Effects of the Thermal Conditions of the Dressing Room and Bathroom on Physiological Responses during Bathing

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Abstract. The effects of the thermal conditions of the dressing room and bathroom on the physiological responses during bathing were assessed. Six female students participated in this experiment. Three climate chambers were used as a living room, a dressing room and a bathroom. The living room was thermoneutral and maintained at 25°C, while the thermal conditions of the dressing room and bathroom were as follows: (A) cold (10°C), (B) cool (17.5°C) or (C) thermoneutral (25°C). The subjects wore standard clothing (0.65 clo). Heart rate (HR), blood pressure, rectal (Tre) and skin temperature, and subjective thermal sensation were recorded.

1) Marked increases in systolic blood pressure (SBP) after undressing and redressing in the dressing room and during washing were observed under the cold conditions.
2) A significant negative correlation was found between the dressing room temperature and increased SBP compared to before bathing ($r = -0.684$, $p < 0.01$, $n = 18$).
3) After exposure, mean skin temperature (Tsk) showed marked differences among the three conditions despite the rest taken under the same thermal conditions.
4) A significant negative correlation was found between Tsk and the increase in SBP of after undressing relative to that before bathing ($r = -0.695$, $p < 0.01$, $n = 18$).

These findings suggested that 25°C was the most appropriate temperature for the bathroom and dressing room, since the increase in blood pressure was minimum and subjective thermal sensation was neutral (neither cool nor warm) to warm under this thermal condition, and 17.5°C at which the increase in blood pressure was within the physiological fluctuation range (± 10 mmHg) is the minimum tolerable temperature.

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Keywords: bathing, thermal conditions in bathroom and dressing room, blood pressure, rectal temperature, skin temperature

Introduction

Most Japanese houses do not have a central air conditioning system. Even when it is cold, only the living room is heated and the other rooms and areas within the home remaining cold. Since most Japanese houses are not equipped with heating systems in the dressing room, bathroom and toilet, the individual is subjected to great cold stress when undressing in winter. Moreover, Hiraiwa et al., (1988) and Funayama et al., (1990) reported deaths of the elderly in the bathroom in winter. The effects of cold exposure on physiological responses have been studied frequently (e.g. Tanaka et al., 1983; Tochi-hara et al., 1993). However, there have been few studies on physiological responses during bathing related to the thermal conditions in the bathroom and dressing room. In our previous field survey, we reported a marked increase in blood pressure and a decline in skin temperature during bathing in winter, especially in the cold dressing room in undressed subjects (1995). However, thermal conditions of the dressing room and bathroom were not correlated with the increase in blood pressure. Hence, the present study was carried out to examine the effects of thermal conditions on the physiological responses of healthy young females during bathing and while in the dressing room and bathroom under controlled thermal conditions.

Materials and Methods

Six healthy female volunteers between 20 and 21 years old (20.5 in average) participated in the study. Their mean ($\pm$ SE) height, body weight, body surface area and body mass index were $159.8 \text{ cm} \pm 3.6 \text{ cm}$, $51.5 \text{ kg} \pm 3.4 \text{ kg}$, $1.52 \text{ m}^2 \pm 0.01 \text{ m}^2$ and $20.8 \text{ kg/m}^2 \pm 0.8 \text{ kg/m}^2$,

respectively. The following criteria were also taken into account: (a) They were established residents in Tohoku and north Kanto area, (b) They have been living in Gunma for three years.

All tests were conducted in three artificial climatic chambers used as a living room, a dressing room and a bathroom at the Institute of Public Health, Tokyo. The living room was kept at a thermoneutral condition (25°C). The thermal conditions of the dressing room and bathroom were as follows: (A) cold (10°C), (B) cool (17.5°C) or (C) thermoneutral (25°C). Air humidity and air velocity were kept at 50% and 0.2 m/s, respectively, in all the three rooms.

On arrival at the laboratory, the subjects entered the living room wearing a long-sleeved sweat shirt and trousers over swim wear (standard clothing), and several sensors were attached to the body. The total thermal insulation value of standard clothing measured with a thermal manikin was 0.65 clo. After 20 minutes rest, the subjects were exposed to experimental thermal conditions for 20 minutes: 5 minutes in the dressing room undressing in a sitting position, 5 minutes washing and 5 minutes immersion (water temperature 40°C) in a bathtub in the bathroom; after bathing the subjects dried themselves using a towel, and then spent 5 minutes in the dressing room wearing standard clothing. Thereafter, they returned to the living room, where they remained for 20 minutes. Therefore, the total duration of each experiment was 60 minutes. The subjects rested on a chair in the living room and dressing room. In the bathroom, they washed with soap and 40°C water in a sitting position on a stool. After pouring two washbowls of water over themselves outside the bathtub they washed their face, arms and legs and body in order. Lastly they poured two washbowls of water over themselves. A Japanese-style bathtub with a width of 0.68 m, length of 1.2 m and depth of 0.55 m (water volume 150 lit.) was used in this experiment. Each subject participated in three experiments on different days and the order of the experiments was randomized. These experiments were carried out in June and early July. All the experiments for each subject were conducted at the same time of day.

Rectal temperature (T_{re}) was measured using a thermoprobe (401J Nikkiso-YSI) inserted to a depth of 120 mm in the subject's rectum. Skin temperature was measured with a thermistor (082 Nikkiso-YSI) taped at 5 sites: forehead, upper back, hand, thigh and foot. The temperature was measured continuously and recorded every minute by a data logger (LT-8A, Mishima Work). The mean skin temperature (T_{sk}) was calculated by the method of Hardy and Dubois (1938): $T_{sk} = 0.07 \times \text{forehead} + 0.35 \times \text{upper back} + 0.19 \times \text{hand} + 0.32 \times \text{thigh} + 0.07 \times \text{foot}$. The heart rate was recorded every minute by a data logger (VHM1-016, Vine). Blood pressure was

measured using an automatic tonometer (HEM-704C, Omron). Thermal sensation was measured using a 9-point scale (1. very hot, 2. hot, 3. warm, 4. slightly warm, 5. neutral, 6. slightly cool, 7. cool, 8. cold, 9. very cold). Blood pressure and thermal sensation were recorded at 15 (before bathing), 23 (after undressing), 28 (after washing), 33 (during immersion), 38 (after redressing), 42 (after bathing), 50 (after bathing), and 58 (after bathing) minutes.

Statistical analyses were performed to confirm the differences between the exposure conditions. Each pair of group means was compared using paired t-tests. Differences with a $p < 0.05$ were considered significant.

Results

Heart rate and blood pressure

Figure 1 shows the changes in heart rate (HR) due to bathing under the three conditions. The HR increased while undressing during the latter half of the period of immersion, while drying using a towel, redressing and walking under each of the three temperature conditions. These increases in HR were observed at the time of the performing in the same behavior under each of the three conditions. No significant differences in heart rate were found among the three conditions at any stage of bathing.

Figure 2 shows the changes in systolic blood pressure (SBP) due to bathing under the three conditions. The SBP increased after undressing in the dressing room and then reached a maximum level after washing in the bathroom. SBP decreased suddenly during immersion in the bathtub and increased markedly after redressing in the dressing room. After bathing, the level of SBP in the living room was similar to that before bathing. Among the three thermal conditions, a greater increase in SBP was found under the cold condition. Significant differences in SBP were found between cold (10.0°C) and cool conditions (17.5°C) after undressing,

Fig. 1 Changes in heart rate caused by bathing. Values are means and standard errors. Condition A, 10.0°C (○); Condition B, 17.5°C (□); Condition C, 25.0°C (△).

Fig. 2 Changes in systolic blood pressure caused by bathing. Values are means and standard errors. Condition A, 10.0°C (○); Condition B, 17.5°C (□); Condition C, 25.0°C (△).

between cool (17.5°C) and thermoneutral conditions (25°C) after undressing, and cold (10.0°C) and thermoneutral conditions (25°C) after undressing, after washing, and after redressing. Figure 3 shows the relationship between dressing room temperature (three conditions) and increased SBP compared to before bathing. After undressing, SBP under the cold conditions (A:10°C) increased by 17 mmHg on average, under cool conditions (B: 17.5°C) increased by 8 mmHg, and under thermoneutral conditions (C: 25°C) increased by 6 mmHg compared to the corresponding SBP before bathing. There were significant differences in the increase in SBP between the cold and cool conditions, and between the cold and thermoneutral conditions. A significant negative correlation was found between the dressing room temperature and increased SBP compared to before bathing ($r = -0.684$, $p < 0.01$, $n = 18$). The increase in SBP was greater at a lower room temperature.

Fig. 3 Relationship between the dressing room temperature and the increase in systolic blood pressure. Values are means and standard errors. Condition A, 10.0°C (○); Condition B, 17.5°C (□); Condition C, 25.0°C (△). ($r = -0.684$, $p < 0.01$, $n = 18$, $Y = -0.766X + 23.694$).

Rectal and skin temperature

Figure 4 shows the changes in T_{re} due to bathing under the three conditions. T_{re} was lower during washing and after redressing in the dressing room in the cold environment. However, there were no significant differences in T_{re} among the three conditions. Figure 5 shows the changes in T_{sk} due to bathing under the three conditions. Before commencement of the experiment, T_{sk} values were similar in all three conditions. However, significant differences were found between cold (10.0°C) and cool conditions (17.5°C), between cool (17.5°C) and thermoneutral conditions (25°C), and cold (10.0°C) and thermoneutral conditions (25°C) at all time points except during immersion. Marked differences were observed in the T_{sk} in the dressing room after bathing. After exposure, T_{sk} showed marked differences among the three conditions despite the rest taken under the same thermal conditions.

Relationship between the T_{sk} and the increase in SBP

Figure 6 shows the relationship between T_{sk} and the increase in SBP in the dressing room; a significant negative correlation was found ($r = -0.695$, $p < 0.01$, $n = 18$).

Thermal sensation

Table 1 shows the changes in thermal sensation due to bathing under the three conditions. Before commencement of the experiment, there were no differences in the thermal sensations among the three conditions. After undressing and redressing in the dressing room and after washing in the bathroom, there were significant differences in the thermal sensation among the three conditions. However, there was no significant difference in the thermal sensation between cool (17.5°C) and cold conditions (10.0°C) after undressing in the dressing room and subjects felt the same degree of coldness under cool conditions (17.5°C) as under cold conditions (10.0°C).

Fig. 4 Changes in rectal temperature caused by bathing. Values are means and standard errors. Condition A, 10.0°C (○); Condition B, 17.5°C (□); Condition C, 25.0°C (△).

Fig. 5 Changes in mean skin temperature caused by bathing. Values are means and standard errors. Condition A, 10.0°C (○); Condition B, 17.5°C (□); Condition C, 25.0°C (△).

Relationship between Tsk and thermal sensation

Figure 7 shows the relationship between the mean skin temperature (Tsk) and thermal sensation; a significant negative correlation was found ($r=0.615$, $p<0.01$, $n=36$).

Discussion

Several studies have shown an increase in heart rate due to Japanese-style bathing behavior in young females. Shintani et al., (1982) studied heart rate and blood pressure of young female subjects with uniform patterns of bathing behavior, and reported that heart rate increased steadily, reaching a maximum after redressing. Shimura et al. (1983) measured the heart rate of five young adult female subjects, and reported that the increase in heart rate occurred while changing clothes such as undressing and redressing. In this study, the increase in heart rate due to bathing occurred at the time of the performing in the same behavior while undressing, during the latter half of the period of immersion, while drying using a towel, while redressing and while walking under three temperature conditions (Fig. 1). These findings were in agreement with those reported previously (Shintani et al., 1982; Shimura et al., 1983), and indicate that there were only small changes in the heart rate due to the differences in thermal conditions in

Fig. 6 Relationship between the mean skin temperature and the increase in systolic blood pressure. Condition A, 10.0°C (○); Condition B, 17.5°C (□); Condition C, 25.0°C (△). ($r=-0.695$, $p<0.01$, $n=18$, $Y=-40.44X+14.125$).

the dressing room and bathroom.

Our previous field survey (1995) demonstrated a marked increase in blood pressure and a decline in skin temperature during bathing in winter, especially in the cold dressing room in partially undressed subjects. To clarify the cause of the increase in blood pressure, its association with the mean skin temperature and thermal sensation in partially undressed subjects were evaluated. However, these factors were not correlated with the increase in blood pressure. These findings may be associated with inconsistent undressing conditions and complicated interaction of various factors such as percentage of body fat, degree of adaptation to cold and the nutritional state of the subjects.

In this study, increases in SBP were found after undressing and after redressing in the dressing room and after washing in the bathroom (Fig. 2). These increases in SBP could have been due to the influence of physical activity. If this was indeed the case, and the physical action of dressing and undressing alone could account for the observed increases in SBP, the degree of increase would have been the same in all three experimental conditions. However, significantly higher increases in SBP were observed under cold conditions than the cool

Table 1 Changes in subjective thermal sensation caused by bathing. Values are means and standard errors.

Condition Time (min.)	A 10.0°C		B 17.5°C		C 25.0°C		Paired t-tests		
	Mean	SE	Mean	SE	Mean	SE	A vs. B	B vs. C	A vs. C
before bathing	4.50	0.20	5.17	0.15	4.50	0.20	n.s.	n.s.	n.s.
after undressing	8.67	0.30	7.83	0.15	5.50	0.45	n.s.	$P<0.01$	$P<0.01$
after washing	8.17	0.15	7.00	0.33	6.00	0.57	$P<0.05$	$P<0.05$	$P<0.05$
during immersion	4.00	0.57	3.83	0.58	3.17	0.15	n.s.	n.s.	n.s.
after redressing	7.50	0.20	5.67	0.50	3.67	0.30	$P<0.05$	$P<0.01$	$P<0.01$
after bathing (7min.)	3.83	0.43	3.67	0.38	4.00	0.33	n.s.	n.s.	n.s.
after bathing (15min.)	3.67	0.30	4.50	0.20	4.50	0.20	$P<0.05$	n.s.	$P<0.05$
after bathing (23min.)	4.17	0.27	4.17	0.27	4.67	0.19	n.s.	n.s.	n.s.

n=6

Fig. 7 Relationship between the mean skin temperature and subjective thermal sensation after undressing and after washing. Thermal sensation; 1 (very hot), 2 (hot), 3 (warm), 4 (slightly warm), 5 (neutral), 6 (slightly cool), 7 (cool), 8 (cold), 9 (very cold). Condition A, 10.0°C (○); Condition B, 17.5°C (□); Condition C, 25.0°C (△).
($r = -0.616$, $p < 0.01$, $n = 36$, $Y = -0.504X + 22.945$).

or thermoneutral conditions both after undressing and after redressing in the dressing room and after washing in the bathroom (Fig. 2). To clarify the cause of the increase in SBP, the relationship between the dressing room temperature after redressing (three conditions) and increase in SBP relative to that before bathing were evaluated. A significant negative relationship was found between the dressing room temperature and increase in SBP (Fig. 3). The greater increase in SBP in the cold environment may be the result of exposure to cold and not from the increased workload such as that involved in washing and undressing. Shintani et al., (1982) reported that while the systolic blood pressure of subjects immersed in warm water (40°C) was not different from that in the control state, it was consistently higher when they were washing themselves outside the bathtub. Although Shimura et al., (1983) found an increase in systolic blood pressure and a decrease in diastolic blood pressure due to bath immersion (42°C) in summer, they did not observe any increase in SBP under cold and/or cool conditions as seen in this study. No marked increase in blood pressure was observed in their studies, probably because their experiments were carried out in thermoneutral environments and their subjects did not receive cold stimulation.

While bathing, which requires the person to be naked, the body is not protected from the cold by clothing, and is directly affected by the environmental temperature. Moreover, a significant negative relationship was found between the Tsk and the increase in SBP (Fig. 6). A greater increase in SBP was observed when the Tsk was less than 32.5°C in cold and/or cool conditions. These findings show that a clear increase in blood pressure is caused by contraction of the peripheral blood vessels to suppress surface heat loss.

Moreover, one of the most interesting findings of

this study was a marked difference in the Tsk observed in the dressing room and living room after bathing. Bathing in a cold environment may affect the subsequent thermal conditions of the body even under a thermoneutral environment. These findings suggested that 25°C is the most appropriate temperature for the bathroom and dressing room, since the increase in blood pressure was minimum and subjective thermal sensation was neutral (neither cool nor warm) to warm under this thermal condition. In this study, as shown in Fig. 3, a significant negative correlation was found between the dressing room temperature and increased rate SBP compared to before bathing. However, there was no significant difference between the cool conditions and thermoneutral conditions. Kuwasawa et al., (1988) studied the thermal sensation of subjects wearing clothing of 1.0 clo in environments between 10 and 22 °C. They pointed out that 17°C was the minimum tolerable temperature for changing clothes judging from the thermal sensation. Our findings also suggest that 17.5°C at which the increase in blood pressure is within the physiological fluctuation range (± 10 mmHg), is the minimum tolerable temperature.

On the other hand, Collins et al., (1985) and Tochihara et al., (1993) measured the blood pressure of young and elderly subjects in the cold. Collins et al., studied the blood pressure of subjects wearing standard clothing of 1.5 clo in environments between 6 and 23 °C, and reported that the increase in SBP was significantly greater in elderly subjects than in younger subjects at temperatures below 15°C. Tochihara et al., measured the blood pressure in cold (10°C) and warm (35°C) environments in relation to age, and reported that increase of systolic blood pressure due to cold exposure in elderly females was larger than that of college-aged females. At the beginning of the cold exposure, the systolic blood pressure of elderly females increased by 21 mmHg on average, and that of college-aged females increased by 5 mmHg. Moreover, they found that the blood pressure of elderly people increased more rapidly than that in young people. Although, the subjects wore standard clothing (Collins et al., 1.5 clo Tochihara et al., 0.63 clo) in both studies, blood pressure increased in the cold in the elderly. In particular, elderly persons with decreased physiological functions may be readily affected by thermal conditions. Therefore, elderly subjects require a higher environmental temperature for undressing and bathing than younger subjects, and the minimum tolerable temperature of the dressing room and bathroom appears to be above 17.5°C. Further studies on the effects of thermal conditions of the elderly during bathing where the body is not protected from the cold by clothing will be carried out under laboratory conditions.

Our previous field survey in winter (1995) showed that the temperature in the dressing room of Japanese

houses was from 6°C to 19°C with an average of 13.5°C. Although 80.6% of the partially undressed subjects in the dressing room felt 'slightly cool', 'cool' or 'cold', a heater was used only in 11.9% of the cases. Tanaka et al., (1989) surveyed the room temperature in a total of 664 bathrooms and dressing rooms in winter. The room temperature was most frequently 10-14°C, and about 80% of the subjects felt cold. In both studies, there were marked temperature differences between the bathroom and dressing room in winter and the most appropriate temperature for people. Our findings indicate that raising the temperature in the bathroom and dressing room by heating systems in winter is indispensable to prevent the increase in blood pressure. Therefore, installation of heating equipment in the dressing room and the bathroom of Japanese houses is recommended.

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