Does Wearing Thermal Underwear in Mild Cold Affect Skin Temperatures and Perceived Thermal Sensation in the Hands and Feet of the Elderly?

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Abstract The present study was to investigate whether increasing thermal insulation affects thermal sensation in the hands and feet; and whether aging is an influential factor in the relationship between thermal responses and subjective thermal perceptions. Six young males (YM), 5 young females (YF), 6 elderly males (OM), and 6 elderly females (OF) volunteered as subjects. Subjects conducted two trials at a constant air temperature of 19°C: One condition included thermal underwear (19CUW) while the other did not (19C). The results showed that (1) rectal temperature (T_{re}) did not show any significant differences between conditions with and without thermal underwear. The T_{re} of the OF was greater than that of the YF (p<0.05) for the 19C condition, while the young and elderly male groups showed similar values. (2) The hand and foot skin temperatures (T_{hand}, T_{foot}) were greater in the OF than in the YF group for the 19C condition (p<0.001). (3) For overall thermal sensation, the OF group was less sensitive to differences between the 19CUW and 19C condition, when compared with the old male and young groups. (4) For thermal sensation in the hands and feet, the elderly groups were less sensitive than the YF. In particular, all elderly females felt the hands were thermally neutral, even in the 19C condition. (5) Hand thermal sensation for the OF group appeared to be irrelevant to T_{hand}. (6) Thermal preference of the elderly groups did not change significantly after adding thermal underwear compared to the young group. In conclusion, wearing thermal underwear in mild cold did not affect local skin temperatures and thermal sensation in the hands and feet for the elderly male and female groups. Adding thermal underwear in mild cold affected the hand skin temperature and thermal sensation of the young female group. In particular, elderly females had specific features concerning local skin temperatures and thermal sensations distinguished from elderly males and young groups. J Physiol Anthropol 27(6): 301–308, 2008 http://www.jstage.jst.go.jp/browse/jpa2 [DOI: 10.2114/jpa2.27.301]

Keywords: mild cold, thermal sensation, thermal preference, ageing, hand and foot skin temperature, rectal temperature

Introduction

There have been significant relationships reported between thermoregulatory responses and thermal sensations. The relationships have been applied to develop comfort zones for various thermal environments and populations. Thermal comfort and thermal sensation are qualitative and subjective concepts, while thermophysiological responses are quantitative with objective measurements. Furthermore, thermal comfort is more involved in multidimensional processes when compared to thermal sensation. Thermal comfort is likely to be connected with non-thermal factors such as lighting, illumination, odors, color, noise, age, gender, and previous individual experiences, as well as the six basic thermal parameters: air temperature, humidity, radiant temperature, air speed, clothing insulation, and metabolic rate (Candas and Dufour, 2005; Fanger, 1970; Parsons, 1993), whereas thermal sensation is more strictly associated with thermal stimuli through peripheral and central thermal receptors in the human body.

Although thermal perception is not strictly correlated to thermoregulatory responses due to individual characteristics and a number of environmental factors, it is considered that there are significant relationships in reasonable ranges. In particular, it is important to investigate comfort zones for the elderly (Collins et al., 1981; Tochihara et al., 1993) as the elderly may be more susceptible to hypothermia during periods of endogenous and/or exogenous thermal stress (Anderson et al., 1996). The reduced thermoregulatory responses and reduced functions of thermal perception in the aged may blunt their thermoregulatory behavior to cold stress, and thus facilitate the onset of hypothermia in daily life (Natsume et al.,...
In general, it has been considered that the elderly prefer higher indoor temperatures in winter, but this is still controversial. Although the thermal vulnerability of elderly people in their homes can be due to a lifestyle involving low activity, poor thermoregulatory responses, and blunted perception of temperature changes (Collins and Hoinville, 1980), some researchers have reported that age has no significant effect on the preferred/neutral ambient temperature (Langkilde, 1977; Fanger, 1970).

Behavioral temperature regulation originates from thermal stimuli which are perceived at the periphery, integrated at the central level and leading to actions or reactions (Candas and Dufour, 2005). The hands and feet have a higher surface area to unit body mass and capillaries are concentrated in the hands and feet. These anatomical characteristics make hands and feet more efficient for heat exchange. In addition, the hands are in directly exposed to the air in daily life. Behavioral temperature regulation such as clothing adjustment/indoor heating/change of posture affects the preferred indoor temperature. The range of preferred temperature largely varies according to time and place. In the early 20th century, comfortable indoor temperature in winter was 18–21°C (Nevins and Gagge, 1972). Collins (1986) noted that the thermally optimum temperature in both young and old groups when sitting wearing 1.0 clo of insulation was found to be 21.1±2.9°C. The World Health Organization (WHO) recommended a minimal indoor temperature of 18°C and a 2–3°C warmer minimal temperature for rooms occupied by sedentary elderly (Collins, 1986). Today, the preferred indoor temperature in winter is approximately 23–27°C, depending on air conditioning, clothing insulation, and climate (Tanabe, 1990; Montoye et al., 1996). Even when the stress of cold is mild, the elderly group still remains vulnerable, because low temperatures may cause reduced resistance to secondary infections following colds or influenza (Collins, 1986).

Currently, the optimal indoor temperature is recommended in the view of energy saving and health improvement through natural adaptation by season. To achieve this goal, the Korean government recommends an indoor temperature of 18–20°C in public places during winter while adding thermal underwear with long sleeves and legs (Choi, 2006). Because thermal sensation in the hands and feet plays an important role in behavioral thermal regulation and work productivity, additional clothing insulation on regional body areas would be a crucial factor, decisive to thermal sensations over the whole body and in local body regions. In addition, subjective perception at a given air temperature and clothing insulation may be dependent on ageing. Practically speaking, it is considered that Korean elderly females’ hands have been more exposed to cold water due to housework such as washing and cleaning when compared to elderly males. There are few studies concerning whether adding thermal underwear during mild cold affects thermoregulatory responses and thermal perception in the hands and feet of the elderly.

Therefore, the present study was aimed at investigating whether 1) wearing long-sleeved and legged thermal underwear affects skin temperatures and thermal sensation in the hands and feet, and 2) ageing is an influential factor in the relationship between skin temperatures and subjective thermal perception.

Methods

Subject

A total of 23 subjects served as volunteers in the present study: Six young males (YM: 20.3±0.5 yrs, 173±1.7 cm, 66.7±9.3 kg, BMI 22±3, BSA 1.81±0.1 m²), 5 young females (YF: 21.0±1.4 yrs, 160±5.4 cm, 53.6±6.4 kg, BMI 21±1, BSA 1.56±0.1 m²), 6 elderly males (OM: 75.3±3.5 yrs, 164.0±7.9 cm, 60.7±1.2 kg, BMI 22±6, BSA 1.67±0.1 m²), and 6 elderly females (OF: 67.7±4.1 yrs, 162.3±6.3 cm, 59.7±3.9 kg, BMI 23±2, BSA 1.65±0.1 m²). No one was an athlete, but all were healthy without any disease. Young females conducted their participation in the follicular phase to avoid the effect of the menstrual cycle. All elderly females were in the menopause and none took female sex hormones. Prior to their participation, written and informed consents was obtained from all subjects.

Experimental conditions and garments

Two experimental conditions were simulated in the climatic chamber: the 19C condition and the 19CUW condition. The 19C condition was a condition analogous to wearing light clothing inside a building at the air temperature of 19°C recommended for winter in Korea (total garment mass 1,202 g=cotton briefs, 67 g+cotton T-shirts with long sleeves, 610 g+cotton long pants, 464 g+cotton socks, 61 g+shoes). The total thermal insulation was estimated at approximately 0.7–0.8 clo (Choi, 2006). The 19CUW condition was another analogical condition in which occupants added long sleeves and legged thermal underwear at an air temperature of 19°C (total garment mass 1,506 g=underwear with long sleeves and long legs 304 g+the same clothing ensembles as the 19C condition). The total thermal insulation was estimated at approximately 1.1–1.2 clo (Choi, 2006). The climatic chamber in both conditions was maintained within a relative humidity of 40%RH and the air speed less than 0.3 m/s.

Measurement and experimental procedures

Skin temperature (Tsk) was measured on seven body sites (the forehead, abdomen, forearm, hand, thigh, calf, and foot) at one minute intervals using a thermometer (LT 8A, Gram Corp., Japan) and mean skin temperature (Tsk) was estimated with the DuBois equation:

\[ T_{sk} = 0.07 \times T_{forehead} + 0.35 \times T_{trunk} + 0.14 \times T_{arm} + 0.05 \times T_{hand} + 0.19 \times T_{thigh} + 0.13 \times T_{calf} + 0.07 \times T_{foot} \]  

(1)

Rectal temperature (Tr) was measured at a depth of 13 cm in the rectum with a rectal probe every one minute (LT 8A, Gram
Corp., Japan). Thermal sensation on the whole body, hands, and feet was recorded with the seven categorical scales of ISO 10551 (1995): “Hot (3), warm (2), slightly warm (1), neutral (0), slightly cool (−1), cool (−2), cold (−3)”\). The subjective measurements were taken every 10 min starting at 0 min with a total of 13 times obtained for 120 min. Thermal preference (ISO 10551, 1995), “Warmer (1), No change (0), and cooler (−1)” was measured in the same way as thermal sensation. The numbers for each description were not presented when subjects were marking, and were added when the data was analyzed. After subjects mounted instruments and donned experimental garments, they sat in a thermally neutral environment for 60 min and then went to the climatic chamber controlled at 19°C. Subjects sat on a wooden chair and were exposed to the environment for 120 min. Each subject conducted a total of 4 trials in the present study. We repeated all trials to check the stability of thermal physiological responses, especially for the elderly groups (23 subjects×2 conditions×2 repetition=92 times). To avoid the effect of circadian rhythm, all experiments started at the same time of day. To avoid the effects of seasonal adaptation, all experiment were conducted during winter (December to February).

**Statistics**

All results were presented as mean and standard deviation (SD) for 120 min. SD in Figs. 1 and 2 means the SD of averaged values of repeated measurements. Subjective measurements were also expressed as a percentage (%) of respondents for each description. To test the differences among the four groups, ANOVA (SPSS v. 12.0) was conducted with the averaged values of repeated measurements. With regard to items showing significant differences, Duncan’s post hoc test was conducted. Pearson’s correlation coefficients were obtained between body temperatures and thermal sensation by age and gender. For correlation analysis, the individual data of repeated measurements were analyzed. The significant difference was set at $p<0.05$.

**Results**

**Rectal and skin temperatures**

Rectal temperature ($T_{re}$) did not show any significant differences between the 19C and 19CUW conditions. $T_{re}$ for elderly females was greater than that of young females in the 19C condition ($p<0.05$), whereas there was no significant difference between young and elderly males (Fig. 1). On average, mean skin temperature ($T_{sk}$) was a little greater in the 19CUW than in the 19C, but this was not significant. There was no significant difference in $T_{sk}$ by age and two conditions (Fig. 1). The hand and foot skin temperatures did not show any

![Fig. 1 Average of rectal, mean skin, hand and foot temperature for 120 min (19C: Condition without underwear in 19°C air temperature; 19CUW: Condition with underwear in 19°C air temperature; YM: Young males; YF: Young females; OM: Elderly males; OF: Elderly females; $T_{re}$: rectal temperature; $T_{sk}$: mean skin temperature; $T_{hand}$: Hand skin temperature; $T_{foot}$: Foot skin temperature. *$p<0.05$, **$p<0.01$, ***$p<0.001$).](image1)

![Fig. 2 Average of overall body, hands and feet thermal sensation obtained for 120 min (19C: Condition without underwear in air temperature of 19°C, 19CUW: Condition with underwear in air temperature of 19°C, YM: Young males, YF: Young females, OM: Elderly males, OF: Elderly females. *$p<0.05$, **$p<0.01$, ***$p<0.001$).](image2)
significant difference by adding thermal underwear except in the case of the young females’ hand skin temperature ($p<0.01$). The hand and foot skin temperature were greater in elderly females than in young females in the $19\text{C}$ condition ($p<0.001$, Fig. 1). For male groups, the hand and foot skin temperature did not show any differences by age (Fig. 1).

**Perceived thermal sensation**

For overall thermal sensation, the young and elderly male groups felt cooler in the $19\text{C}$ condition than in the $19\text{CUW}$ condition ($p<0.01$), but the elderly female group perceived the two conditions as similar thermal environments (Fig. 2). The hand and foot thermal sensations did not show any significant difference by adding thermal underwear except in the case of the young females’ hand thermal sensation. Elderly females were less sensitive than young females in the hands and feet thermal sensation. In particular, all elderly females perceived “the hands are thermally neutral”, even in the $19\text{C}$ condition. On the other hand, male groups did not show clear difference by age.

**Correlation between body temperatures and thermal sensation**

Table 1 shows rectal and mean skin temperature had weak correlations with overall thermal comfort, but the correlations do not seem to have significant meaning, because the correlation coefficients were negative or positive according to groups and conditions. Hand thermal sensation for the elderly female group seems to be irrelevant to the hand skin temperature (Table 1).

**Relationship between hand and foot skin temperatures**

Figure 3 showed that the hand and foot skin temperature had significant relationships, but there did not seem to be

### Table 1  Correlation coefficients between body temperatures and thermal sensation by age and gender ($T_{\text{re}}$ vs. Overall thermal sensation; mean $T_{\text{sk}}$ vs. Overall thermal sensation; $T_{\text{hand}}$ vs. Hand thermal sensation; $T_{\text{foot}}$ vs. Foot thermal sensation)

<table>
<thead>
<tr>
<th></th>
<th>19C</th>
<th>19CUW</th>
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<tr>
<td></td>
<td>YM</td>
<td>YF</td>
<td>OM</td>
<td>OF</td>
<td>Total</td>
<td>YM</td>
<td>YF</td>
<td>OM</td>
<td>OF</td>
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<tr>
<td>$T_{\text{re}}$ vs. $T_{\text{overall}}$</td>
<td>0.192*</td>
<td>−0.264**</td>
<td>0.375**</td>
<td>0.583**</td>
<td>0.273**</td>
<td>−0.054</td>
<td>−0.413**</td>
<td>0.383**</td>
<td>0.428**</td>
</tr>
<tr>
<td>$\bar{T}<em>{\text{sk}}$ vs. $T</em>{\text{overall}}$</td>
<td>0.320**</td>
<td>−0.142</td>
<td>0.320**</td>
<td>0.161*</td>
<td>0.015</td>
<td>0.253**</td>
<td>0.042</td>
<td>0.019</td>
<td>−0.315**</td>
</tr>
<tr>
<td>$T_{\text{hand}}$ vs. $T_{\text{hand}}$</td>
<td>0.511**</td>
<td>0.157</td>
<td>−0.171*</td>
<td>N</td>
<td>0.329**</td>
<td>−0.199</td>
<td>−0.119</td>
<td>N</td>
<td>N</td>
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<tr>
<td>$T_{\text{foot}}$ vs. $T_{\text{foot}}$</td>
<td>0.532**</td>
<td>−0.354**</td>
<td>−0.081</td>
<td>0.241**</td>
<td>0.260**</td>
<td>0.471**</td>
<td>−0.456**</td>
<td>−0.244**</td>
<td>−0.210**</td>
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19C: Condition without underwear in air temperature of $19\text{C}$, 19CUW: Condition with underwear in air temperature of $19\text{C}$, YM: Young males, YF: Young females, OM: Elderly males, OF: Elderly females. N means that it was not possible to calculate the correlation, because the numbers of thermal sensation were all the same. * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

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**Fig. 3** Relationship between hand and foot skin temperature by age and gender (19C: Condition without underwear in air temperature of $19\text{C}$, 19CUW: Condition with underwear in air temperature of $19\text{C}$, YM: Young males, YF: Young females, OM: Elderly males, OF: Elderly females).
significant differences between the 19C and 19CUW conditions. The range of local skin temperatures was the narrowest in the elderly female group (Fig. 3).

**Relationship between hand and foot thermal sensations**

Figure 4 showed that the hand and foot thermal sensations had significant relationships for the young groups, not for the elderly groups. The young groups showed a much closer relationship between the hand and foot thermal sensations than the elderly groups. Elderly females indicated all “neutral” hand thermal sensation in both conditions, while the foot thermal sensation showed some distributions.

**Thermal preference**

By adding thermal underwear, the young group expressed more satisfaction than in the 19C condition. However, the thermal preference of the elderly groups did not seem to change by adding thermal underwear. Even in the 19CUW condition, more than 80% of the elderly male group responded “Warmer” (Fig. 5).

**Discussions**

The aims of the present study were to investigate whether 1) wearing long-sleeved and legged thermal underwear affects skin temperatures and thermal sensation in the hands and feet, and 2) ageing is an influential factor in the relationship between skin temperatures and subjective thermal perception. Simply speaking, adding thermal underwear affected the hand skin temperature and thermal sensation of the young female group, but we could not find significant effects on the hands/feet skin temperature and thermal sensations of the elderly groups. The thermo-physiological gap between the young and elderly groups was greater in females than in males. In other words, the present results showed that the young female group was thermally more sensitive than the young male group; the elderly female group was more thermally insensitive than the elderly male group. In particular, elderly females had specific features concerning the hands and feet thermal sensations distinguished from the young female group.

First, $T_{re}$ of the elderly female group in the 19C condition was greater than that of the young females, while $T_{sk}$ showed
similar values. This means that a core-shell temperature gradient was greater in the elderly females than the young females. This result is contradictory to previous reports suggesting that a diminished core-shell temperature gradient for the elderly may provide useful clinical signs of an associated thermoregulatory failure (Collins et al., 1977). Ageing may be associated with a decreased ability to maintain body core temperature during cold exposure, but it may be dependent on the intensity of cold or the duration of cold exposure or gender. Inoue et al. (1992) reported that the decrease in $T_c$ was significantly greater for older men during cold exposure, but this trend was not apparent during 17°C exposure compared to their responses during the 12°C exposure. Also, Collins (1986) described that deep body temperature does not usually fall until resting clothed elderly people are exposed for two or more hours to an ambient temperature of 9°C or below. However, it needs to be mentioned that our study was not a longitudinal study which follows the ageing effects of individuals, but a cross-sectional study which compares different age groups.

Second, the hand and foot temperatures were approximately 3°C greater in the elderly female group than in the young female group for the 19°C condition. According to Tochihara et al. (1993), the finger skin temperature of elderly females during cold exposures of 10°C was significantly higher than those of young females. Wagner et al. (1974) reported that finger blood flows were higher in older men than in boys at the $T_{an}$ of 16–17°C. Collins et al. (1977) concluded that vasoconstriction in the hand deteriorated with age through a 4-year-follow-up longitudinal study with a group of the elderly. Younger subjects rapidly reacted to cold stress by increasing their metabolic rates and minimizing peripheral heat loss by rapid cutaneous vasoconstriction, whereas older men did not increase their metabolic rates to the same extent as younger subjects, and they were less able to maintain their body heat stores by cutaneous vasoconstriction (Wagner et al., 1974). The elderly have a less effective response to cold exposure with a less effective peripheral vasoconstriction (Anderson et al., 1996). While the present results from female groups are supported by previous studies, the results obtained from the male groups seem to show some inconsistency with previous studies. Thus, it is necessary to investigate the thermophysiological discrimination between elderly males and females.

Third, the present study showed that the elderly female group was less sensitive for the hands and feet thermal sensation than the young female group. It is noteworthy that all elderly female subjects felt that the hands were thermally neutral in both conditions. It is well documented that peripheral temperature perception is impaired and behavioral temperature regulation becomes less efficient in elderly people (Collins, 1986). The elderly are more likely to maintain a lower ambient temperature in their homes compared with younger individuals, suggesting decreased ability to perceive cold. Among the four groups in the present study, the least sensitive group in the hand thermal sensation was the elderly female group, while the most sensitive group was the young females. Generally, older subjects express little or no discomfort during the cold exposures in contrast to the marked complaints of discomfort among the younger subjects (Krag and Kountz, 1950; Horvath et al., 1955). Some elderly subjects experienced feelings of warmth in quite cold environments (Watts, 1971).

Fourth, it has been generally considered that the elderly prefer higher indoor temperatures in winter, but this is still contradictory. The present study found that the elderly male group responded more with “Warmer” preferences than the young male group. When considering rectal, mean skin, hand and foot skin temperature obtained from the present results, the reason why the elderly males expressed more preference about “Warmer environment” than young males does not seem to be caused by differences in the skin and core temperature regulation between the elderly and young male groups. The present result seems to be contradictory to several previous studies. Collins and Hoinville (1980) reported that the preferred temperature was similar between the elderly and young group at an air temperature of 21.1°C. Rohles (1969) also reported that there was no significant difference in the preferred temperature by age, and Fanger (1970) noted that a neutral temperature was similar between the old and young. However, that kind of inconsistency may result from confusion in the interpretation of results. That is, do elderly males become to prefer warmer thermal environments with ageing? Either way, do a higher percentage of elderly males prefer a certain warm temperature in a mild cold? The present results only mention the latter.

In addition, the thermal preference of the elderly groups did not change largely by adding thermal underwear in mild cold when compared to the young group. This means that the elderly group was less sensitive to the change of thermal environment. The elderly who are less cognizant of changes in environmental temperature may fail to make appropriate behavioral modifications to prevent hypothermia. The thermal insensitivity of the elderly has been well documented (Collins et al., 1981; Edholm, 1978; Natsume et al., 1992; Watts, 1971). Cowburn and Fox (1974) observed that older individuals are less able to discriminate between temperature differences than young adults. Young adults were able to discriminate between a temperature difference of 0.5°C, while individuals over the age of 65 failed to recognize temperature differences of up to 5.0°C (Anderson et al., 1996). Collins et al. (1977) found that twenty young subjects could perceive mean temperature differences of $0.8 \pm 0.2°C$ (cold), while elderly subjects could discriminate only between a mean temperature difference of $2.3 \pm 0.5°C$ (cold). There is an age-related decline in autonomic nervous function which leads to impairment of thermoregulatory capacity in a high proportion of old people. Natsume et al. (1992) found that thermal discrimination in men is decreased with increasing age. The fluctuation of preferred ambient temperature was significantly wider in the older group. This is ascribed to a decrease in the ability to
discriminate temperature differences. This effect may be attributed in part to degeneration of thermoreceptors, and to diminution of the sensitivity of functioning nerve fibers due to a decrease in oxygen supply to cutaneous tissues in the cold (Natsume et al., 1992). Cutaneous cold receptors are less densely distributed in elderly men (Murata and Iriki, 1974).

Lastly, it is necessary to mention the thermophysiological differences between the elderly males and females, because the elderly female group showed featured characteristics separated from the elderly male group in the present study. The representative differences would be the menopause of elderly females. Even though the hot flashes that accompanied thermal responses such as the increase of sweating and heart rate appear at in the beginning of the menopause (Griffiths, 1994; Ivarsson et al., 1998), the change of reproductive hormone levels due to the menopause resulted in the change of skin blood circulation (Charkoudian, 2003). Because all elderly female subjects who participated in the present study were in the menopause, the higher hand skin temperature may be related to the change of female sex hormones due to menopause. Meldrum et al. (1979) measured finger skin temperature as an indicator for the hot flashes with women in the menopause and they reported that finger skin temperature was on average 2.7°C higher at the time of hot flashes. Moreover, they also noted that the finger skin temperature was higher in women in the menopause than in young females or elderly females treated by estrogen. According to the previous reports, it could be concluded that the higher hand temperatures in the elderly female group than that of elderly males in the present study resulted from the deterioration of skin blood vessel control due to ageing, and the change of reproductive hormone levels in the menopause.

Having asserted the above, it is necessary to mention several limitations in the present study: (1) The first limitation is the small sample size of each group. Because of the small sample sizes, caution should be taken when generalizing these results. Even though other researchers conducted their studies on the elderly and young with similar sample sizes (Anderson et al., 1996; Inoue et al., 1992; Choi et al., 2003), broader generalizations cannot be made. (2) The measurement of perceived thermal sensation in the present study was recorded using the seven categorical scales from ISO 10551 (1995). Some of the insignificant findings for the elderly in this experiment may be due to the inherent insensitivity of the 7-point categorical scale or the insensitivity of the elderly population in perceiving changes in temperature. More sensitive scales may uncover more significant results. For instance, the use of combined categorical scales and Visual Analog Scales (VAS) to assess thermal perception in thermal physiological research has been growing (Arens et al., 2006; Davey et al., 2007; Frank et al., 2000; Greenspan et al., 2003; Nagano et al., 2005) due to the increased sensitivity of these scales versus categorical scales. On the other hand, it has been reported that elderly respondents may not be as familiar with the VAS for the measurement of affective subjective perception (Lukacz et al., 2004). Both insensitivities in the perception scale itself and the perception capability of the elderly would be relevant to the results of perceived thermal sensation obtained in the present study. This issue is worthy of note for further investigations into the elderly.

Conclusions and Suggestions

Our original question was whether wearing thermal underwear in mild cold affect skin temperatures and perceived thermal sensation in the hands and feet of the elderly. The background of the question was to find optimal recommendations for both comfort support of the elderly and energy saving in homes in the winter. Young/elderly and male/female subjects participated as subjects in the present study. We found that wearing thermal underwear in mild cold did not improve local skin temperatures and thermal sensation in the hands and feet of the elderly. Adding thermal underwear in mild cold affected the hand skin temperature and hand thermal sensation of the young female group. In particular, elderly females had specific features in the hands/feet thermal sensations distinguished from elderly males and young groups. Concerning the development of thermal sensation voting scales for the elderly and the differences of thermal discrimination between elderly males and females, further studies are required.

Acknowledgement We would like to express our thanks to Drs. Victor S. Koscheyev and Gloria R. Leon. We thank Joe Warpeha and Jung-Hyun Kim for their cordial assistances. This work was supported by Kyobo Environmental Research and partially by The Second Stage of BK 21.

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Received: January 9, 2008
Accepted: September 10, 2008
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