Thermal Comfort and Sleep under Different Room Temperatures

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I. INTRODUCTION

To get a comfortable sleep, the most important thing is how well we do thermoregulate during the rest in bed before sleeping as well as during sleep. In other words, the ambient temperature of the sleeping room is very important in the organization of human sleep[22].

In recent years, the effect of ambient temperature on human sleep has been increasingly studied. These studies were primarily concerned with the relation between thermoregulatory processes and sleep, and more precisely with the findings that various thermoregulatory processes are inactivated or severely curtailed during REM sleep in a number of animals[25], also that panting and shivering in heat and cold, respectively, cease during REM sleep in cats[23]. Haskel et al.[13] noted that although REM sleep latency was increased at high and low temperature, REM sleep was depressed to a greater extent by lower than by higher temperatures whereas the reverse was obseved for SWS. It has also been found that a load imposed upon thermoregulatory mechanisms should markedly affect sleep processes, and that, conversely, sleep in conditions of thermic stress should interfere with adequate thermoregulatory reactions[24]. Sleep in an animal under thermic stress is, on the whole, both shorter and less deep than under normal thermic conditions[23].

In a study where the possible qualitative and quantitative variations of the sleep parameters due to slight changes of the air temperature were evaluated in the usual sleeping environmental temperatures of 13°, 16°, 19°, 22° and 25 C which are usually met in European dwellings, Muzet et al.[20,21], showed that slight changes in temperature, within the thermal comfort zone, although not accompanied by dramatic EEG sleep modifications, may affect body heat exchanges and therefore the body temperature. The results strongly suggest a coupling between body temperature cycle and the sleep mechanisms.

In the present study, as a different attempt to clarify the thermal comfort and sleep under different room temperatures considered as the thermal comfort zone from preceding studies [20], the thermal alliesthesial responses, global thermal pleasantness sensation, global temperature sensation were measured during two periods, before and after sleep: a bedding down period of one hour (before sleep) and a twenty minutes waking period (after two hours sleep).

The subjects, young women, were exposed to five different ambient temperatures of 15°, 18°, 21°, 24° and 27°C throughout the evening from 18.00 to 22.00 hours in winter season. In addition, we intended to

suggest the range of temperatures considered as a neutral environment for clothed and covered young women subjects asleep in European winter season.

Ⅱ. METHODS

1. Subjects

Five young women students of physiotherapy with ages ranging from 19 to 22 years, weight from 58 to 73 kg and height from 160 to 185 cm were subjected in a climatic chamber for a total of 19 evenings at five ambient conditions: 15°C, 18°C, 21°C, 24°C and 27 °C air and wall temperatures.

Other ambient parameters were kept constant: RH 45%, wind speed 0.2~0.3 m/sec. Under the extreme thermal stress of 15 C and 27°C, only two of the five subjects participated in the experiments.

2. Measurements

Behavioural parameters measured during the experiment were thermal alliesthesial responses, global thermal pleasantness sensation and global temperature sensation. The estimate of thermal alliesthesial responses was performed using two methods, namely, the thermal pleasantness ratings in response to a set of temperature stimuli and the choice of most pleasant local temperature, using a Peltier thermode (thermode area 6×6 cm).

A set of temperature stimuli of 20.0°, 22.5°, 25.0°, 27.5°, 30.0° and 32.5 C was applied on the cheek. Temperature stimuli were applied using a rectangular Peltier Thermode type PKE 36 HO2-1 marketed by Peltron in Nuernberg, Germany. Temperature on the thermode surface is selected by a control knob capable of being adjusted from −20.0°C to +70.0°C and desired temperature is reached within 60~90 s, depending upon ambient temperature, cooling water flow rate and temperature .

The subjects also chose their most pleasant local temperature on the cheek by voluntary control, using the temperature control knob of the thermode without looking at the temperature scale.

At the same time, global thermal pleasantness sensation and global temperature sensation were asked. Hensel[5] presented a clear distinction between temperature sensation and thermal comfort. Temperature sensation is an "objective" MEASUREMENT process tending to estimate the external thermal stressor: the CONTROL tending to offset any deviations from the state of thermal neutrality is thermal discomfort, behavioural and autonomic temperature-regulatory response .

For the thermal pleasantness unpleasantness ratings, the following five point scale was used .

very pleasant	−2.0
pleasant	−1.0
indifferent	0.0
unpleasant	−1.0
very unpleasant	−2.0

Global temperature sensation was rated +10 as very warm, +5 as warm, O as neutral, −5 as cool and −10 as cold.

3. Schedule

Experimental conditions and time schedule for measurement are shown in Fig. 1. Subjects engaged in their hard daily school activities from morning 07.00 to evening 17.40 hours. They arrived at the laboratory around 18.00 hours and stayed for 30 minutes in normal room temperature while they were prepared for the test. They were asked to avoid afternoon exercise, naps, coffee or alcoholic drinks during the afternoon before coming to the laboratory.

After having their body weight determined pre-

cisely, subjects wore long pyjamas consisting of clothing materials of 100% cotton and bedding composition consisted of two cotton sheets and one wool blanket with usual mattress.

At 18.30 hours, subjects were asked to be lying in bed. The light was switched off at 19.40 hours. From 19.40 hours, subjects tried to fall asleep till 21.40 hours, After these two hours of sleep, subjects were awakened by us and remained in bed till 22.00 hours. Both during the one hour bedding down period before sleeping and during the twenty minutes waking period, subjects were asked every 15 min in six steps to answer their thermal pleasantness/unpleasantness ratings in response to a set of temperature stimuli of 20.0°, 22.5°, 25.0°, 27.5°, 30.0° and 32.5°C applied on the cheek, and also asked to choose the most pleasant local temperature again on the cheek by controlling the small peltier thermode. Each stimulus was given in a randomized sequence.

Heart rate measurement, global thermal pleasantness sensation and global temperature sensation ratings were made also during these six steps. Oxygen consumption was measured between 19.15 and 19.30 hours.

Ⅲ. RESULTS

Effects of the room temperatures on the behavioural responses

In Fig. 2, mean values of thermal pleasantness/unpleasantness ratings applied on the cheek at six different times (steps 1, 2, 3, 4, 5 and 6) of the experiment are plotted against the corresponding stimulus temperatures of 20.0°, 22.5°, 25.0°, 27.5°, 30.0° and 32.5°C in five different room temperatures. The ratings for steps 1, 2, 3 and 4 were carried out between 18.30 h and 19.40 h for the bedding down period, while the ratings for steps 5 and 6 of the waking period were carried out between 21.40 h and 22.00 h.

Under all conditions except at 27°C, it can be observed that local thermal pleasantness ratings show a tendency towards hypothermia, especially during the bedding down period (steps 1, 2, 3 and 4), subjects having perceived as pleasant the stimuli above 27.5°C, as unpleasant the stimuli below 27.5°C.

During the waking period (steps 5 and 6), the subjects would tend to rate cool stimuli (22.5°C, 25.0°C) as indifferent, and stimuli above 25.0°C as pleasant. At 27°C condition, cool stimuli are answered as pleasant and warm stimuli are answered as unpleasant during the waking period.

In Fig. 3, mean values of regression coefficients and preferred local temperatures on the cheek are plotted against six different steps of the experiment at five different room temperatures. Rating stimulus slopes (regression coefficients) were calculated for both hypothermic and hyperthermic conditions . Positive slopes were, as expected, associated with hypothermia and negative slopes with hyperthermia. The point where the curve intersects the "a=0.0" line, corresponds to the value of the parameter when body temperature is equal to the thermoregulatory set point .

Regression coefficients of rating/stimulus line (Fig. 3 above) and most preferred local temperatures (Fig. 3 below) confirm that the subjects are hypothermia throughout the bedding down duration under 15°, 18° and 21°C conditions, and that, especially, preferred local temperature increased nearly to 33°C under the 15°C condition. As for the waking period, regression coefficients of the rating/stimulus line are very close to thermal neutrality under the conditions of 15°, 18° and 21°C, and preferred local temperatures are chosen between 29°C and 30°C at these three room temperatures. But under 15°C, the subjects show a tendency to return towards an hypothermic state after being awakened.

Under the 24°C condition, the slopes of rating/stimulus line show that during the bedding down

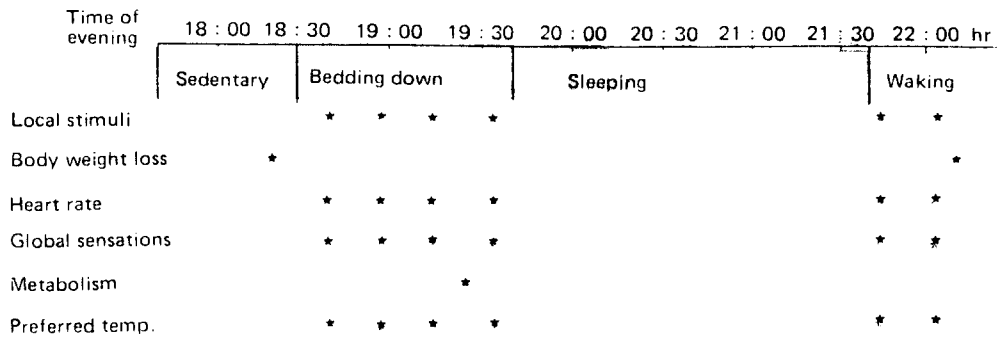

Fig. 1. Experimental conditions and time schedule for measurements.

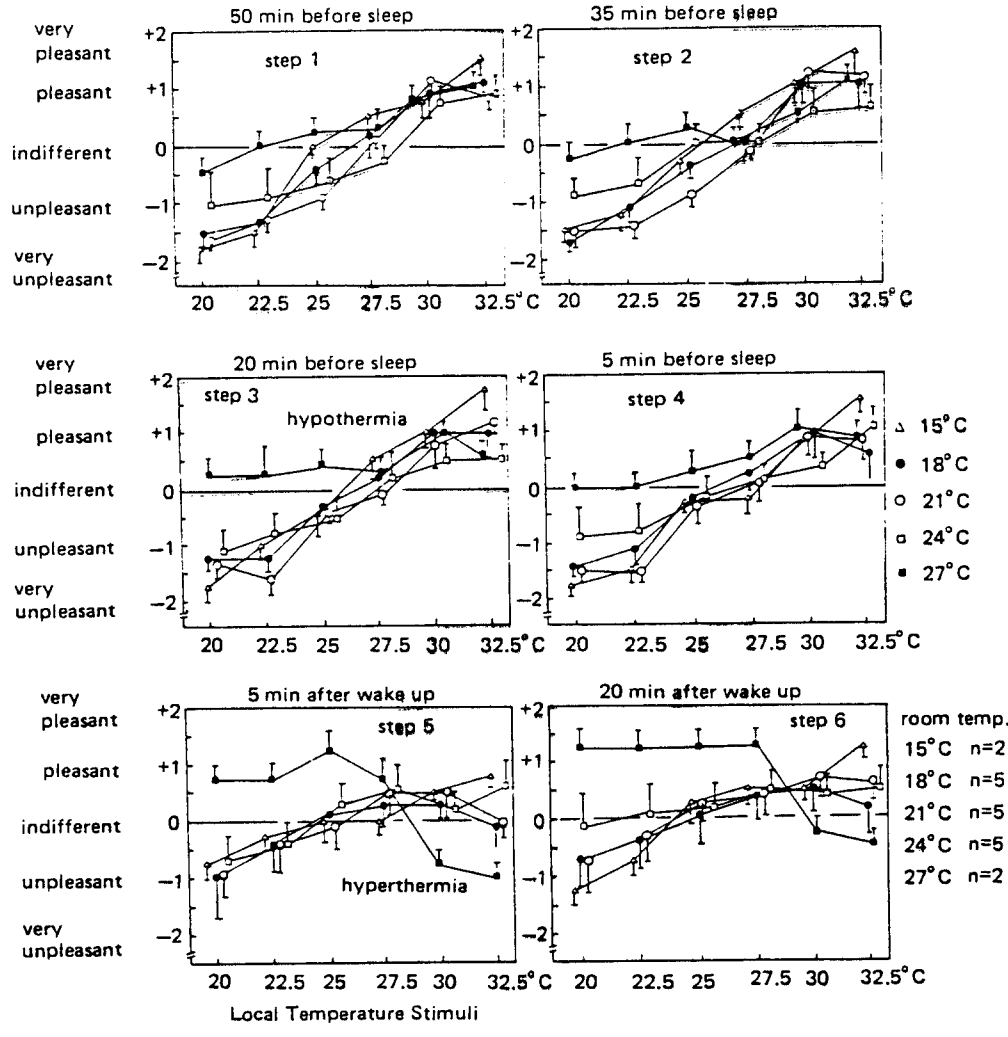

Fig. 2. Mean values of the local thermal pleasantness/unpleasantness ratings (on cheek) at the six different times of the experiment are plotted against each stimulus of 20, 22.5, 25, 27.5, 30 and 32.5°C in the climatic sleep chamber of 15, 18, 21, 24 and 27°C room temperatures (R.H. 45%; wind speed 0.2~0.3 m/sec). Each stimulus was given in a randomized sequence.

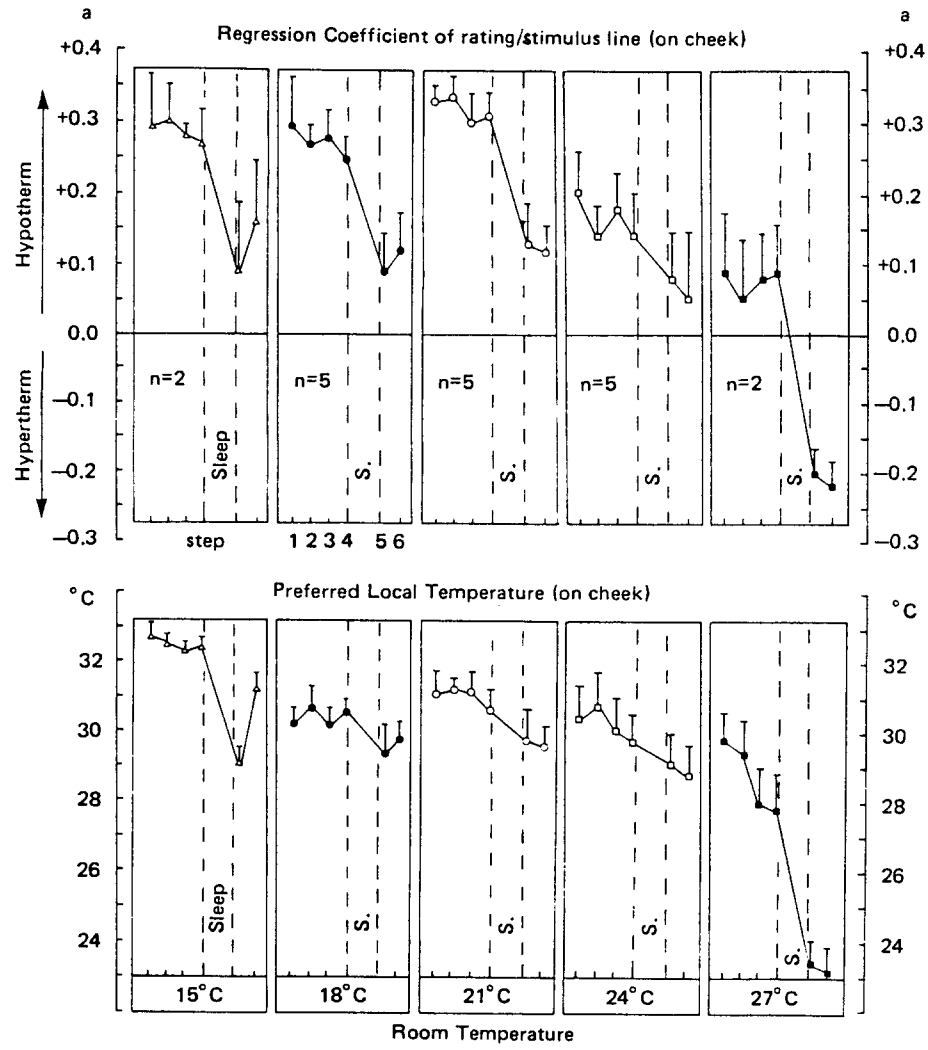

Fig. 3. Mean values of regression coefficient and preferred local temperature at the five different room tempertures. Regession coefficient "a" is the thermal pleasantness rating/stimulus slope. Preferred local temperatures are chosen by voluntary control using a small PELTIER thermode (thermode area 36 cm²).

period, a state very close to zero is maintained, while an increasing tendency towards hyperthermia and a decrease in preferred local temperatures (28°C~29°C) are observed during the waking period.

Under the 27°C room temperature condition, it can be seen that this sleep environment causes an hyperthermic state throughout the duration of the waking, characterized by increasing negative values in the rating/stimulus line and a decrease in preferred local temperatures (23°C~24°C).

The highest preferred local temperature (33°C) is observed for the 15°C condition of the bedding down period, while the lowest preferred local temperature (23°C) is obtained for the 27°C condition of the waking period, both preferred local temperatures being significant at a 0.005 level for the 18°C and

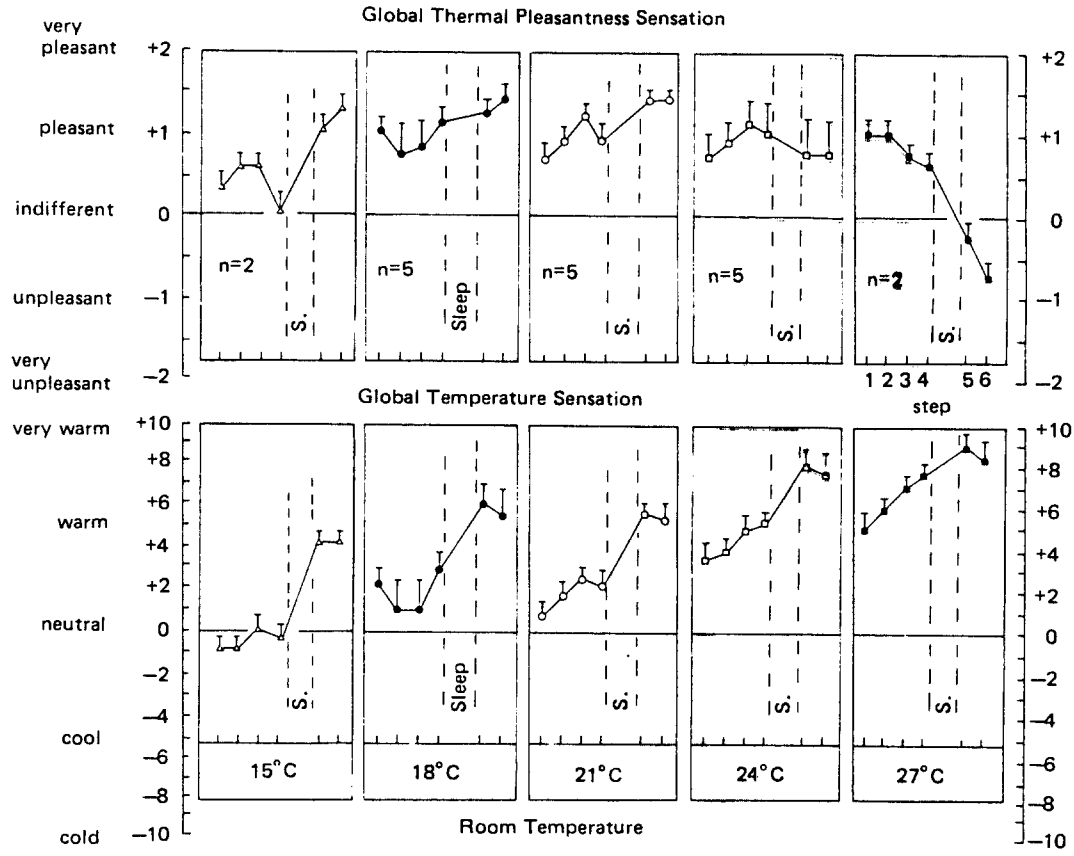

Fig. 4. Mean values of global thermal pleasantness sensation and global temperature sensation votings at the six different steps are shown. Steps 1, 2, 3, 4 are the duration of the bedding down and 5, 6 are the duration of the waking. Sleeping was taken during two hours from 19:40 hr to 21:40 hr in the evening.

21°C conditions. These values reveal an identical result to the result shown by the rating/stimulus slopes.

Mean values of global thermal pleasantness sensation and global temperature sensation votings for the six steps are shown in Fig. 4. Pleasantness ratings of around +1.0 are given for the 18°, 21° and 24°C conditions of the bedding down period, whereas during the waking period, the subjects remained feeling pleasant under the 15°, 18° and 21°C room temperatures. Global temperature sensation votes at 15°C room temperature are from the start close to −2 "cool", with a slight increase towards neutral at the step 4 (Fig. 4 below). After awakening, the subjects are voting "very warm" (between +7 and +9) under the 24° and 27°C conditions, suggesting that warmth discomfort is increasing from these 24°C and 27°C room temperatures. The results show the same tendecy to the results shown in rating/stimulus slopes and preferred local temperatures.

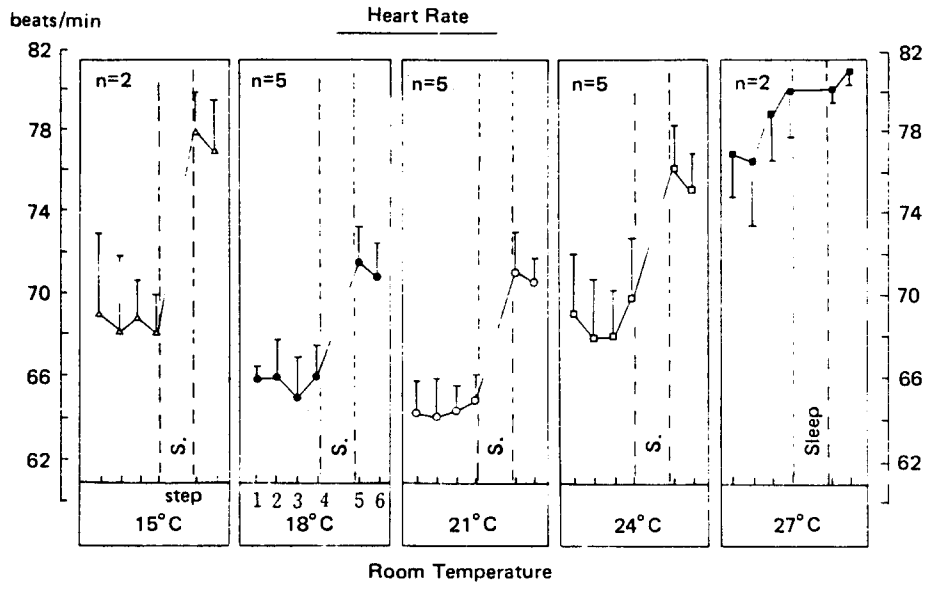

Fig. 5. Mean values of heart rate measured at the six different steps under the five different room temperatures. Steps 1, 2, 3, 4 were measured every 15 minutes during one hour of the bedding down period. Steps 5 and 6 were measured during 20 minutes of the waking period.

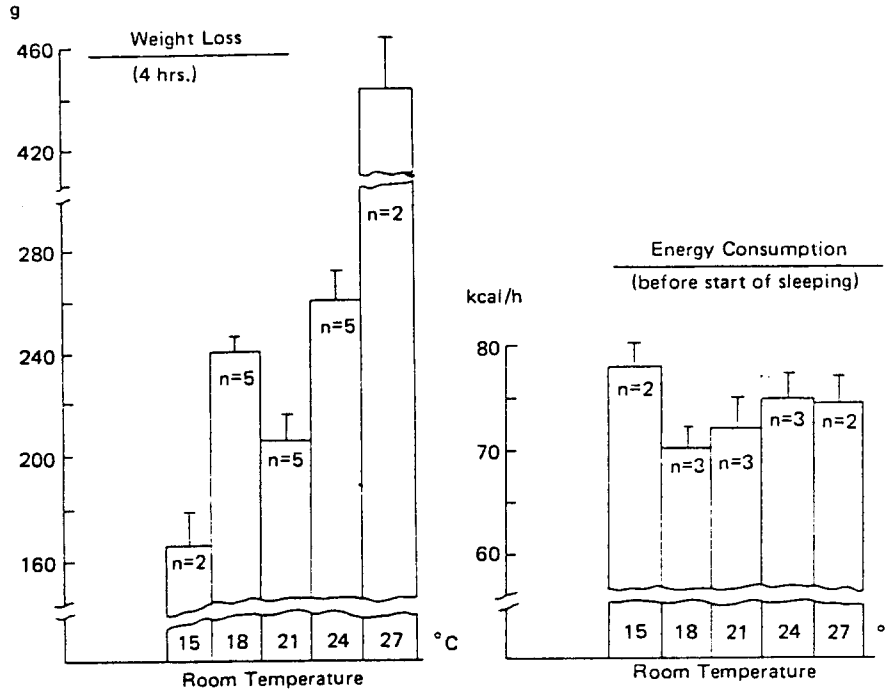

Fig. 6. Mean values of energy consumption and body weight loss at five different room temperatures. Energy consumptinon was measured at 20 min before start of sleeping. Body weight loss was measured at the beginning and the end of the experiment.

Mean values of heart rate measured at the six steps under the five different room temperatures are shown in Fig. 5. The heart rate at 27°C is significantly higher ($p<0.01$) than in the 18°C and 21°C conditions. At 15°C and 24°C room temperatures, there is also a small increase of the heart rate after waking, when compared with the couditions of 18°C and 21°C.

Fig. 6. shows mean values of energy consumption and body weight loss at the same five room temperatures. Energy consumption was measured 20 minutes before the start of the sleeping period, whereas body weight loss was measured at the beginning and the end of the experiment.

Under the 18°C condition, energy consumption was lower than in any other room temperatures. The body weight loss corresponding to four hours was 441 ± 20.2 g(mean±standard error) in 27°C room temperature, 240 ± 5.7 g in 18°C, 205 ± 10.2 g in 21°C, 260 ± 10.5 g in 24°C and 166 ± 12.4 g in 15°C. Thus, the body weight loss is significantly greater in 27°C than in 18°C condition ($p<0.001$). This observation of warmth-discomfort in 27°C room temperature has already been substantiated by the results of the regression coefficient of rating/stimulus line, preferred local temperatures.

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