Effects of Room Temperature on Physiological and Subjective Responses during Whole-body Bathing, Half-body Bathing and Showering

Nobuko Hashiguchi, Furong Ni and Yutaka Tochihara

Department of Ergonomics, Kyushu Institute of Design, Japan

Abstract  The effects of bathroom thermal conditions on physiological and subjective responses were evaluated before, during, and after whole-body bath (W-bath), half-body bath (H-bath) and showering. The air temperature of the dressing room and bathroom was controlled at 10°C, 17.5°C, and 25°C. Eight healthy males bathed for 10 min under nine conditions on separate days. The water temperature of the bathtub and shower was controlled at 40°C and 41°C, respectively. Rectal temperature (Tre), mean skin temperature (Tsk), blood pressure (BP), heart rate (HR), body weight loss and blood characteristics (hematocrit: Hct, hemoglobin: Hb) were evaluated. Also, thermal sensation (TS), thermal comfort (TC) and thermal acceptability (TA) were recorded.

BP decreased rapidly during W-bath and H-bath compared to showering. HR during W-bath was significantly higher than for H-bath and showering (p<0.01). The double products due to W-bath during bathing were also greater than for H-bath and showering (p<0.05). There were no distinct differences in Hct and Hb among the nine conditions. However, significant differences in body weight loss were observed among the bathing methods: W-bath>H-bath>showering (p<0.001). W-bath showed the largest increase in Tre and Tsk, followed by H-bath, and showering. Significant differences in Tre after bathing among the room temperatures were found only at H-bath. The changes in Tre after bathing for H-bath at 25°C were similar to those for W-bath at 17.5°C and 10°C. TS and TC after bathing significantly differed for the three bathing methods at 17.5°C and 10°C (TS: p<0.01 TC: p<0.001). Especially, for showering, the largest number of subjects felt “cold” and “uncomfortable”. Even though all of the subjects could accept the 10°C condition after W-bath, such conditions were intolerable to half of them after showering.

These results suggested that the physiological strains during H-bath and showering were smaller than during W-bath. However, colder room temperatures made it more difficult to retain body warmth after H-bath and created thermal discomfort after showering. It is particularly important for H-bath and showering to maintain an acceptable temperature in the dressing room and bathroom, in order to bathe comfortably and ensure warmth. J Physiol Anthropol 21 (6): 277–283, 2002 http://www.jstage.jst.go.jp/en/

Keywords: bathing, showering, room temperature, physiological responses, subjective responses

Introduction

Generally, Japanese people prefer taking tub baths for cleanliness, warmth and relaxation. Most prefer a hot bath with immersion to the neck. Whole-body bathing (W-bath) defined as hot water immersion to the neck causes serious cardiac strain due to thermal effects and high hydrostatic pressure (Hiramatsu et al. 1999). A great number of accidental deaths in the bathroom have been related to this style of bathing.

Recently, half-body bathing (H-bath), defined as water immersion to the xyphoid process, and showering have been recommended as substitutes for W-bath. H-bath is also recommended for patients with cardiovascular and respiratory disease due to lower hydrostatic pressure on the chest. Showering is used at home and often at medical facilities. For example, showers are taken as part of rehabilitation for myocardial infarction patients, and are often used for post-surgical patients. Ueda (1984) reported that increases in skin temperature and heart rate were smaller for a H-bath than a W-bath at the water temperature of 43°C. Ohnaka et al. (1995) reported that blood pressure (BP) increased during showering in contrast to a rapid decrease in BP during W-bath. Although the physiological strains of H-bath and showering are expected to be smaller than those of W-bath, few studies on the actual effects of H-bath and showering on physiological responses have been carried
Most accidental deaths in the bathroom occur in winter (Akiyama et al., 1999). Kanda et al. (1995) surveyed thermal conditions in the bathroom during winter and summer and reported that as most houses were not equipped with a heating system in the dressing room and bathroom, the average temperature in the dressing room in winter was 13.5°C, ranging from 6°C to 19°C. Cold exposure and large temperature differences cause serious physiological strains on the human body (Tochihara et al., 1993, 1996). Several studies have shown that large changes in blood pressure or heart rate were observed before, during and after bathing under cold conditions in the dressing room and bathroom (Kanda et al., 1996; Tochihara 1999). Therefore, low temperatures in the dressing room and bathroom are said to be another reason for accidental death in the bathroom. However, the studies on H-bath and showering under various bathroom thermal conditions are limited in number. The room temperature during H-bath and showering might have different effects than W-bath on physiological responses and thermal comfort because of the smaller surface area exposed to warm water. In order to establish safety and comfort standards during H-bath and showering, studies on the effects of room temperature on physiological strain are needed.

Hence, the present study was carried out to point out the differences in physiological strains during W-bath, H-bath and showering. Moreover, the effects of bathroom thermal conditions on physiological and subjective responses during and after the three types of bathing were evaluated.

Methods

Subjects

Eight healthy young male volunteers participated in this study. Their mean (±SD) age, height and body weight were 23.5(±0.8) years, 167.2(±3.6) cm and 60.2(±4.6) kg, respectively. Each subject gave written informed consent for this experiment according to the protocol approved by the Ethical Committee of Kyushu Institute of Design.

Procedures

The study was conducted from April to June 2001. The air temperature and relative humidity of the pre-room were controlled at 25°C and 50%RH, respectively. The air temperature of the dressing room and bathroom were controlled at either 10°C, 17.5°C or 25°C. In this study, three different bathing methods: W-bath, H-bath and showering were investigated under these three thermal conditions. The time schedule of the experiment is shown in Figure 1. On arrival at the laboratory’s pre-room, the subjects wore a long sleeved shirt and trousers. After waiting at least 25 min in a sitting position, the subjects were then moved into the dressing room, and stayed there for 7 min wearing only shorts. Then, the subjects moved to the bathroom and bathed for 10 min. During the W-bath period, the subjects were immersed to the neck in a Japanese style bathtub, and during the H-bath period, to the xiphisternum in the same bathtub. During showering, they were drenched by an assistant below the neck in a sitting position outside the bathtub. Water temperature of the bathtub and shower were controlled at 40°C and 41°C, respectively, which are the most comfortable temperature of bath and shower for the Japanese (Hong et al., 1991; Kamata et al., 1992). After bathing, they dried themselves with towels. Once again, they rested in the dressing room for 10 min. The nine experiments were conducted on nine separate days, at the same time each day.

Measurements

Rectal temperature (Tre) and skin temperatures at 7 sites (forehead, chest, forearm, hand, thigh, calf and foot) were measured with thermistors every minute. Mean skin temperature (Tsk) was calculated using the formula of Hardy-DuBois (Hardy and DuBois, 1938).

BP was obtained on the right-upper arm using an automatic tonometer (HEM-737, OMRON, Japan). Thermal sensation (TS), thermal comfort (TC) and thermal acceptability (TA) were evaluated, as follow: TS was rated using a 9 point scale (−4=Very cold, −3=Cold, −2=Cool, −1=Slightly cool, 0=Neutral, 1=Slightly warm, 2=Warm, 3=Hot, 4=Very hot) and TC was rated on a 4 point scale (0=Comfortable, 1=Slightly uncomfortable, 2=Uncomfortable, 3=Very uncomfortable). TA was rated on a 2 point scale (0=Acceptable, 1=Unacceptable). As shown in Figure 1, BP and subjective data were recorded at the following time-intervals: −10, −5 (before bathing), 1 (just after undressing), 6 (after undressing), 8 (starting bathing), 16 (just before finishing bathing), 21 (3 min after bathing) and 27 (10 min after bathing) minutes.

HR was obtained from the electrocardiogram using
chest electrodes. Heart rate (HR) was computed for three minutes while resting, and also before, during and after bathing. The double product during bathing was calculated by multiplying systolic blood pressure by HR.

Body weight was measured using a platform scale with an accuracy of ±1 g before and after the experiment. A venous blood sample was obtained before and after the experiment. The hematocrit values (Hct) and hemoglobin concentration (Hb) were used to estimate blood viscosity.

Statistical analysis

Results of physiological data were presented as means±SD. Physiological data were analyzed by repeated-measures analysis of variance (ANOVA) using Visual Stat for Windows Release 4.5J software (Stat Soft. Inc.). For the ANOVA of Tre, Tsk, BP, HR and the blood sample, the factors were bathing methods, room temperatures and time. For the ANOVA of double product and body weight loss, the factors were bathing methods and room temperatures. Analyses of the data on Tre, Tsk, and BP were carried out separately for: before (0–7 min), during (8–17 min), and after (18–27 min) bathing. In order to clarify the differences between each condition, a multiple comparison was performed using Tukey’s HSD. The relationship between subjective data and room temperatures or bathing methods was analyzed using the Kruskal-Wallis test and Spearman’s correlation coefficient by rank test. Differences at p<0.05 were considered significant for all statistical analyses.

Results

Rectal temperature and Mean skin temperature

Figure 2 shows the changes in Tre due to bathing under the nine conditions. Tre increased with time during and after bathing under all conditions. Tre was significantly affected by the interaction between the bathing methods and the room temperatures during bathing (F(4, 48)=3.2 p<0.05), and a low p-value was shown after bathing (F(4, 48)=2.2 p<0.1). During and after bathing, W-bath showed the largest increase in Tre, followed by H-bath and showering. Moreover, the increases in Tre in warmer rooms were higher than in cooler rooms during and after W-bath and H-bath. Especially, there was a significant difference after bathing between 25°C and 10°C for H-bath (p<0.05). Tre for H-bath at 25°C increased by almost 0.2°C after bathing from the baseline (0 min); this increase was similar to the changes that occurred with W-bath at 17.5°C and 10°C.

Figure 3 shows the changes in Tsk due to bathing under the nine conditions. Tsk was affected by the interaction between the bathing methods and the room temperatures during bathing (F(4, 28)=9.5 p<0.001) and after (F(4, 28)=5.6 p<0.01) bathing. During bathing, W-bath showed the largest increase in Tsk, followed by H-bath, and showering. Though there was no distinct difference in Tsk among the room temperatures for W-bath, Tsk in warmer rooms were higher than in cooler rooms for H-bath and showering. The maximum value of Tsk during bathing was significantly different between 25°C and 17.5°C or 10°C for H-bath and showering. After bathing, significant differences in Tsk were found at each room temperature with all bathing methods. The differences in Tsk for H-bath between 25°C and 10°C was largest among the bathing methods.

Blood pressure and Heart Rate

Figure 4 shows the changes in systolic blood pressure (SBP) and diastolic blood pressure (DBP) under the nine conditions. SBP was significantly affected by the room
temperatures before bathing (F(2, 14) = 10.4 p < 0.01). At 10°C, SBP increased by 11.6 mmHg on average; this value was significant larger than the increase at 17.5°C and 25°C before bathing. During bathing, SBP was significantly affected by the bathing methods (F(2, 14) = 9.5 p < 0.01), but the room temperatures had no distinct effect during bathing. SBP for W-bath and H-bath during bathing were significantly lower than for showering (p < 0.05). After bathing, the room temperatures had a significant effect (F(2, 14) = 19.2 p < 0.001). A remarkable increase in SBP was found at 10°C compared to 25°C and 17.5°C after bathing. Similar phenomena were obtained for DBP changes.

Figure 5 shows HR values under the nine conditions. Significant effects of room temperatures/time interaction (F(6, 42) = 11.8 p < 0.001) and bathing methods/time interaction (F(6, 42) = 18.2 p < 0.001) were found. At 10°C, HR before bathing decreased on average by 8.8 beats/min and there was a significant difference between 10°C and 25°C (p < 0.01). HR increased during bathing under all conditions; mean values of HR for W-bath, H-bath and showering reached 87, 80 and 76 beats/min, respectively. Significant differences in HR between W-bath and H-bath or showering were found during bathing (p < 0.01), but there were no distinct differences due to room temperature. After bathing, HR decreased under all conditions, and at 10°C, HR was significantly lower than at 25°C. However, there were no distinct differences after bathing among bathing methods. The largest changes in HR were observed under 10°C condition from the beginning to the end of the experiment. Double products during bathing were significantly affected by bathing methods (F(2, 14) = 8.63 p < 0.01). Double products were significant larger for W-bath than for H-bath and showering (p < 0.05). However, there were no distinct differences in double products among the room temperatures.

**Body weight loss, Hemoglobin, and Hematocrit**

Figure 6 shows body weight loss under the nine conditions. Weight loss was affected by the interaction between the room temperatures and bathing methods (F(4, 28) = 9.19 p < 0.001). Weight losses were as follows: W-bath > H-bath > showering. Weight losses for W-bath and H-bath at 25°C were greater than those at 17.5°C and 10°C.

Hb and Hct increased after bathing under all conditions, and significant differences in Hb and Hct were found between before and after bathing (Hb: F(1, 7) = 19.44 p < 0.01, Hct: F(1, 7) = 29.37 p < 0.001). However, there were no distinct differences in Hb and Hct due to the nine conditions.

**Subjective responses**

TS and TC during bathing were affected by the bathing methods, but there were no distinct differences for the
room temperatures. In addition to the effect of the room temperatures, significant effects of bathing methods on TS and TC after bathing were found at 17.5°C and 10°C (TS: \( p < 0.01 \), TC: \( p < 0.001 \)). The number of subjects who felt "cold" and "uncomfortable" after bathing followed the order of showering > H-bath > W-bath. After showering, 75% and 100% of subjects reported "slightly uncomfortable" through "very uncomfortable" at 17.5°C and 10°C, respectively. Half of the subjects found the 10°C condition after showering "unacceptable". In contrast, half of the subjects felt comfortable and all subjects accepted the 10°C condition after W-bath.

Discussion

Physiological strain during W-bath, H-bath and showering

In accordance with previous studies (Kanda et al., 1996; Bone et al. 1999), BP decreased during W-bath (Figure 4). In this study, BP decreased during H-bath as well. The decrease in BP during bathing occurs due to cutaneous vasodilation (Miwa et al., 1994). HR during bathing increased under all conditions (Figure 5); such increase during hot water bathing is a compensatory mechanism for cutaneous vasodilation and decreased venous return (Miwa et al., 1999). Significantly, while there were no distinct differences in BP during bathing between W-bath and H-bath, HR for W-bath during bathing was significantly larger than for H-bath. Double products for W-bath were also significantly larger than H-bath during bathing. Since double products reflect myocardial oxygen consumption (Nagasawa et al., 2001), this finding indicates that the cardiovascular strain is smaller for H-bath than W-bath. The great physiological strain during W-bath likely contributes to serious conditions such as ischemic heart disease.

There have been several studies comparing the physiological responses of showering, bed bath and tub bathing (Jonston et al. 1981, Ekstrand et al. 1991, Winslow et al., 1985). Ekstrand et al. (1991) reported minor differences in HR and BP between the bathing methods for low-risk patients with myocardial infarction. Winslow et al. (1985) showed that peak heart rate and occurrence of dysrhythmia did not differ significantly among the types of bathing. However, in these studies, the water temperature (35.0–36.5°C) of the bath or shower was low compared to the 41–42°C range that is preferred by Japanese people. Ohnaka et al. (1995) studied physiological responses to shower and tub bath using water temperatures of 41 and 40°C, and noted that there was no rapid decrease in BP for showering, in stark contrast to W-bath. Decreases in BP, which is one of the causes of syncope in the tub bath (Inamura et al., 1995), for showering were smaller than for W-bath in this study as well. Moreover our study showed that the increases in HR and the double products during showering, as well as H-bath, were significantly smaller than those for W-bath. These results suggested that cardiovascular strain was smaller for showering than for W-bath.

Hb and Hct are used as indexes of the relative plasma volume (Migita et al., 1995); there is a significant positive correlation of Hct with blood viscosity (Shirakura et al., 1982). Hb and Hct increased after bathing under all conditions. This finding indicates that blood viscosity increases in all methods of bathing. However, we found no significant differences in Hb and Hct among the bathing methods. Body weight losses occurred in the following order: W-bath > H-bath > showering (Figure 7); bathing methods had a great influence on body weight losses. These results suggested that dehydration via sweating due to H-bath and showering were smaller than for W-bath.

It was verified that the physiological strains indicated by HR, double product, and body weight loss for H-bath and showering were smaller than for W-bath.

Physiological responses to room temperature before, during, and after the three methods of bathing

A large number of fatal accidents in the bathroom are reported in winter in Japan (Akiyama et al., 1999). One of the reasons for these accidents is that most Japanese houses are not equipped with central heating and the wintertime temperature in the dressing room is very low compared to the living room (Kanda et al., 1996; Miwa et al., 1999); a field survey demonstrated that the average dressing room temperature is 13.5°C in winter (Kanda et al., 1985). Sigeomi et al. (2001) surveyed the thermal conditions in four cities during winter and reported that the lowest average dressing room temperature among these cities was 10.6°C. In this study, SBP increased by 11.6 mmHg and HR decreased by 8.8 beats/min on average when the subjects entered a 10°C dressing room. The
increase in BP and the decrease in HR before bathing were significantly greater at 10°C than at the other room temperatures. The same was true after bathing. The responses in BP and HR in the dressing room were caused by cutaneous vasoconstriction and an increase in stroke volume due to cold exposure (Miwa et al., 1999).

During bathing, BP and HR were significantly affected by the bathing methods, but not by room temperature. After bathing, BP and HR were significantly affected by room temperatures, but not by bathing methods: the thermal effects of the different bathing methods did not carry over. Thus, the stress to the body due to cold exposure both before and after bathing should be considered regardless of bathing methods. As the influence of cold exposure on BP has been shown to be larger for the elderly than the young (Tochihara et al., 1993), the elderly are even more at risk for cardiovascular failure such as cerebral hemorrhage from bathing in a frigid room.

This study showed that the changes in Tre after W-bath and H-bath were influenced by the room temperatures. (Figure 2). Especially, significant differences in Tre after H-bath among the room temperatures were found only at H-bath. The changes in Tre for H-bath after bathing at 25°C were similar to those due to W-bath at 17.5°C and 10°C. Thermal effects similar to W-bath could be obtained for H-bath, if the room temperature in the bathroom was high (25°C). The great differences in Ts at depended upon room temperature and were also found during and after bathing for H-bath (Figure 3). Namely, the room temperatures had a great influence on body temperature changes for H-bath compared to W-bath and showering. These results show that it is advisable to avoid low temperatures in the dressing room and bathroom in order to maintain body warmth.

Significant relationships between room temperature and TS or TC were found after bathing for all bathing methods. Moreover, TS and TC after bathing significantly differed for the three kinds of bathing at 17.5°C and 10°C. In cold conditions, the largest number of subjects felt “cold” and “uncomfortable” for showering, followed by H-bath and W-bath, respectively. Half of the subjects did not accept the 10°C condition for showering. These subjective responses suggested that low temperature in the dressing room had a great influence on thermal sensations after showering, and that it is difficult to obtain thermal comfort at 17.5°C or less after showering. In contrast, half of the subjects felt comfortable and all subjects accepted the 10°C condition after W-bath. It is known in Japan that the dressing room and bathroom temperatures in many Japanese houses are low during winter. Since W-bath prevents the progressive discomfort due to cold exposure after bathing, the Japanese might prefer W-bath in the winter.

The low temperature in the dressing room and bathroom caused rapid changes in BP and HR from before to after bathing regardless of bathing methods. Moreover, for H-bath, room temperature had a great influence on Tre changes. It is difficult to obtain thermal effects similar to W-bath under cold conditions. As for showering, the subjective responses to the low room temperature were significantly worse than with W-bath and H-bath. Thermal discomfort occurred readily after showering under cooler conditions.

In summary, the physiological strains during H-bath and showering, indicated by HR, double products and body weight loss, were smaller than W-bath. However, differences in the room temperatures had a great influence on body temperature changes after H-bath and subjective responses after showering. Colder room temperatures made it more difficult to retain body warmth after H-bath and created thermal discomfort after showering. It is particularly important for H-bath and showering to maintain an acceptable temperature in the dressing room and bathroom, in order to bathe comfortably and ensure warmth.

Acknowledgements The authors wish to thank the subjects for their cooperation. This study was supported in part by a grant from Sekisui Hometechno. Co., LTD.

References
Jonston BL, Watt EW, Fletcher GF (1981) Oxygen...
consumption and hemodynamic and electrocardiographic responses to bathing in recent post-myocardial infarction patients. Heart and Lung 10: 666–671
Winslow EH, Lane LD, Gaffney FA (1985) Oxygen uptake and cardiovascular responses in control adults and acute myocardial infarction patients during bathing. Nursing Research 34: 164–169

Received: March 11, 2002
Accepted: August 21, 2002
Correspondence to: Yutaka Tochihara, Department of Ergonomics, Kyushu Institute of Design 4–9–1 Shiobaru, Minami-ku Fukuoka 815–8540, Japan
Tel: +81–92–553–4522
Fax: +81–92–553–4569
e-mail: n-hashi@rms.kyushu-id.ac.jp