THERMAL SENSATION AND THERMOREGULATION IN ELDERLY COMPARED TO YOUNG PEOPLE IN JAPANESE WINTER SEASON

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ABSTRACT
This paper presents the results of an experimental study on the thermal comfort requirements of elderly people compared to college-age people. Subjects were exposed to five conditions: 23^{o}C, 25 ^{o}C, 27 ^{o}C, 29 ^{o}C, 31 ^{o}C with 60%Rh under insensible air flow. We obtained responses to a thermal comfort questionnaire and thermophysiological data to better clarify the relationship between thermophysiological responses and thermal comfort. In all experimental conditions there was little difference in EWL between the younger and older group although the metabolic rate for the elderly group was only 70% that of the younger group. Overall elderly people's reported thermal sensations were cooler than the younger people. The elderly subjects' mean skin temperature was higher at 23^{o}C and lower at 31^{o}C than the younger subjects. It appears that, compared to younger people, elderly people have reduced warmth sensitivity in cold seasons and similarly reduced cold sensitivity in hot seasons.

INDEX TERMS
Thermal comfort, Elderly people, Thermal sensation, PMV, Mean skin temperature

INTRODUCTION
A recent field survey found that the living room air temperature during the winter where only elderly people were living was 4^{o}C lower than that in homes where elderly people lived together with a younger family. It was found that not only do young people wear less clothing than elderly people but also that young people prefer a warmer environment (Tsuzuki et al. 2001). The purpose of the current study is to first, investigate the preferred temperature of Japanese elderly people in the winter season. And second, to compare the physiological responses in elderly and younger people wearing an uniform clothing. We collected thermophysiological data to better clarify the relationship between thermoregulation and thermal comfort.

METHODS
Test chamber
The experiments were carried out in climatic chambers. The climatic chambers were 5.0m x 4.5m x 2.7m in Advanced Institute of Industrial Science and Technology, Tsubuka Japan and 3.2m x 4.3m x 2.7m in Japanese Industrial Standards Center, Tsukuba, Japan. The five environmental conditions (23^{o}C/60%Rh, 25^{o}C/60%Rh, 27 ^{o}C /60%Rh, 29 ^{o}C/60%Rh, 31 ^{o}C /60%Rh) were estimated to compare thermal comfort and thermoregulation in the thermoneutral zone in winter season. Air velocity (v) was maintained at less than 0.2 m/s. And mean radiant temperatures were equal to the ambient temperatures because the walls were covered by cloth curtains.

Subjects
One hundred and nine elderly and 100 young people were recruited through a local association for the elderly and a human resource company recruited the young people. One requirement for participation in this study was that the subjects must be healthy and undergo regular examination by a medical doctor. It was also stipulated that participants must arrive and depart from our laboratory by a taxi or car to prevent cold in the winter.

Table 1. Physical characteristics of subject groups

	number	Age years	Height [illegible]	Wight [illegible]	BSA* (m^2)
Elderly	109	72.4 (5.3)	152.5 (8.5)	55.7 (8.6)	1.48 (0.14)
Men	52	71.9 (5.2)	159.2 (5.1)	60.1 (6.8)	1.58 (0.09)
Women	57	72.8 (5.4)	146.4 (5.9)	51.7 (8.1)	1.39 (0.12)
Young	100	23.5 (2.2)	165.2 (8.1)	57.8 (10.7)	1.59 (0.17)
Men	50	23.1 (1.9)	171.7 (5.4)	64.9 (10.2)	1.71 (0.13)
Women	50	23.8 (2.4)	158.8 (4.5)	50.7 (4.9)	1.46 (0.08)

* Body surface area (m^2)= 0.008883 x Height $^{0.663}$ x Weight $^{0.444}$

Procedure
The duration of the experiment for each subject was 180minutes. In the first 30 minutes, the subject listened to an explanation of the experiment, changed their clothes and were set up with individual thermister sensors. After the 30-minutes preparation period, the first questionnaire for thermal comfort was distributed. Subsequently, the subjects were interviewed at 30 minute intervals. Subjects were sedentary, sitting quietly, talking and reading magazines. Two to four subjects participated in the experiment at the same time. Physical characteristics of the subjects including height, weight, and body fat content were measured by standard techniques. The physical characteristics of the subjects are described in Table 1. A questionnaire was distributed during the experiment to gather personal characteristics of age, birthplace, primary place of residence, occupation before retiring, daily activities or present occupation. In addition, we obtained responses to a thermal comfort questionnaire which contained questions about thermal sensation and thermal comfort sensation for the whole body, local thermal sensation for specific body areas, thermal acceptability and thermal preference.

Clothing for the experiment consisted of cotton sweatshirts, sweatpants and calf-length socks of the same design and materials, commonly used. These were obtained in different sizes for the experiment. The subjects wore the clothing over underwear. The clo value for the standardized outfit was measured at 0.63 clo using thermal manikin technique. Skin temperatures were taken every 30 seconds at eight extremities of the body (forehead, abdomen, back, forearm, hand, thigh, calf and foot) using thermistor sensors taped to the skin. Mean skin temperature (Tsk) was calculated according to the following equation of Hardy & DuBois (1937): Tsk=0.07・forehead+0.35・abdomen+0.14・arm+0.05・hand+0.19・thigh+0.13・calf+0.07・foot.

The heart rate (HR) and blood pressure was measured at 60 minute intervals. We used two methods to determine the metabolic rate, the Douglas bag method was used for the elderly subjects. Exhaled gas was collected in a Douglas bag during a period of 5 to 10 minutes during the experiment. The metabolic rate was determined by measuring O_2 consumption, CO_2 production and the expired gas volume. Exhaled gas volume for the younger subjects was measured by a gas meter attached to a mask which collects the expired gas. The gas meter was connected to a PC and recorded. The body mass was measured every hour with an accuracy of +/-1g and the evaporative water loss(EWL) was determined from the change in body mass as a factor of time and body surface area. The subjects evaluated the thermal conditions using the categories shown in Table 2 at 30 minutes intervals.

Table 2. A questionnaire

Thermal sensation	**Evaluation of thermal environment and preference**
▪ : Very hot (+4)	Is this environment thermally acceptable?
▪ : Hot (+3)	▪ : Acceptable (1) ▪ : Unacceptable (0)
▪ : Warm (+2)	
▪ : Slightly warm (+1)	Is this environment thermally satisfied?
▪ : Neutral (0)	▪ : Satisfied (1) ▪ : Dissatisfied (0)
▪ : Slightly cool (-1)	
▪ : Cool (-2)	Would you like a warmer or cooler environment?
▪ : Cold (-3)	▪ : Warmer (1) ▪ : No change (0) ▪ : Cooler (-1)
▪ : Very cold (-4)	

RESULTS

Figures 1 and 2 show the time course of oral temperature and mean skin temperature measurements respectively. The results of the three conditions in this study are illustrated. At 27°C oral temperatures remained constant for both groups. However, at 31°C the oral temperature for the elderly group was higher than the young group. At 23°C the oral temperature for elderly group decreased more steeply compared to the young group. Mean skin temperatures at 27°C conditions revealed no difference between young and elderly groups. However, the elderly subjects' mean skin temperature was higher at 23°C and lower at 31°C than the younger subjects.

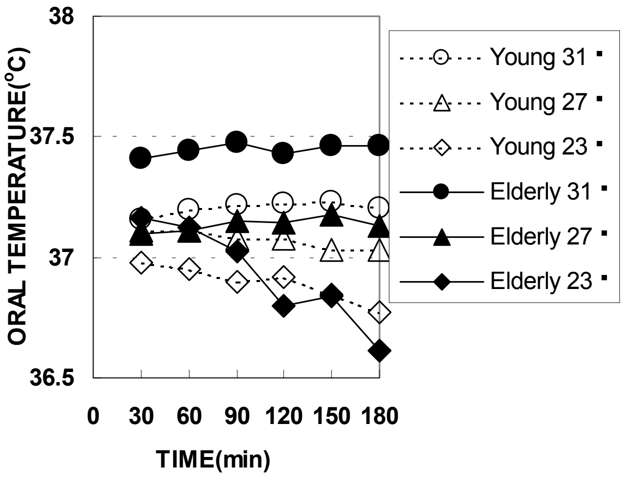

Figure 1. Oral temperature

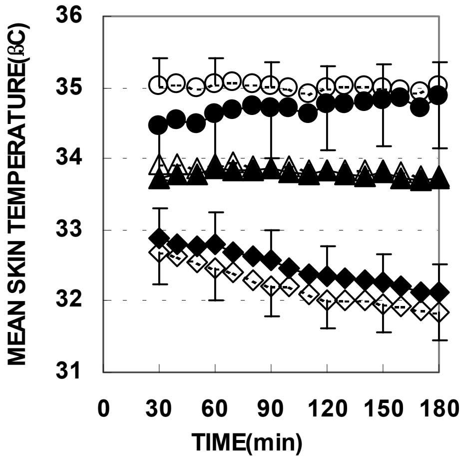

Figure 2. Mean skin temperature

Figures 3 and 4 show metabolic rate and evaporative water loss (EWL) results respectively. No change in mean metabolic rate was discovered among the 5 environmental conditions. However, the metabolic rate for the elderly group was only 70% that of the younger group throughout the experiment. EWL increased in the 31°C for both the elderly and the younger groups although no significant difference was observed between the 23°C and the 29°C conditions or between the two groups.

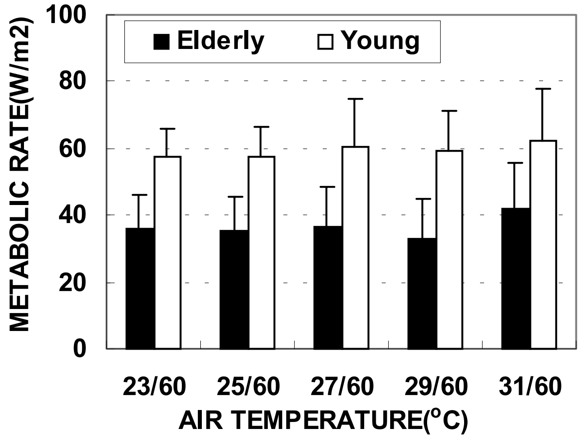

Figure 3. Metabolic rate

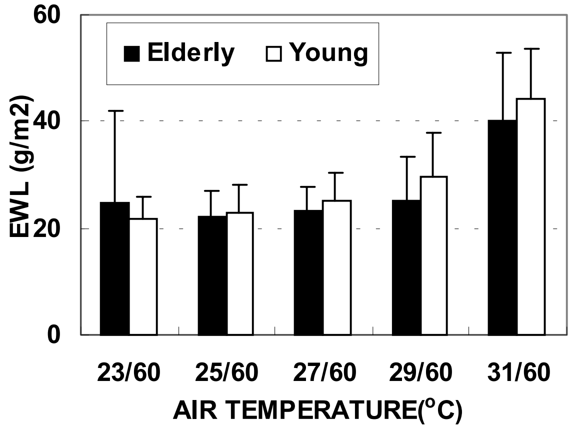

Figure 4. Evaporative water loss

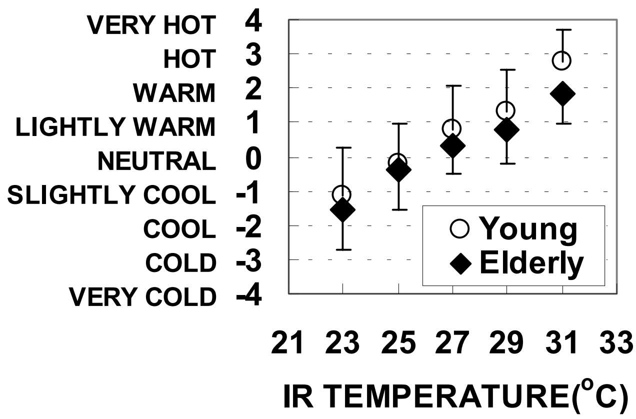

Figure 5. Relationship between air temperature and thermal sensation

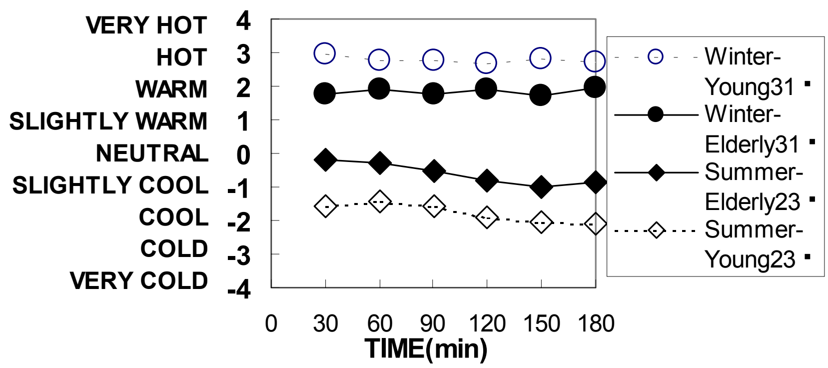

Figure 6. Time course of average thermal sensations for elderly and young groups

The average of last two recordings of thermal sensation during the 180 minute exposure is shown in Figure 5. The elderly subjects' reported thermal sensations were cooler than the young group in all five conditions. The biggest difference between the young and elderly groups is shown under the 31 °C exposure. Figure 6 compares the time course of the thermal sensations for the 23 °C and 31 °C conditions in both the summer and winter experiments (Tsuzuki 2001). In our previous summer data, the average thermal sensation for the elderly at 23 °C changed from 0 to –1 during the 180-min exposure. Whereas the younger subjects' thermal sensation changed only from -1.5 to -2. At 31°C, in the present study, the average thermal sensation for the elderly subjects was stable and 1 category higher than that of the younger subjects.

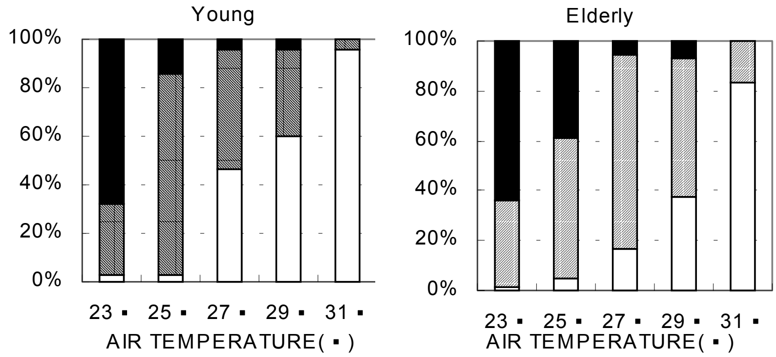

Figure 8. The rate of thermal preference for elderly and young groups

Figures 7 and 8 show the rate of "unacceptable" and that of thermal preference respectively. At 25 °C and 27 °C the unacceptable rates were less than 5% for both the elderly and young groups. However, at 23 °C, 29 °C and 31 °C the rating of "unacceptable " rose to over 20%. With respect to thermal preference at 25 °C for young group "no change " was reported by 82% of the subjects. 78% of the elderly subjects reported "no change" at 27 °C.

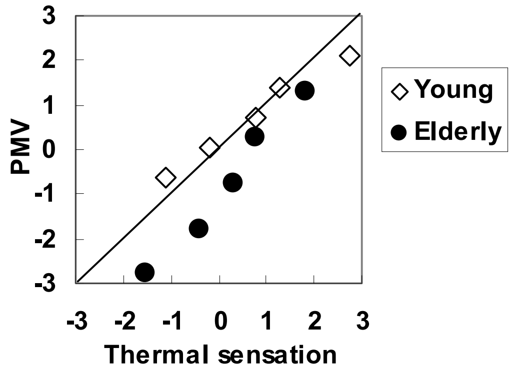

Figure 9 Relationship between thermal sensation and PMV

Figure 9 shows the relationship between thermal sensation and PMV in the elderly and younger subjects. PMV was determined from the actual metabolic rate, clothing insulation, and environmental conditions. For the young group, the relationship between actual thermal sensation and calculated PMV was pretty good except at 31 °C. However, for the elderly group under the 27 °C condition, the calculated PMV was colder than the reported thermal sensation.

DISCUSSION

The elderly subjects' reported thermal sensations were cooler than the young counterparts at 31 °C. However in the summer experiment the 23 °C environment promoted a warmer thermal sensation from the elderly group compared to the younger subjects. It appears that, compared to younger people, elderly people have reduced warmth sensitivity in cold seasons and also cold sensitivity in hot seasons. With respect to physiological responses, the elderly subjects' skin temperatures remained lower at 31^{o} C and higher at 23^{o}C, perhaps because elderly subjects' skin vasodilatation and vasoconstriction are both weaker than younger subjects. In addition the elderly subjects' vasodilatation and vasoconstriction started more slowly than the young subjects. From the summer data recorded previously, the elderly subjects' skin vasoconstriction was weaker than the young subjects at 23 ^{o}C. In this study, the opposite was found. Further, the elderly subjects' oral temperature was higher at 31 ^{o}C and lower at 23 ^{o}C than the young subjects. As in our summer study, the metabolic rate for the elderly group was only 70% that of the younger group. In addition there was little difference in EWL between the younger and elderly subjects. Oral temperature appears to be unaffected by the thermal balance between heat production and heat loss. The unacceptability rate was minimal for both young and elderly people at 25 ^{o}C and 27 ^{o}C. At the same time their thermal preference remained unchanged and thermal sensation was +/- 0.5, around thermal neutrality (0) in both temperature conditions with the uniform clothing (0.63clo).

CONCLUSION AND IMPLICATIONS

The preferred temperature of Japanese elderly people was investigated during the winter season. And thermophysiological data were collected to better clarify the relationship between thermophysiological responses and thermal comfort. The conclusions and implications were obtained as follows.

1. The metabolic rate for the elderly group was only 70% that of the younger group and there was little difference in EWL between the younger and elderly subjects among the five conditions.
2. The unacceptability rate was minimal for both younger and elderly subjects at 25 ^{o}C and 27 ^{o}C. At the same time their thermal preference remained unchanged and thermal sensation was +/- 0.5; around thermal neutrality (0) in both temperature conditions with the uniform clothing (0.63clo).
3. In the heat balance the decrement in metabolic rate might not offset because the EWL did not decrease for elderly people. It was hard to offer a reasonable explanation as to why no difference in preferred temperature was found between the young and elderly groups.
4. The calculated PMV for the elderly group was colder than the reported thermal sensation below 27 ^{o}C condition in Figure 9. It suggests that PMV is hard to evaluate the environment at low metabolic rate.

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