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Age Effects on Physiological Responses and Bed Climate during Sleep after Heating the Lower Extremities

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Five healthy young and elderly female volunteers slept from 23:00 to 7:00 in a climate chamber that was controlled at 13℃ 60% RH followed by the heating of the lower extremities for 30 min. The heart rate, skin temperature (T_{sk}), body movement and bed climate were measured continuously through the night. A subjective sensational evaluation and a subjective sleep evaluation were conducted before and after the recording sessions. During heating, the finger T_{sk} was significantly higher in the elderly while the chest, leg and mean T_{sk} were higher in the young. During sleep, a significant difference in T_{sk} was observed only in the chest, and it was lower in the elderly. No significant difference was observed in heart rate and bed climate. The subjective sleep evaluation was good both in the young and in the elderly. These results indicate the possibility that the healthy elderly whose sleep is followed by the heating of the lower extremities can maintain subjective sleep evaluation, T_{sk} (except for the chest), and bed climate at the same level as the young.

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Keywords: elderly, lower extremities, heating, sleep.

INTRODUCTION

According to Yanase (1981), the most frequent factor which disturbs the sleep onset among young females in winter are cold sensations in the feet. Due to this problem, more than 33% of young females wear socks or use electric heaters inside the bedding, such as electric blankets (Yoshizumi *et al.* 1993). Previous studies have shown the efficiency of using electric blankets (Okamoto 1993a) and heating the feet before sleep in regard to reducing sleep onset latency (Tsuchie 1992). Considering that sleep onset latency (Spiegel 1981) and thermal comfort before sleep (Okada *et al.* 1984) are closely linked with sleep dissatisfaction, avoiding cold in the feet before sleep can be one of the important factors for comfortable sleep in winter.

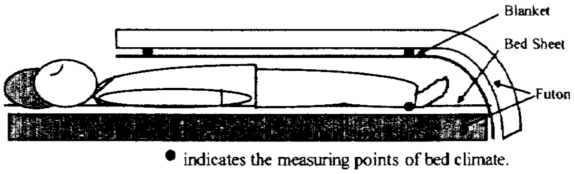
In spite of the fact that 60% of elderly people use heating equipment inside their bedding (Okamoto 1993b), the efficiency of avoiding cold sensations in the foot before sleep in the elderly is yet unknown. This is because most previous studies have used healthy young subjects. Difficulty in falling asleep and sleep dissatisfaction increases with age, due to an increase in stage wake, a decrease in slow wave sleep, and fragmentation in sleep (Spiegel 1981). In animal studies in cold environments, transient arousal was found to have increased significantly in the aged (Bowersox *et al.* 1988). It is extremely important to find out the efficiency of avoiding cold sensations in the foot before sleep in the elderly in order to achieve comfortable sleep in winter.

In this study, the lower extremities were heated before sleep. The objective of this study was to compare the effects of heating the lower extremities before sleep in terms of heart rate, skin temperature, bed climate and subjective sleep evaluation between the young and the elderly.

METHODS

Conditions and materials

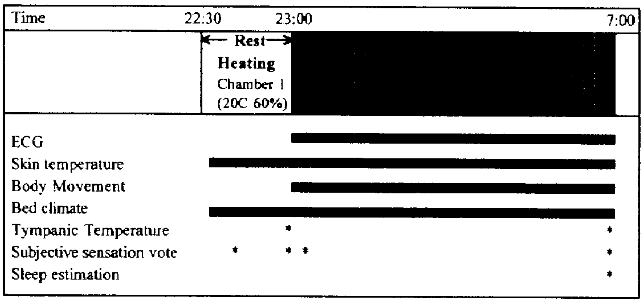
Five healthy young and elderly female volunteers served as subjects. The mean (S.D.) physical characteristics of the young/elderly subjects were age 21.8 (0.64)/60.3 (3.97) years, height 158.2 (3.99)/153.5 (2.20) cm, weight 50.62 (6.50)/59.1 (9.96) kg and BSA 1.45 (0.10)/1.52 (0.11) m^2. They were informed of the conditions before the experiment and agreed to be



	Material	Size (lenth/width cm)	Weight (Kg)	Thickness (cm)
Futon (Over the body)	Cotton 90% Polyester 10%	210/100	6.90	6.83
Blanket	Cotton 100%	200/140	1.58	0.84
Sheet	Cotton 100%	360/145	0.55	0.04
Futon (Under the body)	Cotton 90% Polyester 10%	200/134	4.50	5.07

Fig. 1. Bedding condition and measuring points of bed climate

Table 1. Procedure of the experiment



Asterisk indicates the measuring point.

tested in the laboratory for two nights. In order to avoid the effects of the menstrual cycle, the young subjects participated in the experiment when they were in the follicular phase. They were asked to wake and sleep at a regular time before the experiment. Intake of alcohol, caffeine and medicine, as well as intense exercise were forbidden before and during the sessions.

The experiment was performed from February to March. Two climate chambers were used. The first chamber stimulated a living room and the second chamber a bedroom. They were controlled separately and the temperature and relative humidity were controlled at 20℃ 60% RH for the first chamber and 13℃ 60% RH for the second. Temperature and humidity were established according to a survey which was conducted in winter (Okamoto *et al.* 1993b). Subjects wore long sleeve pyjamas (100% cotton) and shorts. They slept on a futon that was covered with a sheet, a blanket, and a futon. The characteristics and conditions of the bedding are shown in Fig. 1. In order to keep the bed conditions as consistent as possible, the futons were dried with a futon drying machine (FD-6PR, National) for 1.5 h starting at 9:00.

Measurements

Heart rate was recorded by using a multiple recorder (RMP-6008, Nihon Kohden) in time intervals of 1 min. The skin temperature (T_{sk}) of the finger, arm, chest, thigh, leg and toe were recorded in time intervals of 3 min by using a thermometer (Data Collector AM7002, Anritu). Mean T_{sk} was calculated by Ramanathan's four point method (Ramanathan 1964). Body movement was measured with a pressure sensor made of piezoelectric elements following the procedure of Suenaga *et al.* (1987) in which the sensor was placed on the waist area. The sensor was connected to a multiple recorder (RMP-6008, Nihon Kohden) and the artifact was counted as body movement. Bed climate was measured by using a thermometer and a hydrometer (Data Stoker TRH-DM2, Shinei) continuously through the night in time intervals of 3 min. The following three areas of bed climate were measured; the chest, foot area over the foot (foot over), and foot area under the foot (foot under). The measuring areas for bed climate are shown in Fig. 1. Tympanic temperature was measured before and after sleep with a thermometer (First Temp, IMS). Subjective sleep evaluations were conducted after sleep by using an OSA sleep questionnaire (Oguri *et al.* 1985). Subjects were asked to describe their thermal sensations of the leg, shoulder, and the entire body (+3: very hot to −3: very cold), humidity sensations (+3: very dry to −3: very humid) and comfort sensations (+3: very comfortable to −3: very uncomfortable) just after they had entered chamber 1, 30 min after heating their lower extremities, just before sleep, and just after sleep.

The experimental procedure is shown in Table 1. Subjects entered chamber 1 at 22:30 and immediately put on a waist length long sleeve gown (100% cotton) and their lower extremities were heated with a Kotatsu. The temperature level of the Kotatsu was adjusted to a moderate level where all the subjects did not feel too hot and felt comfortable as determined in a prior survey. At 23:00, subjects moved to chamber 2 and were asked to sleep from 23:00 to 7:00. The heart rate, T_{sk}, body movement, and bed climate were measured continually. Subjects slept for two nights, with the first night being an adaptation night.

In order to analyse the statistic significance of the data, two way analysis of variance for repeated measures and one way analysis of variance were used. The factors for the two way analysis of variance were

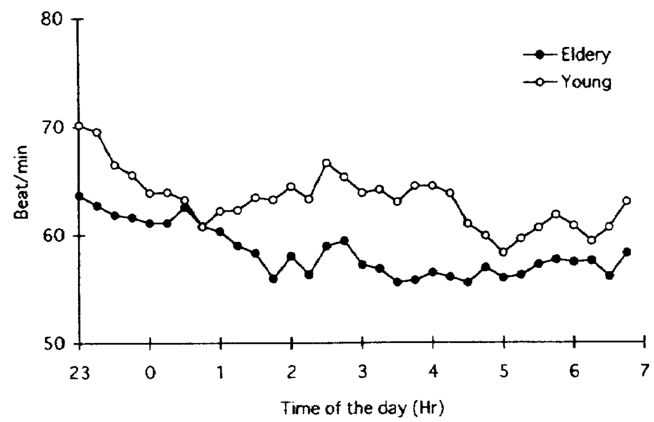


Fig. 2. Changes of heart rate

Average of five subjects.

age (young and elderly) and time. The level of significance was considered as $p<0.05$.

RESULTS

As for heart rate, only the effect of time was significant ($F_{(7,56)}=4.07$; $p<0.01$). The heart rate decreased both in the young and in the elderly (Fig. 2).

Figure 3 shows the results of T_{sk} and Table 2 shows the results from two way analysis of variance for repeated measures. T_{sk} before sleep showed a significant effect of age in the chest, finger, leg and mean T_{sk}. Finger T_{sk} was higher in the elderly while the chest, leg and mean T_{sk} were lower in the elderly. Interaction was observed in the thigh and toe T_{sk}. Although the temperature was higher in the elderly at the beginning, it was higher in the young after heating. In T_{sk} during sleep, a significant effect of age was observed only in the chest. Chest T_{sk} was kept lower in the elderly than in the young. The toe T_{sk} tended to be lower from 5:00-6:00 in the elderly, as three out of five subjects went to the lavatory.

The mean (S.D.) number of body movements during sleep tended to be lower in the elderly (27.64 ± 12.3) than in the young (37.7 ± 18.85).

The results for the chest and foot under area of the bed climate are shown in Fig. 4. In the chest area, no significant effect of age was observed and the temperature was maintained at 32-33℃, except for 5:00-6:00 in the elderly. The relative humidity of the chest area tended to be higher in the elderly, however, there was no significant difference. In the foot under area, temperature and humidity did not show any significant effect of age and were maintained at 28-32℃, 35-45% RH.

Tympanic temperature before and after sleep

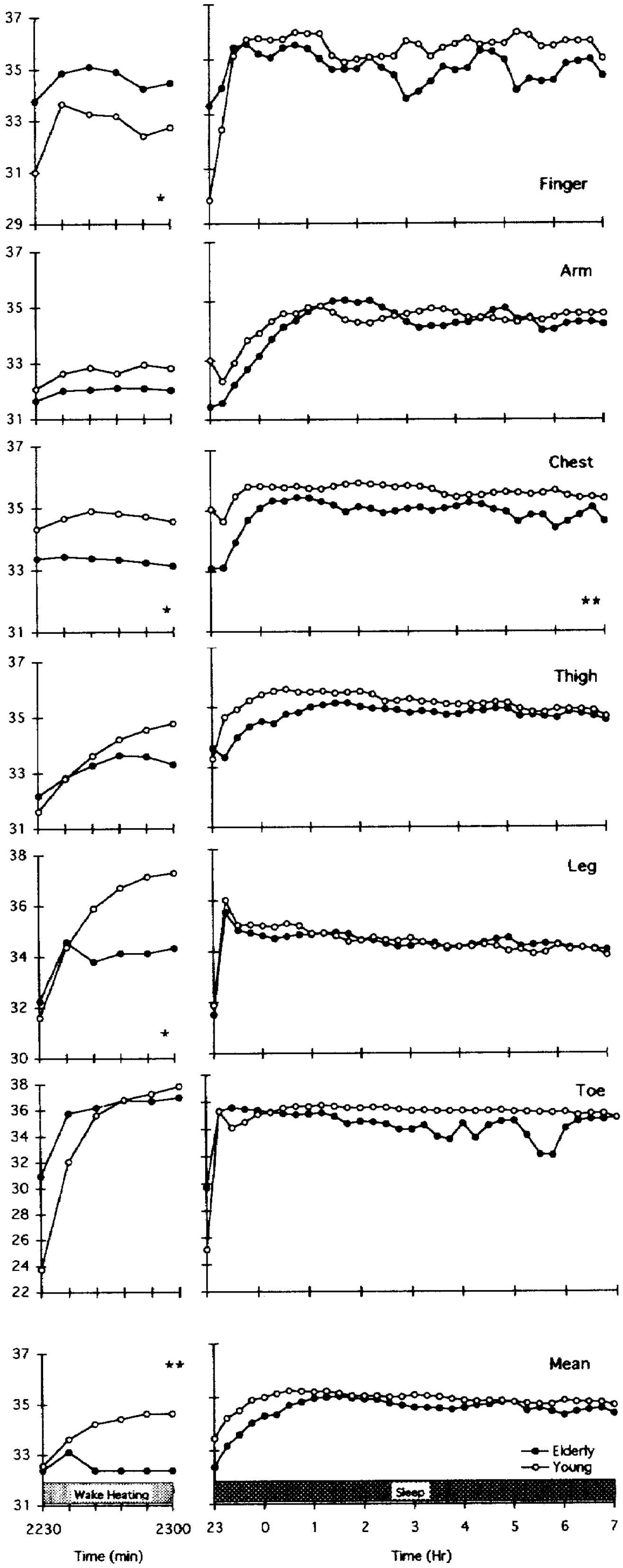


Fig. 3. Changes of skin temperature

Average of five subjects. The asterisk indicates the level of significant effect by age (* $p<0.05$; ** $p<0.01$).

tended to be lower in the elderly (before, 37.0±0.30; after, 36.7±0.49) than in the young (before, 37.3±0.29; after 36.9±0.23) but there was no significant effect of age.

Thermal sensations of the leg and shoulder are shown in Fig 5. As for thermal sensations of the leg, the effect of time ($F_{(2,16)}=11.96$; $p<0.001$) was significant. Concerning thermal sensations of the shoulder, although there was a tendency to increase during the heating, no significant effect of time was observed. However, sensations after sleep were significantly higher in the elderly ($F_{(1,8)}=5.72$; $p<0.05$). There was no significant effect of age in subjective sleep evaluation. All factors accounted for good scores of around 50 points.

DISCUSSION

Our first objective was to observe the effect of heating the lower extremities before sleep on T_{sk}. Regarding T_{sk} before sleep, that of the finger was significantly higher in the elderly. This was in agreement with previous studies that found that vasoconstriction ability in a cold environment decreases in the aged which leads to higher peripheral T_{sk} (Wagner *et al.* 1974; Wagner and Horvath 1985). Leg T_{sk} was higher in the young during heating. Although the heat exposure in our study was limited to the lower extremities, this agreed with a previous study that reported a smaller increase in leg T_{sk} by heat exposure in the elderly (Tochihara 1994) which can be due to the inability of the vasomotor system to maintain the cutaneous blood flow at the same level as in the young (Sagawa *et al.* 1988). The T_{sk} change in the lower extremities were accompanied by subjective thermal sensations of the leg both in the young and in the elderly.

It is notable that in spite of these differences in T_{sk} before sleep, a significant effect of age was observed only in the chest T_{sk} during sleep. Jennings *et al.* (1993) examined finger temperature responses during sleep in young and elderly subjects. They did not find any decrease in capability of retaining heat by peripheral vasoconstriction during NREM sleep in the elderly and the average core body temperature were comparable, in spite of the increased stage wake and decreased REM in the elderly. They concluded that a decrease in REM is one of the reasons for maintained finger T_{sk} in the elderly. The decrease in mean T_{sk} by cooling stimulation is smaller during REM than

Table 2. *F*-ratios and associated probability levels from analysis of variance for repeated measures: age (young and elderly) by time

	Heating			Sleep		
	Group	Time	Interaction	Group	Time	Interaction
Finger	5.68*	4.11**	0.60	2.60	3.97**	2.27*
Arm	0.51	5.81***	0.68	0.23	8.89***	0.63
Chest	8.17*	1.49	1.35	11.89**	22.14***	2.83*
Thigh	0.77	83.52***	17.00***	0.36	1.09	0.93
Leg	7.50*	22.07***	8.06***	0.09	5.07***	0.24
Toe	1.72	33.11***	44.89***	1.59	0.94	0.75
Mean	14.73**	31.82***	44.89***	0.02	2.09	0.91
df	1/8	5/40	5/40	1/8	7/56	7/56

The asterisk indicates the level of significance (*$p<0.05$; **$p<0.01$; ***$p<0.001$).

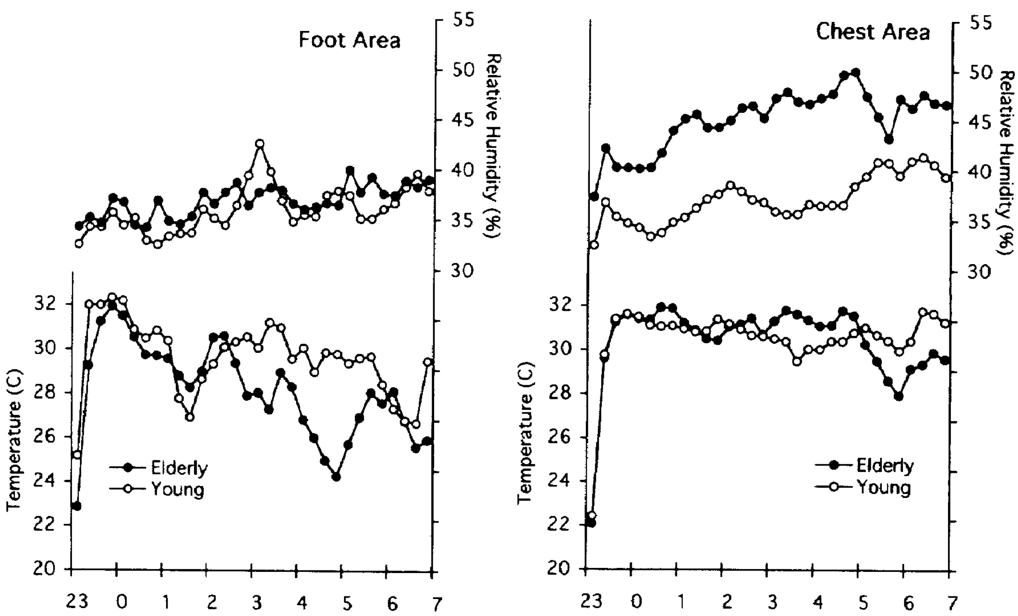


Fig. 4. Changes of bed climate of the chest and foot over area

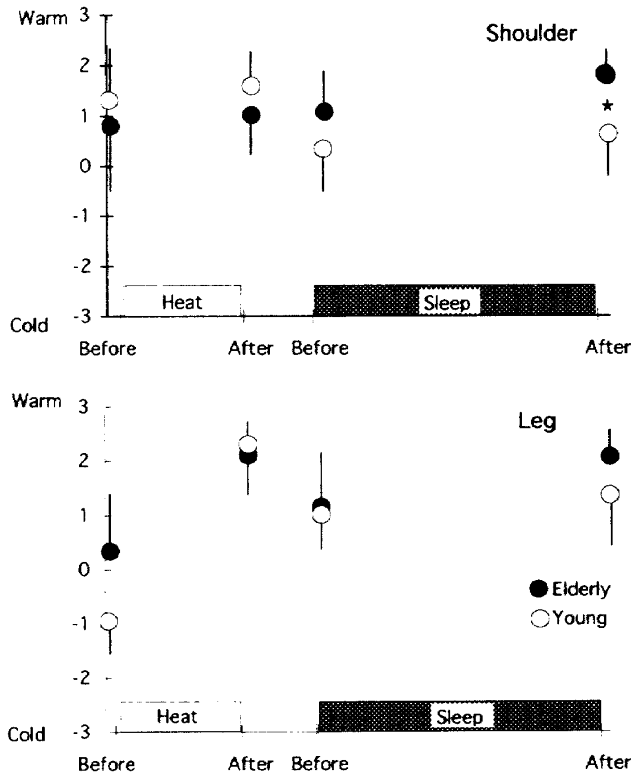


Fig. 5. Average of thermal sensation before and after sleep

Average of five subjects. Vertical line indicates the standard deviation. The asterisk indicates the level of significant effect of age (* $p<0.05$).

during slow wave sleep, which indicates that thermal transients are more disrupted during REM (Candas *et al.* 1982). REM duration in each sleep cycle decreases in the elderly (Okudaira 1984). It is possible to consider that no significant difference in T_{sk} may be related to sleep construction differences. Further study on comparing our data with sleep construction and core body temperature is needed. However, our findings suggest that, at least when lower extremities were heated before sleep, the elderly can maintain T_{sk} (except for the chest) at the same level as the young.

Our second objective was to observe the relation between subjective sleep evaluation and bed climate in the young and the elderly. Although three out of five elderly subjects went to the lavatory after sleep onset, there was no significant effect of age in regard to subjective sleep evaluation and their scores were good. It can not be considered, however, that there were no differences in objective sleep construction as subjective sleep evaluation of the healthy aged does not always deteriorate in spite of sleep disturbances caused by aging (Buysse *et al.* 1991). On the other hand, the bed climate of the chest area was maintained at 32-33℃, 35-50% RH both in the young and the elderly. Although T_{sk} in the chest was significantly higher in the young, this was not reflected in the bed climate temperature. One reason may be the tendency of fewer body movements in the elderly. These results indicate that when the elderly had subjectively good sleep evaluation, there are no significant differences in bed climate. Some studies have shown that bed climate is maintained at a lower temperature in the elderly (Mizunoe 1991). Although our results showed a tendency to be lower, they were not statistically significant. One reason may be the effects of heating the lower extremities before sleep. Another reason might be the characteristics of the subjects. In this study, all subjects were healthy and four out of five were still working. However, previous studies have not gone into detail about the background of their subjects. The selection of elderly subjects may be very important, as individual differences in physiological responses increase in the elderly (Ogawa 1994).

Although further study on sleep construction and core body temperature is needed, our results suggest the possibility that at least when the lower extremities are heated before sleep, the healthy elderly can maintain a good subjective sleep evaluation, T_{sk} level (except for the chest) and bed climate during sleep at the same level as the young.

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年齢差が下肢加温後の睡眠中の生理反応および寝床内気候に及ぼす影響

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就寝前の下肢加温が，睡眠中の生理反応および寝床内気候，睡眠感に及ぼす影響を若年者と高年者で比較した．対象は，健康な若年女性 5 名（平均年齢 21.8 歳），高年女性 5 名（平均年齢 60.3 歳）とした．実験は，2 室の人工気候室を用い，1 室は居間を想定し 20℃，60% RH，2 室は寝室を想定し 13℃，60% RH に保った．就寝前に 1 室で炬燵を用いて 30 分下肢を加温し，その後 2 室で 23：00～7：00 まで就寝してもらった．心拍数，皮膚温，体動，寝床内気候は連続測定し，温冷感，快適感，湿潤感，睡眠感は就寝前，起床時にそれぞれ申告を行った．就寝時の心拍数に有意差はみられなかった．下肢加温時の皮膚温は，指は高年者で有意に高く，逆に胸，下腿，平均皮膚温は有意に低かった．就寝時では高年者で胸が有意に低い以外，年齢による差はみられなかった．寝床内気候は若年者，高年者ともに 32～33℃，35～50% RH に保たれ，睡眠感もよく，有意差はみられなかった．下肢加温後の睡眠では，高年者は睡眠感，胸以外の皮膚温，寝床内気候は若年者と同じレベルを保つ可能性が示唆された．

キーワード：高年者，下肢，加温，睡眠．