

THERMAL RESPONSES TO AIR TEMPERATURE BEFORE, DURING AND AFTER BATHING

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INTRODUCTION

Because most Japanese houses are not equipped with central heating, temperatures in dressing rooms, bathing rooms and other rooms are lower than in western countries. Large numbers of sudden deaths during and after bathing at home are reported in Japan, most occurring in winter (1). Since cold exposure and large temperature differences cause serious health hazards, the reason for these accidental deaths might lie in the combination of cold, pre- and post-bath room temperatures with high bath water temperatures. Although the effect of room temperature on thermal responses during and after bathing was studied in several laboratories (2), the number of studies dealing with wide ranging room temperatures and their effects on physiological and subjective responses is limited.

Therefore, the purpose of this experiment is to investigate the safety range of room temperatures for bathing, judged from physiological and subjective responses.

METHODS

Subjects. Twelve male students were subjects in the experiment. Their mean (SD) age, height and weight were 22.0 (± 1.0) years, 170.1 (± 4.3) cm and 56.8 (± 3.6) kg, respectively.

Procedure. The time schedule of the experiment is shown in Figure 1. Two adjacent climatic chambers and a bathroom were used. One was a pre-room kept at 26°C. The other was a test room kept at 5, 10, 15, 20, 25, 30 or 35°C. Air humidity and velocity were kept at 50% and 20 cm/s in both rooms. It was difficult to control the temperature and humidity of the bathroom during the bathing. After staying more than 30 min in the pre-room, physiological and subjective responses were measured for 10 min. Thereafter, the subjects moved to the test room, took off standard clothing (0.6 clo) and stayed there for 6 min. The subjects moved to the bathroom and bathed for 8 min, immersed to the neck in a

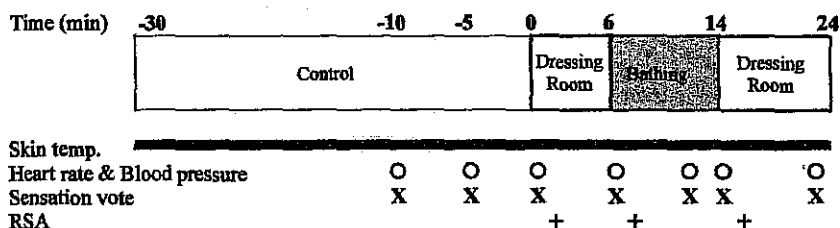


Figure 1. Time schedule.

Japanese-style bathtub. The water temperature of the bath was kept at 40°C. After bathing, the subjects dried themselves with towels and stayed in the test room for another 10 min. The subjects wore only shorts in the test room. The subjects bathed under 7 test-room thermal conditions on separate days, and all the experiments for each subject were conducted at the same time of day. The experiments were carried out during autumn.

Measurements. Skin temperatures were measured with thermistors every minute. The skin sites monitored were forehead (T1), abdomen (T2), forearm (T3), hand (T4), thigh (T5), leg (T6) and foot (T7). Mean skin temperature (T_{sk}) was calculated according to the formula of Hardy and DuBois: $T_{sk} = 0.07T1 + 0.35T2 + 0.14T3 + 0.05T4 + 0.19T5 + 0.13T6 + 0.07T7$. Heart rate (HR) and blood pressure were obtained on the right upper arm from an automatic tonometer. Thermal sensation (+4: very hot, +3: hot, +2: warm, +1: slightly warm, 0: neutral, -1: slightly cool, -2: cool, -3: cold, -4: very cold) and acceptance of the thermal environment (1: acceptable, 2: not acceptable) were also measured during the experiments.

Analysis. Measurements were analyzed by paired t-test. The significance level was set at $P < 0.05$.

RESULTS

Mean skin temperature. Figure 2 shows changes in T_{sk} before, during and after bathing. Each value shows the average for 12 subjects. In the pre-room, T_{sk} was almost 34°C under the 7 thermal conditions. Although T_{sk} during bathing depended on the water temperature (40°C), T_{sk} in the test room differed significantly from the room temperature.

Blood pressure and heart rate. Figure 3 shows changes in systolic blood pressure (SBP). One minute after entering the test room, SBP at 5°C, 10°C and 15°C increased significantly; on the other hand, SBP at 35°C decreased. There were no distinct changes in SBP at 20°C, 25°C and 30°C. Under every thermal

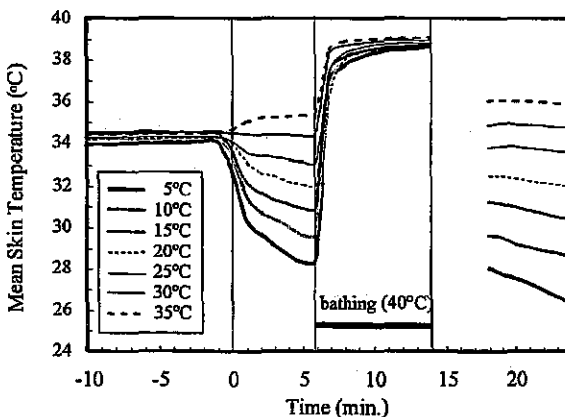


Figure 2. Changes in mean skin temperature

condition, SBP decreased during immersion. SBP increased 3 min after bathing and decreased 9 min after bathing. Similar phenomena were seen in the changes in diastolic blood pressure. HR at 35°C increased as a result of bathing, but there were no distinct changes in HR under other conditions.

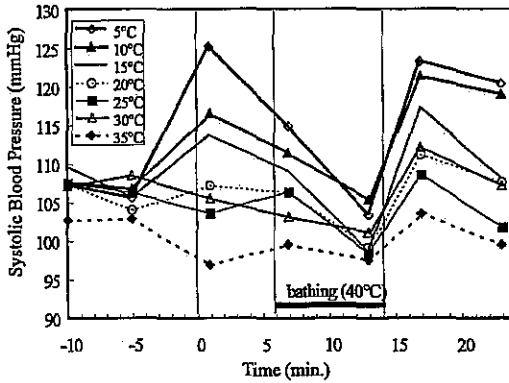


Figure 3. Changes in systolic blood pressure

Subjective responses. Changes in thermal sensations with bathing under 7 thermal conditions are shown in Figure 4. The average thermal sensations in the pre-room were almost "neutral." Thermal sensations during bathing were "warm" except at 35°C; it was "very hot" at 35°C. In the test room, except when bathing, most of the subjects felt "cold" below 20°C and "hot" at 35°C. At 25°C and 30°C, their thermal sensations were between "slightly warm" and "slightly cool."

Relations between percentage of dissatisfaction (PDI) and room temperature were calculated before and after bathing. There were significant quadratic curves. According to these regression equations for PDI, the minimum PDI value was obtained when room temperature was 31°C (before bathing), 25°C (3 min after bathing) and 26°C (9 min after bathing).

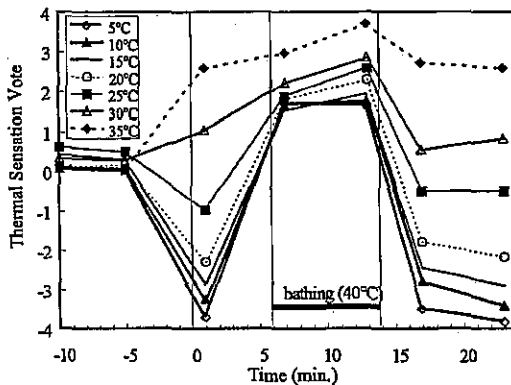


Figure 4. Changes in thermal sensation

DISCUSSION

Many field and experimental studies (e.g., [3]) reported that thermal comfort under uniform thermal conditions was obtained when T_{sk} was between 33°C and 34°C. There were significant linear relationships between T_{sk} and room temperature. Therefore, the room temperature comfort range before bathing, 3 min after bathing and 9 min after bathing was 24 to 29°C, 23 to 27°C and 24 to 27°C, respectively (Figure 5).

There were large changes in blood pressure due to bathing. However, the degree of these changes was strongly influenced by room temperature. Room temperatures that caused changes in blood pressure less than 10 mmHg were those in the range of 20°C to 30°C. These changes in blood pressure mean that there were no strict thermal stresses. Since HR increases considerably when bathing at 35°C, temperature in the dressing room and bathroom should be below 30°C.

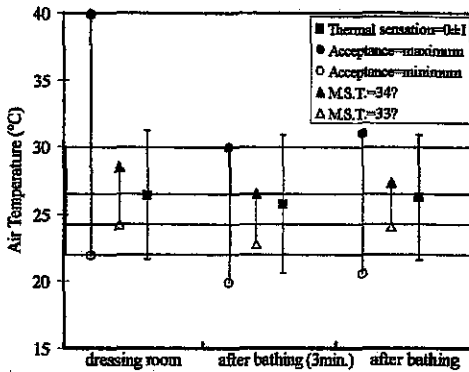


Figure 5. Safety range and optimum temperature in dressing room and bath room

There were significant linear relationships between thermal sensation and room temperature. Neutral thermal sensations were obtained at 26°C before and after bathing. The safety ranges of bathroom temperature, judged from thermal sensations ("slightly cool" to "slightly warm") and the acceptance of the thermal environment (80% of the subjects accepted the thermal conditions), are shown in Figure 5.

CONCLUSIONS

From these results, it can be concluded that the dressing room and bathroom temperature safety range is from 22°C to 30°C. Optimum room temperature is probably from 24°C to 26°C. However, these results came from the young; further research is needed for the elderly.

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