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Acclimatization effect on the evening fall in core temperature under the influence of two types of clothing

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Abstract. This paper reports the effect of acclimatization on the evening fall in core temperature under the influence of two different types of clothing. Two groups of subjects dressed in either knee-length skirts or full trousers during the daytime for the three months from April to June. To compare the circadian rhythm of core temperature, the experiments were carried out before and after the three month program of acclimatization. It was found that the subjects who had worn knee-length skirts showed lower rectal temperatures during the nighttime and a bigger amplitude of circadian rhythm in July than in March.
Key words. Rectal temperature; clothing; circadian rhythm; amplitude; acclimatization.

The circadian rhythm of core temperature is a well documented physiological phenomenon[1]. Minors and Waterhouse[2] pointed out that overt circadian rhythms consist of endogenous and exogenous components: the endogenous component is due to the activity of the body clock and the exogenous component results from our lifestyle and environment. Although many researchers have studied the exogenous component of the circadian rhythm, little attention has been paid to the effect of clothing as an exogenous component.

The skin temperatures of the extremities in humans, which are low during the day and high at night, show circadian rhythms that are antiphase to the circadian rhythm of core temperature[3]. These circadian variations of skin temperature are mostly responsible for the core temperature rhythm in humans[1,4,5]. Recently, Tokura and his group[6–8] found that the range of oscillation in the circadian rhythm of core temperature was greater when half-sleeved shirts and knee-trousers were worn rather than long-sleeved shirts and full trousers. They attributed these differences to whether the extremities were covered or uncovered by clothing. Li et al. disclosed that two types of clothing could play a role in seasonal cold and warm acclimatization[9–11]. However, it remains to be seen what effect clothing types have on acclimatization of the circadian physiology. Therefore, the present experiment investigated changes from spring to summer in acclimatization of the evening fall in core temperature under the influence of two types of clothing.

Methods

Subjects. Ten female adults served as subjects (age: 22.6 ± 1.8 and 20.0 ± 0.4 years; weight: 53.7 ± 2.7 and 55.0 ± 0.9 kg; height: 158.9 ± 2.6 and 157.5 ± 1.3 cm for the skirt and trouser groups, respectively). Experimental procedures were clearly explained and all subjects gave their consent to the experiment. Subjects were randomly divided into two equal groups. One group wore knee-length skirts (skirt group) and the other group wore full trousers (trouser group) between getting up and going to bed for the three months from April to June. Judging from the answers of the subjects to questions about their daily clothing before the beginning of the acclimatization program, dressing habit did not seem to differ between the two groups. Furthermore, there did not seem to be any consistent difference between the two groups in the clothing worn over the upper half of the body, as assessed by checking them at least once a week.

Acclimatization program. As the season advanced, the outdoor air temperature gradually increased. The mean daily outdoor temperatures were 6.6 °C in March, 12.5 °C in April, 17.2 °C in May, 21.3 °C in June and 23.8 °C in July. Air conditioning systems were not used during this period.

Protocol. Experiments were carried out at the end of March and beginning of July in order to investigate the effect of clothing worn during daily life on diurnal changes in core temperature. Attention was focused especially on those changes from evening to the next morning. Using the Squirrel Data Logger (Grant, U.K.) we measured rectal temperature (T_{re}) and leg skin temperature continuously for 24 h both in March and in July, before and after the acclimatization program. The measurements were carried out at the same phase of the menstrual cycle in each individual and continued from 9.00 to 9.00 h the following day. The subjects retired at 23.00 h and rose at 7.00 h. Lighting by fluorescent lamps (200 lux) was turned on at 7.00 h and off at 21.00 h. The desk stand with dim light was

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turned on at 21.00 h and off at 23.00 h. The subjects engaged themselves in reading a book or listening to light music from 7.00 to 21.00 h while sitting in a sofa, and had light meals at noon (rice, chicken, vegetable, energy content: ca. 460 kcal) and at 18.00 h (rice, egg soup, energy content: ca. 230 kcal). They wore a brassiere, undershirt and long-sleeved shirt over the upper half of the body, and knickers and knee-trousers over the lower half of the body during the experimental periods. When they were sleeping they used blankets, wearing the same clothing worn during the waking period. Ambient temperature (T_a) and relative humidity in the chamber were controlled at 25 °C and at 60% RH, respectively.

Data analyses. The best fitting curve to raw measurements of rectal temperature was used to assess amplitude. The fitting curve was obtained according to the least-square cosinor method which was given by Halberg et al.[12]. Data were analyzed using Student's t-test (paired and unpaired) to compare acclimatized changes of T_{re} for the same group or to compare skirt-trouser difference for the same season.

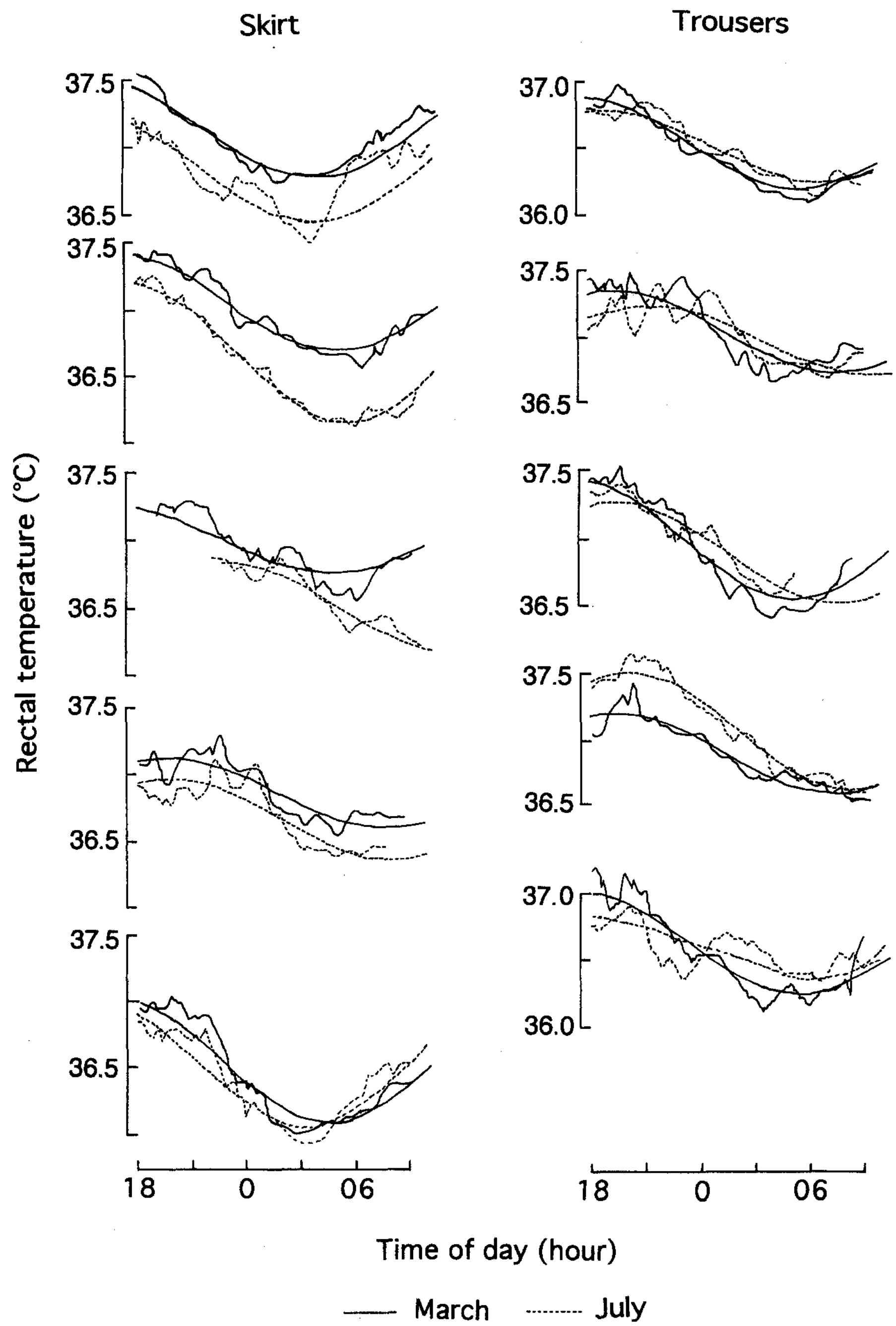

Figure 1. The time course of rectal temperature and the best fitting curves were individually compared between March (solid line) and July (dotted line) in both groups (left: skirt group; right: trouser group).

Results

Temporal changes of T_{re} from the evening to the morning of the following day are shown in the figure. The best fitting curves have also been inserted. It was found that the T_{re} in all 5 subjects in the skirt group was lower in July than in March. The ranges of oscillation in T_{re} were calculated to be 0.67 ± 0.07 °C (mean ± SE) in the skirt group and 0.69 ± 0.05 °C in the trouser group in March; 0.80 ± 0.08 °C in the skirt group and 0.59 ± 0.08 °C in the trouser group in July. The skirt group showed higher values in July than in March ($p < 0.10$), while the trouser group did not show any significant changes between the months. Also there were no differences between the two groups in March and, even though the values tended to be higher in the skirt group than in the trouser group in July, this difference was not significant.

The average minimum value of core temperature was 36.70 ± 0.15 °C in March and 36.40 ± 0.13 °C in July in the skirt group, and 36.48 ± 0.09 °C in March and 36.51 ± 0.08 °C in July in the trouser group. Thus, the value was significantly reduced from March to July in the skirt group only ($p < 0.05$).

There were no consistent differences in core temperature behavior during the daytime either in March or July between the skirt and trouser groups.

Increase in leg skin temperature from the evening (18.00–23.00) to the night (23.00–4.00) was compared in March and July between the skirt and trouser groups. It was 1.78 ± 0.22 °C in the skirt group and 1.33 ± 0.30 °C in the trouser group in March, which was not significantly different. It was 2.93 ± 0.17 °C in the skirt group and 2.20 ± 0.13 °C in the trouser group in July, which was significantly greater in the skirt group than in the trouser group ($p < 0.05$).

Discussion

The main finding in our present experiments was that the minimum level of core temperature from the evening to the morning of the following day was lower from March to July in the skirt group but not in the trouser group, and that a range of oscillation in circadian rhythm of core temperature became higher from March to July in the skirt group, but not in the trouser group. What physiological mechanisms could account for these facts?

The variation in the extremity skin temperature is mainly responsible for the creation of a circadian rhythm in core temperature[1,4]. In our present experiment, the increase in leg skin temperature from the evening to the night was significantly greater in the skirt group, which seemed to be responsible for the quicker and larger decrease in rectal temperature from the evening to the night in the skirt group.

Hashimoto and Tokura[7] found that the core temperature was significantly lower during the nighttime at T_a of 26 °C in subjects wearing half-sleeved shirts and knee-length trousers than in subjects wearing long-sleeved shirts and full-trousers; core temperatures were not different during the daytime. They suggested that the quicker and larger increase in the skin temperature of the extremities during the evening and nighttime might be responsible for the quicker fall and lower core temperature during the nighttime. Jeong and Tokura[6] found that the evening fall in rectal temperature after retiring was significantly more rapid in half-sleeved shirts and knee-trousers than in long-sleeved shirts and full-trousers. Based on these results we have suggested that direct exposure of the lower extremities to the surrounding in the daytime results in an increase in cutaneous sympathetic tone in order to maintain core temperature. In our present experiment, the lower extremities in the skirt group were directly exposed to outside air during the daytime, and the cutaneous sympathetic nervous system would be more stimulated than in the trouser group. The evening fall in core temperature is caused by cutaneous vasodilatation, and we have speculated that this relaxation would be more marked if daytime vasoconstrictor activity had been higher. This would be accompanied by higher skin temperatures in the lower extremities and, hence, lower core temperatures in the skirt group. In the present study, the fact that although the subjects wore identical clothing in the tests, the core temperature behaved differently between March and July in the skirt group, suggests the occurrence of acclimatization by repeatedly exposing the lower extremities to the surroundings.

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