The Effect of Floor Heating System on Physiological and Psychological Responses in Sitting Posture with Throwing Legs

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INTRODUCTION

Floor heating systems have been gradually equipped in Japanese houses. In general the advantages of floor heating system might be considered its health promotion and energy-saving effects in winter. It was pointed out that the noise and air pollutant levels were relatively low in the room with floor heating system compared with the other heating systems. Although there were several reports on the temperature measurements and the subjective evaluation by using floor heating system[1) 2)], we could not find out the report focused on its comprehensive physiological and psychological effects. In this study, we conducted the experiments both with and without floor heating system in the climatic chambers. The subjects were seven healthy males and they were sitting with their legs thrown out in front of them. By using measured items we discussed the effect of floor heating system on physiological and psychological responses.

METHODS

The experiments were conducted at the two climatic chambers of the Laboratory of Environmental Ergonomics, Hokkaido University. The outside sizes of the main climatic chamber equipped with the present floor heating system were W2700×D2700×H2100.

The experiment consisted of two conditions. The first one was the experiment with floor heating system (Exp-F). The second one was that without floor heating system as the control (Exp-C). Air temperature was set to keep 21 ℃ in both experiments. The relative humidity was kept 45 % level. Actual measured values are shown in Table 1. The average floor temperature was set to 25.9±0.1 ℃ with floor heating.

Table 1 Actual air temperature and relative humidity

	Floor heating	Control

Air Temperature [℃]	21.2±0.1	21.2±0.3
Relative Humidity [%]	44±1.1	44±0.1

The subjects were seven healthy males (age:23.1±0.9 [years], height:174.7±2.6 [cm], weight:64.0±5.0 [kg]). The clothing ensembles were selected from typical working uniform in winter. Subjects wore T-shirts (cotton), trunks (cotton), long-sleeve shirts (cotton and polyester), pants (cotton and polyester), work suit (cotton and polyester) and socks (cotton).

Subjects stayed at rest in the other climatic chamber (antechamber) controlled at 25 ℃, RH45 % over 90 min. At least 15 minutes before moving into the main chamber, the subjects stayed in sitting posture with their legs thrown out in front of them. After the initial measurement of the items in detail below, they moved quickly to the climatic chamber controlled by floor heating or room-air conditioner, and kept sitting posture their legs thrown out in front of them during 60 minutes.

The eleven point skin temperatures, the rectum temperature and the temperature of under tongue were measured with the thermistor (LT-ST08-12, Gram). The eleven measurement points of skin temperature consisted of the head, the abdomen, the back, the forearm, the hand, the in front of thigh, the back of thigh, the in front of crus, the back of crus, the foot, and the heel. In addition before and after the dominant experiment, we measured whole body temperature distribution with a thermography (TH5100, NEC).

Skin blood flow of the head, finger, and crus were measured by using a laser Doppler blood-flowmeter (ALF-21D, Advance). Blood pressures and electrocardiograms (ECG) were also measured by using a biological information monitor (BP608-EV, Omron). The measurement of blood pressure in the main climatic chamber was performed every fifteen minutes.

In this experiment, the reaction time to the auditory stimulus was measured to click a mouse of PC when the subjects detected it. As an indicator of the motor function or the muscle stiffness, the bipolar surface electromyograms (EMG) of the right trapezius was measured every 30 minutes (0, 30, 60 min) keeping elevation of scapular region for 10 seconds. The mean power frequency (MPF) was determined by using FFT.

As psychological items, thermal sensation vote (TSV) and thermal comfort vote (TCV) were selected.

RESULTS and DISCUSSION

The skin temperature of the head and the back changed differently from the other parts. With floor heating the parts which were contacted with the floor (back of thigh, back of crus and heel), the skin temperatures increased. For many parts which were not contacted with the floor, the skin temperatures decreased. However by using floor heating, the skin temperatures decrease was inhibited.

In Fig. 1 the skin temperature changes of the main four parts are shown. With floor heating system the skin temperatures of both the back of the thigh and crus, which contacted with the floor heating increased. The skin temperature of the back of thigh increased from 33.0 ℃ to 34.1 ℃ and kept the level of 34.1 ℃. The back of the crus skin temperature was increased from 32.4 ℃ to 33.2 ℃. The skin temperatures of the front crus, which did not contact with floor heating directly, decreased in the both conditions .When using floor heating, the skin temperature decreased 0.4 ℃ from 32.8 ℃ to 32.4 ℃, without floor heating, decreased 1.7 ℃ from 32.7 ℃ to 31.0 ℃. It was indicated that the floor heating system could relieve the skin temperature fall of it. At the both experimental conditions (with and without floor heating) the head skin temperatures also decreased. When using floor heating, the skin temperature decreased 2.0 ℃ from 34.4 ℃ to 32.4 ℃. In the case without floor heating, that decreased 0.9 ℃ from 34.0 ℃ to 33.1 ℃, of which tendency would be in contrast with those of the extremities.

Fig. 2 summarizes the measured results of skin and rectum temperature during 60 minutes. In the present experiments, both Exp-F and Exp-C the initial air temperature was 25 ℃ and the test air temperature was 21.2 ℃. It was considered to be a step change test from moderate thermal condition to slightly cool condition. The skin temperatures of almost parts were decreased. However in Exp-F with floor heating system the skin temperatures of the back of thigh and the back of crus, which were contacted with floor, increased about 1 ℃.

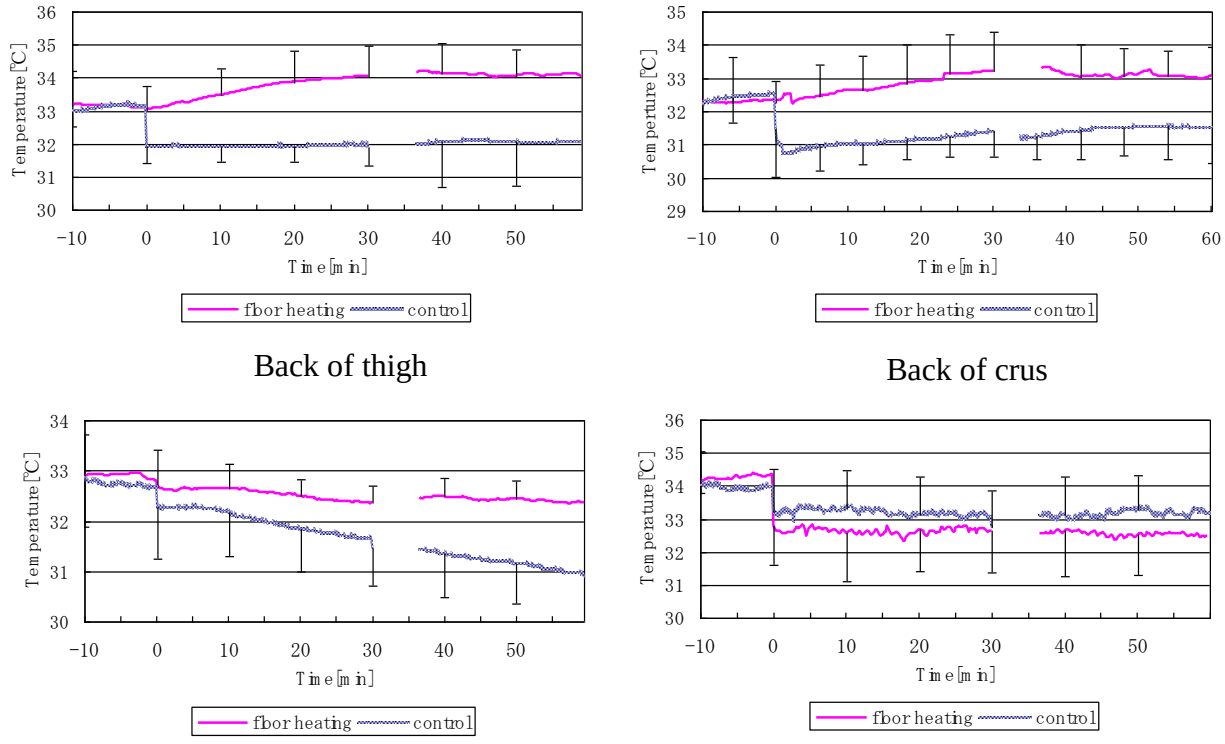


Fig. 1 Skin temperature change with time

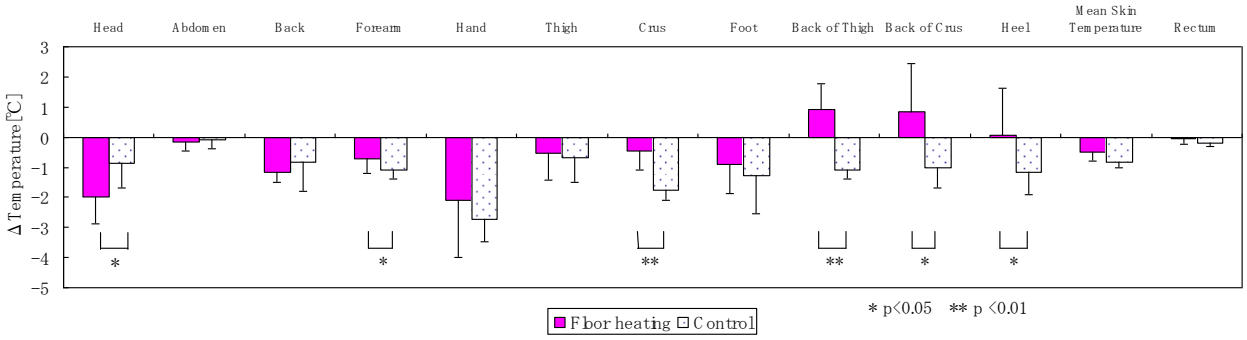
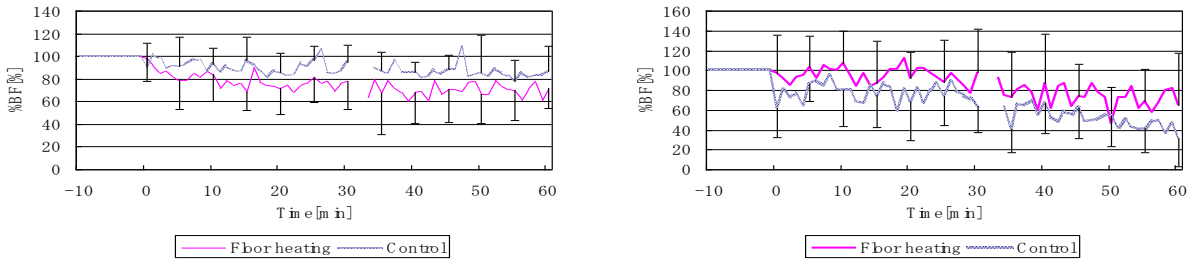


Fig.2 Variations in skin and rectum temperature



Head Finger

Fig. 3 The measured result of %Blood flow

The %blood flow rate of the front crus by using floor heating were the same level of those without floor heating. Fig. 3 shows the measured results of the blood flow rate of the head and the finger. The %blood flow rates of the head by using floor heating system were about 10 % lower than those of the control. On the contrary the blood flow rates of the finger with floor heating were higher than those of the control. It was considered that floor heating might induce the parasympathetic activation [3) 4)].

The measured values of the blood pressure were almost the same level at both conditions. The value of the systolic blood pressure was around 120 mmHg. The value of the diastolic blood pressure was 65 mmHg and the value of the mean blood pressure was 85 mmHg.

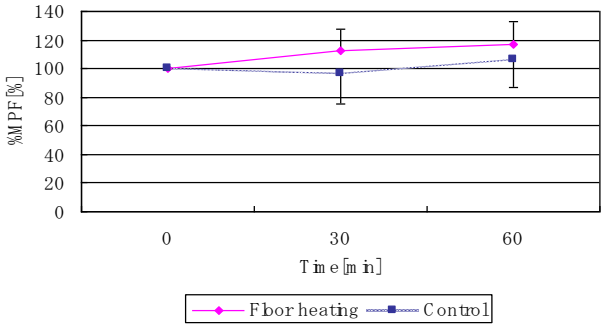


Fig. 4 The measured result of %MPF

Fig. 4 summarizes the results of the %MPF. The value at 0 min was defined as 100%. Without floor heating, the mean value of %MPF decreased down to 97% at 30min. On the other hand, the mean value of %MPF with floor heating increased to 112% at 30min, which was higher than that without floor heating. However, the statistical significance could not be calculated.

As is well known that mean power frequency decrease by muscle fatigue or cooling[5].In this experiment, the %MPF without floor heating decreased until 30 minutes. With floor heating, the %MPF increased until 60 minutes. These facts suggest that the strain of trapezius was relieved by floor heating until 30 minutes.

The reaction time was about 320 msec for both conditions, and significant differences was not able to be found.

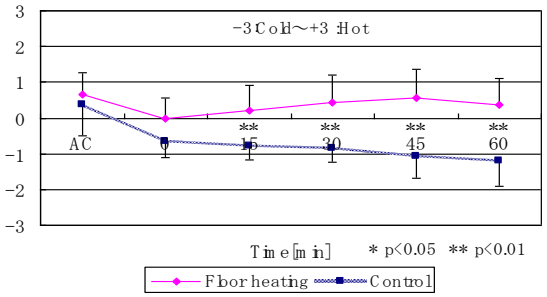


Fig. 6 Thermal sensation vote

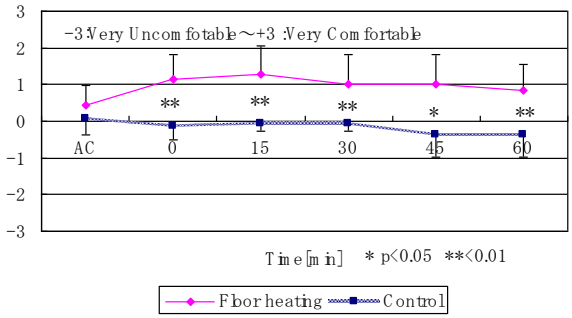


Fig. 7 Thermal comfort vote

Fig. 6 shows the measured result of the thermal sensation vote. After entered the main chamber, subjects felt slightly cool without floor heating system. With floor heating system, most subjects answered from “0: neutral” to “+1: slightly warm”. After 15 minutes, the significant differences was able to be found. In Fig. 7 the measured result of the thermal comfort vote are shown. Without floor heating system, most subjects kept answered “0: neutral”. With floor heating system, most subjects felt slightly comfortable. The significant differences were recognized just after the subjects entered the main chamber.

The findings of the present study were summarize that the floor heating systems could have the effect to inhibit the a fall of the skin temperatures and improve stiff shoulders, TSV and TCV.

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