on core and skin temperature. Taking a bath 4 hours before bedtime led to decreased core temperature and skin temperature of the feet and discomfort at bedtime. However, bathing 2 hours before bedtime decreased the core temperature but increased the skin temperature of the feet, and a comfortable thermal sensation was obtained. Bathing 4 hours before bedtime followed by a 10-minute foot bath before bedtime can reduce sensations of cold. We found that thermal comfort for improved sleep can be achieved with a bathing time 2 hours before bedtime or a foot bath just before going to bed.

Keywords: Bathing time, Cold sensitivity, Women, Thermal comfort, Foot bath

INTRODUCTION

In Japan, cold sensitivity is a common complaint (Uzunköprü et al., 2019; Carlsson et al., 2010; Compton et al., 2000), particularly among women. However, because this is not a serious or life-threatening condition, it is a difficult issue to treat or research (Carlsson et al., 2014). Women who experience sensitivity to cold often feel the cold most intensely when they go to bed. Additionally, many women feel the cold to such a degree that it is difficult to fall asleep in winter, even in a heated environment. In the current study, we investigated the effects of bathing, which can raise body temperature; core temperature, skin temperature, and thermal sensation, for preventing feelings of cold at bedtime. We hypothesized that this method would improve sleep.

EXPERIMENTAL SCHEDULES

Our study participant was a healthy, 21-year-old woman with intense sensitivity to cold. The participant conducted the following four experiments by herself. The experimental schedules are shown in Table 1. **Experiment I:** Room temperature (using a thermometer: DRETEC, China) and core temperature (oral temperature measured using a thermometer specifically for women: MC-172L, OMRON, Japan) were measured every 60 minutes from

Table 1. Schedules and conditions of Experiments I–IV.

Measurement	Measuring site	Measuring time	Bath time
Experiment I			
Room temperature	Room	7:00-23:00	18:00-20:00
Oral temperature	Oral		
Experiment II			
Oral temperature	Oral	Before and after bathing time: 20:00-21:00 Measured every 20 minutes from 21:00 to 24:00	20:00-20:30
Skin temperature	Arch		
	Toes		
Thermal comfort	Foot		
Experiment III			
Room temperature	Room	Before and after bathing time when from 20:00 or 22:00 Before bedtime at 24:00	20:00-20:30 or 22:00-22:30
Oral temperature	Oral		
Skin temperature	Arch		
	Toes		
Thermal comfort	Foot		
Experiment IV			
Room temperature	Room	Before and after bathing time from 20:00 Before and after foot bathing time from 22:00 Before bedtime at 24:00	20:00-20:20 and 10 min foot bath from 23:00
Oral temperature	Oral		
Skin temperature	Arch		
	Toes		
Thermal comfort	Foot		

7:00 to 23:00 for 7 days in May. **Experiment II**: Japanese-style bathing, which involves soaking in hot water up to the shoulders in deep bathtubs for a long time in the evening to night, is unique (Tochihara, 2022). In this study, we employed a shower instead of a Japanese-style bathing. After bathing at 20:00, room temperature, core temperature, and skin temperature of the arch and toes were measured using an electronic thermometer (TOAMIT, TOA). The skin temperature of the arch/toes, core temperature, and thermal sensation were measured before and after bathing. **Experiment III**: The bathing time was changed from 20:00 to 22:00. The participant's core and skin temperatures were measured with thermal sensation before and after taking a bath. **Experiment IV**: When the participant felt a cold sensation, she measured her core temperature, skin temperature of the arch/toes, and thermal sensation before and after taking a 10-minute foot bath at approximately 23:00.

EVALUATION OF THERMAL SENSATION

Foot thermal sensation was evaluated using a ratio scale, shown in Figure 1, divided into two steps showing how the reference thermal sensation for each day was obtained and how the thermal sensation was received at the target times in Experiments II to IV, but not in Experiment I. The first step was to integrate the magnitude of the sensation of warmth and the sensation of coldness on the same axis. Warmth and coldness were assessed at 7:00 on the morning of each day. The participant rated "cold" or "warm" sensations, with the left end of the axis representing "just right," and the right end of

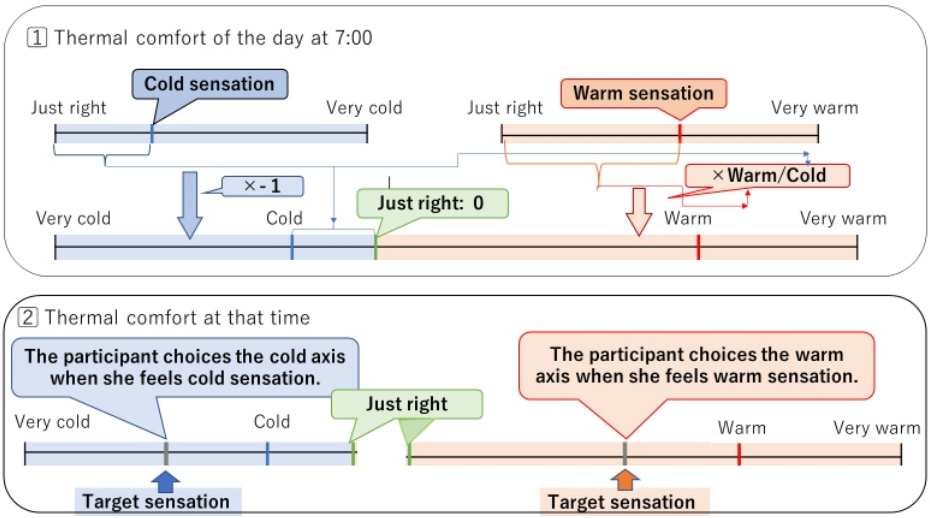

Figure 1: Evaluation of thermal sensation.

the axis representing "very cold" or "very warm." Because the participant is sensitive to cold, the distance from "just right" to "cold" or "warm" on the two scales was unequal. The "warm" sensation then was corrected by multiplying the coefficient, which was the warm value divided by the cold value. The "cold" sensation was expressed by multiplying the absolute value by a negative value. The warm sensation and the cold sensation were represented on a single straight line, with "0" indicating "just right."

In the second step, when evaluating the thermal sensation at the desired measurement time, the participant chose either the warm axis or the cold axis and recorded the sensation at that time. For example, when the participant felt a cold/warm sensation, she selected the cold/warm axis. Target cold/warm sensations are indicated by the arrows below the left/right lines.

RESULTS AND DISCUSSION

Result I: The room temperature and participant's core temperature over one week in May are shown in Figure 2, and the average values are shown in Figure 3. The core and room temperatures changed each day. The correlation coefficient was calculated between both. The correlation coefficient between core and room temperatures showed a significant positive correlation (0.578, $p < 0.001$), indicating that a higher room temperature was associated with a higher body temperature in the participant. The room temperature increased significantly from morning to noon and decreased significantly in the evening. However, body temperature increased temporarily from evening to nighttime and was significantly decreased in the middle of the night.

The participant normally ate dinner at approximately 18:00 and took a bath at approximately 20:00. Because body temperature increases following the ingestion of food owing to specific dynamic effects and, when bathing, heat is conducted to the body by immersion in water that is warmer than

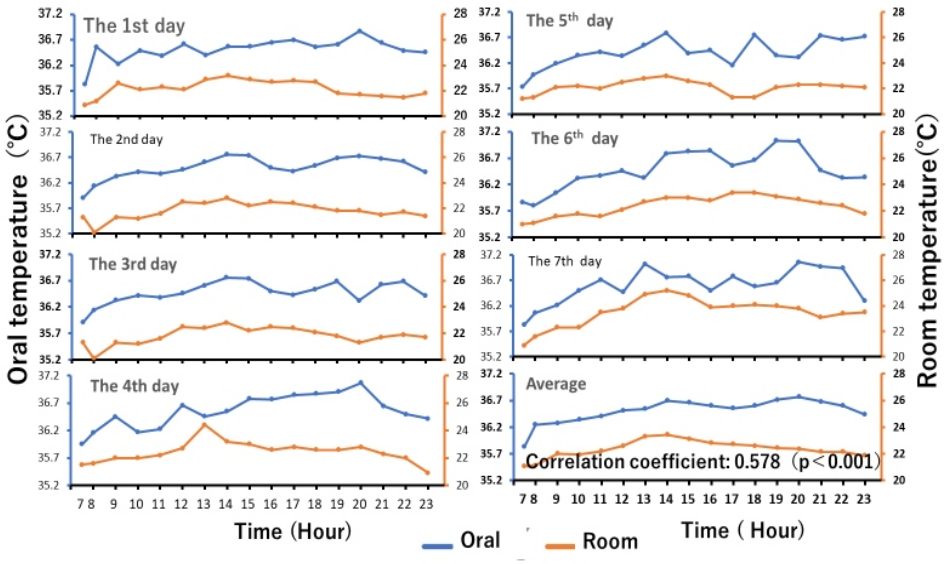

Figure 2: Room and core temperatures over one week in May.

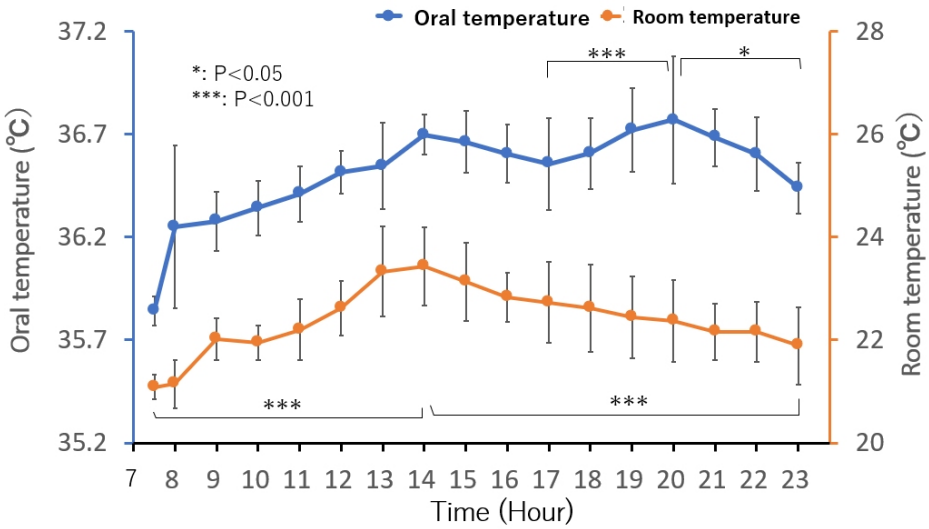

Figure 3: Average room and core temperatures.

the body temperature, both eating and bathing have been found to elevate body temperature. However, because eating before bedtime is considered to be unhealthy, bathing was used in the following experiments.

Result II: Changes in core and skin temperature after bathing are shown in Figure 4. Oral temperature was significantly higher after bathing compared with before bathing until 21:20, then decreased significantly from 22:00. The skin temperature of the foot arch was significantly higher after bathing until 22:00 and the skin temperature of one toe was significantly higher until 21:40 compared with before bathing (Figure 4a).

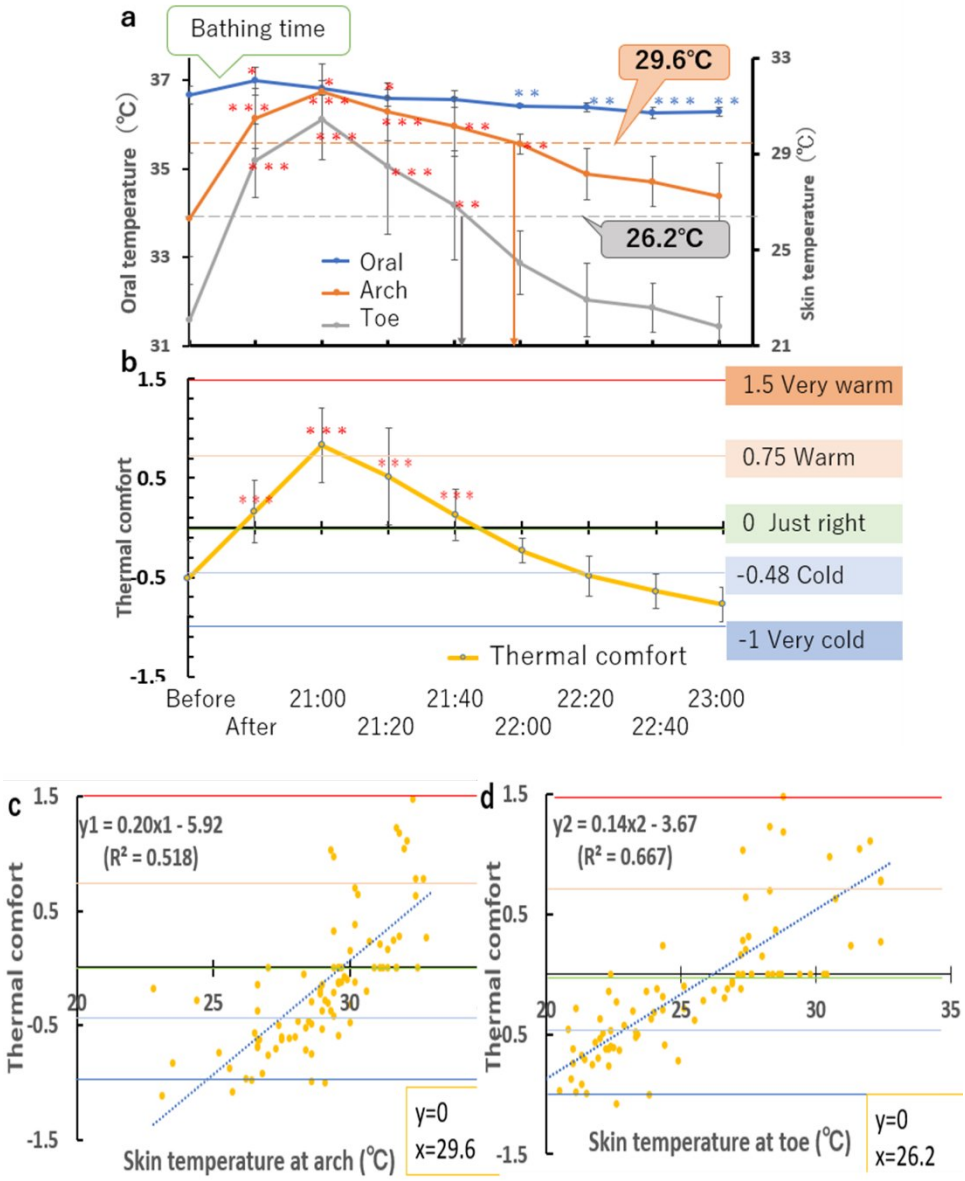

Figure 4: Changes in core and skin temperatures according to bathing time a, b) Changes in core and skin temperatures/thermal comfort by bathing time. c, d) Relationships between thermal comfort and skin temperature at the arch and toes. Skin temperatures of 29.6 °C and 26.2 °C in Figure 4a were calculated from Figure 4c and 4d.

The thermal sensation was significantly higher after bathing until 21:40, compared with that before bathing, and was evaluated by the participant as "warm" (Figure 4b). We calculated the relationships between skin temperature of the arch/toes and sensations of coldness. The skin temperature (X1: arch, X2: toes) was calculated with the following equations: $Y1 = 0.20X1 - 5.92$ ($R^2 = 0.518$) and $Y2 = 0.14X2-3.67$ ($R^2 = 0.667$). The skin temperature of the arch/toes (X1/X2) was at a

comfortable thermal sensation, with Y1 = 0 (arch) and Y2 = 0 (toes); these skin temperatures were 29.6 °C and 26.2 °C, respectively (see Figure 4c, 4d). In other words, a warm sensation in the feet was maintained for approximately 40 minutes after bathing; however, the oral temperature decreased from 1 hour after bathing. We then changed the bathing time from 20:00 to 22:00 and compared the results with those of Experiment II.

Result III: Core (oral) and skin temperatures and their thermal sensations are shown in Figure 5. Both oral and skin temperatures and their thermal sensations were significantly increased after bathing at 20:00 and 22:00. The rate of increase in the core temperature with bathing at 20:00 was significantly higher than that at 22:00; however, there was no difference in the skin temperature of the arch/toes and the thermal sensation. That is, core temperature decreased from 20:00 to 22:00, according to the participant's circadian rhythm. However, the effect of a warm bath on the skin temperature of the foot was maintained regardless of whether a bath was taken at 20:00 or 22:00. We found that with bathing at 22:00, the sensation of warmth in the feet remained comfortable until 0:00, or bedtime (see Fig. 4d-2). Next, we investigated the effects of a 10-minute foot bath at 23:00.

Result IV: Core and skin temperature and the thermal sensations before and after bathing at 22:00 or after a 10-minute foot bath at 23:00 are shown in Figure 6. Oral temperature increased after bathing at 22:00 (Experiment III), but not after a foot bath. However, thermal sensations were increased after taking a bath and after a foot bath. The rate of increase in skin temperature of the toes after a foot bath was significantly higher than the rate after taking a bath, and this increase was maintained until bedtime.

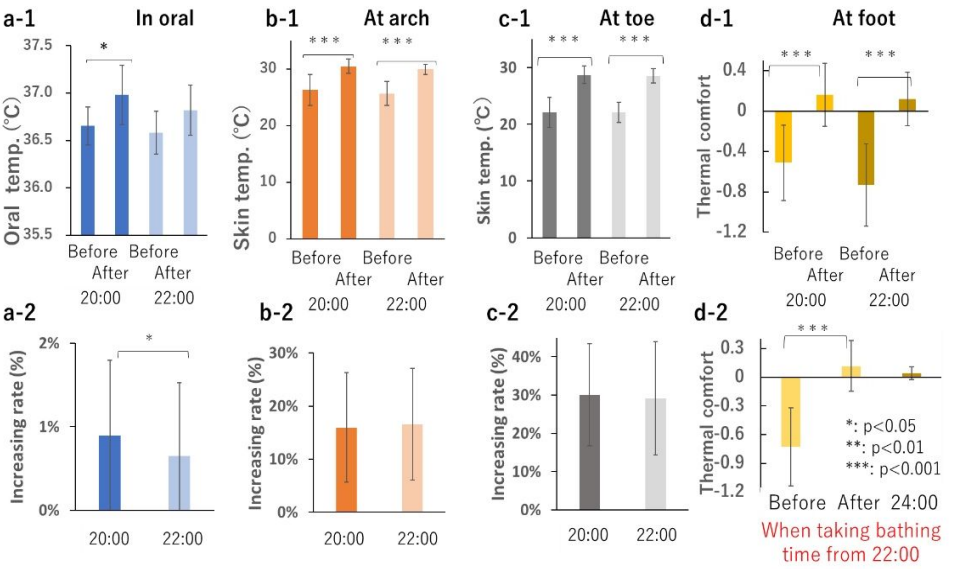

Figure 5: Core and skin temperature and its thermal sensation before and after bathing at 20:00 or 22:00 a-1 shows oral temperature, and its rate of increase is shown in a-2; b/c-1 shows skin temperature and its rate of increase is shown in b/c-2; d-1 shows thermal comfort and its change from 20:00 to bedtime at 0:00 is shown in d-2.

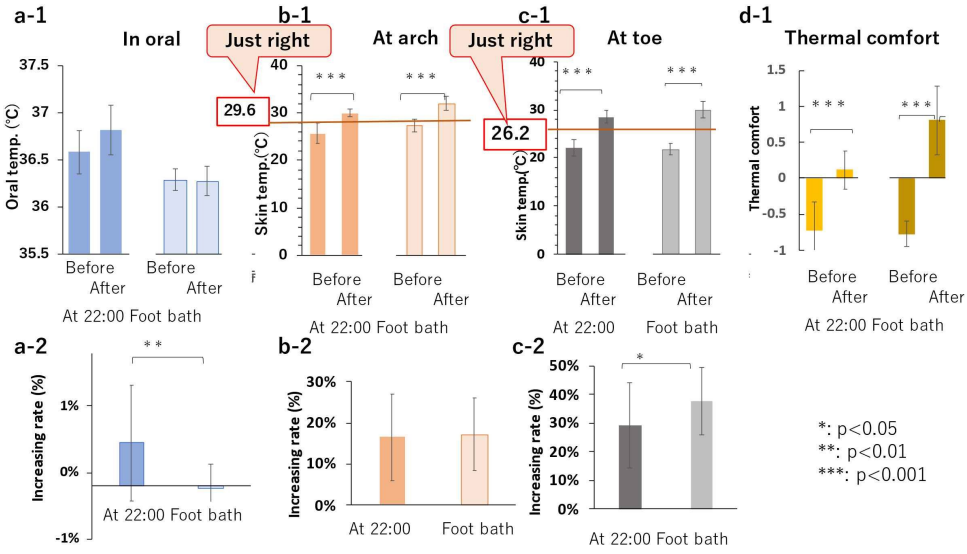

Figure 6: Core and skin temperature and thermal sensations before and after taking a bath at 22:00 or a 10-minute foot bath at 23:00.

Therefore, having a foot bath at 23:00 would be expected to make it possible to sleep more comfortably.

DISCUSSION

Comfortably falling asleep requires a decrease in core body temperature and an increase in limb skin temperature. If the room temperature is maintained at 20 °C for 30 minutes before awakening, the skin temperature of the limbs will stay warmer during the daytime (Mitsuno et al., 2008a, 2008b). Comfortable sleep is not considered to be possible if the hands and feet feel cold at bedtime (Home Economics Society Clothing Hygiene Subcommittee, 2016). Therefore, we examined changes in core body temperature throughout the day (Experiment I). Although the core temperature at 20:00 should normally be lower than that at 17:00, according to one's circadian rhythm, it was significantly increased in our participant (see Result I). Core temperature rises owing to the specific dynamic effect of eating dinner (at approximately 18:00 in our participant) and owing to heat conduction with bathing (at 20:00 in our participant). We opted to investigate warming the skin temperature by bathing to avoid the negative health effects of eating before going to bed. And many experimental and epidemiological studies and surveys have shown that taking bath improve sleep quality, especially shortens sleep onset latency of elderly (Tochihara, 2022; Yagi et al., 2019). When we examined the core temperature, skin temperature, and thermal sensation of the feet after bathing at 20:00 (Experiment II), the core temperature was significantly increased for up to 1 hour after bathing, then decreased significantly until 23:00. The skin temperature of the feet peaked at 21:00, then decreased. However, the thermal comfort level that felt "just right" changed to coldness at 22:00, 2 hours after bathing (see Result II). Therefore, we shifted the bathing time by 2 hours

from 20:00 and compared the effects of bathing at 22:00 and at 20:00 (Experiment III). The core temperature did not rise significantly after taking a bath at 22:00; however, the skin temperature of the feet was significantly increased after bathing. This result confirmed that the rate of increase was comparable to that with bathing at 20:00. We also found that with bathing at 22:00, our participant was able to stay comfortable until 0:00, at which time she went to bed (see Result III). In Experiment IV, the participant took a 10-minute foot bath at 23:00 to warm the skin temperature, which had decreased. The core temperature did not change before and after the foot bath, but the skin temperature of the feet increased significantly, and a comfortable thermal sensation was maintained until bedtime. Thus, the results indicated that more comfortable sleep can be achieved by bathing 2 hours before going to bed or having a foot bath just before going to bed. In the future, we plan to increase the number of participants and verify our experimental findings.

CONCLUSION

In Japan, it is thought that comfortable sleep cannot be achieved if the hands and feet are cold at bedtime, and cold sensitivity affects many people, especially women. We examined one participant's changes in core body temperature throughout the day and found that core temperature rose owing to the specific dynamic effect of eating and heat conduction when bathing. The participant's core temperature was significantly increased up to 1 hour after bathing; the skin temperature of her feet peaked 1 hour after bathing and then decreased. However, the participant's sensation of thermal comfort changed from just right to cold at 2 hours after bathing. When bathing time was shifted later by 2 hours, the participant's core temperature did not rise significantly after bathing; however, the skin temperature of her foot increased significantly, and she was able to stay comfortable until bedtime. A 10-minute foot bath before bedtime also increased the skin temperature of the feet, and the participant was able to maintain a comfortable thermal sensation until bedtime. Thus, we found that sleep could be improved by bathing 2 hours before bedtime or having a foot bath before going to bed.

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