Analysis of gravity effect on human blood flow and skin temperature through postural change

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Abstract. The blood flow of human body has much impact on the thermo-physiological response. When person change the posture, the gravity acts changes its direction and thus the blood flow can be changed. It is hypothesized that the gravitational effects of postural changes affect blood flow and skin temperature, which in turn affect comfort. To verify this, in the present study, a subject experiment focusing on postural changes was conducted for two conditions (Case 1 and Case 2). In the Case 1 experiment, the subjects were asked to raise their hands for 10 minutes after 30 minutes of rest in the chair-sitting position. As a result, significant skin temperature change were observed in the upper arm, forearm, and hand. The largest skin temperature change was observed in the hands, which showed a decrease in skin temperature of approximately 1.2 °C. The change had influence on the whole-body average value. In Case 2, the subjects were placed in the supine position for 10 minutes after 30 minutes of rest in the chair position. As a result, a decrease in skin temperature of approximately 1 °C was observed on the hands and 0.5 °C in the foot was observed.

1 Introduction

Due to the recent spread of the new coronavirus, people are spending more time at home, refraining from going out and working remotely. People are spending more time at home sitting in chairs, working, or lying down and watching TV. There are more opportunities to stay in the same posture for long periods. Therefore, it is necessary to pay attention to comfort while in the same posture for long periods.

Since gravity always acts on the human body, the human body is affected by gravity in the direction from the upper body to the lower body. When the posture is changed from this state, the direction in which gravity acts can be change depending on the body part. For example, when a standing person lies on his/her back, gravity, which had been acting from the head to the legs, now acts from the abdomen to the back. The change in the effect of gravity due to the change in posture has a significant effect on the blood flowing through the blood vessels in the human body. When gravity acts in the same direction as the direction of blood flow, blood flow increases, and when gravity acts in the opposite direction of blood flow, blood flow decreases. A change in blood flow means a change in skin temperature [1], and a change in skin temperature can also mean a change in comfort.

Tanabe et al. [2], Sakamoto et al. [3], and Hokoi et al. [4] have also conducted studies on skin temperature and blood flow. However, none of the studies focused on the possibility that the effects of postural changes could also affect comfort. Therefore, it is hypothesized that gravity effects due to postural changes would affect blood flow and skin temperature, which in turn would affect comfort. The purpose of this study is to clarify the effect of gravity due to postural changes on blood flow and skin temperature. Therefore, the changes in skin temperature due to gravity by subject experiments have been verified.

2 Outline of Experiment

A subject experiment was conducted to verify changes in skin temperature due to gravity. The experiment was conducted in a climate chamber. An outline of the experiment is shown in Table 1 and Figure 1. The subjects were 11 adult males, clothed in short sleeves and short pants, and the ambient temperature was 25 °C. The experiment was conducted for 40 minutes, with the first 30 minutes in a resting position in a chair-sitting position and the remaining 10 minutes in a posture-change condition. The posture was varied in two conditions: the first (Case 1) was performed in the raised arms position and the second (Case 2) was performed in the supine position. Skin surface temperatures were measured at five
locations: forehead, upper arm, forearm, dorsum of the hand, and dorsum of the foot. Blood flow was measured only at the hand.

There are many capillaries at the ends of the human body, and in addition, the distance between the skin surface and blood vessels is close. On the other hand, the upper arm and forearm have fewer blood vessels than the extremities, and the distance between the skin surface and the blood vessels is farther apart. Therefore, in case 1, it is hypothesized that the skin temperature of the back of the hand would change significantly after the posture change, while that of the upper arm and forearm would change more slowly than that of the back of the hand.

Blood released from the heart requires more momentum to be released toward the upper body than toward the lower body. However, in the supine position, the effect of gravity, which was acting in the opposite direction of blood toward the upper body, is weakened. In addition, the weight effect, which was working in the same direction as the blood flow in the lower body, is weakened. Therefore, in case 2, it is assumed that blood volume would increase, and skin temperature would increase in the upper body, while skin temperature would decrease in the opposite direction in the lower body.

3 Result and Discussion

3.1 Skin temperature

The results of the time change of the skin temperature are shown in Figures 2 (a) and (b). The whole-body average is calculated using Hardy&Dubois’ 7-point method.

The skin temperatures at each body part were stable from 0 to 1800 seconds before the postural change. Attention is focused on the period from 1800 seconds after the postural change from the chair-sitting position to the posture with both hands raised. Comparing the upper arm, forearm, and hand, the skin temperature of the hand showed the largest change, with a decrease in skin temperature of approximately 1 °C. Slight skin temperature fluctuations were observed on the forearm and upper arm. The forearm skin temperature decreased by about 0.5 °C and the upper arm skin temperature increased by about 0.25 °C. The increase in upper arm skin temperature could be attributed to the use of upper arm muscles in raising both hands. Another possibility is that raising the hands caused blood to flow down from the hands and forearms in the direction of the upper arms, which increased blood flow, and the skin temperature increased accordingly.

The skin temperature began decreasing from 1800 seconds after the posture change. This indicates that the local act of raising the hands even affects the whole-body average.

Figure 2 (b) shows the results of Case 2. In the forehead, the skin temperature of one subject was not measured, and the skin temperature of another subject was not partially measured. Therefore, the mean value was calculated by excluding the portions that were not accurately measured.

<table>
<thead>
<tr>
<th>Table 1 Outline of Experiment</th>
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<tbody>
<tr>
<td>Number of Subjects</td>
</tr>
<tr>
<td>Ambient Temperature</td>
</tr>
<tr>
<td>Clothes</td>
</tr>
<tr>
<td>Experiment Time</td>
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<tr>
<td>Chair Seating: 30 min</td>
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<tr>
<td>Postural Change: 10 min</td>
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<tr>
<td>Experimental Conditions</td>
</tr>
<tr>
<td>Case1: Raise both hands</td>
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<tr>
<td>Case2: Supine posture</td>
</tr>
</tbody>
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Fig.1 Time schedule of Experiment

Fig.2 (a) Time change of skin temperature in Case 1

Fig.2 (b) Time change of skin temperature in Case 2
The skin temperatures were almost constant between 0 and 1800 seconds before the postural change. After 1800 seconds, when the posture was changed from the chair-sitting position to the supine position, the skin temperature of the foot showed a gradually decreasing trend, with a decrease of approximately 0.5 °C. The skin temperature of the forehead, on the other hand, did not show any change. Focus on the upper arm, forearm, and hand. Attention is paid to the period after 1800 seconds, which is after the postural change. The largest change was observed in the hand, with a decrease of approximately 0.7 °C. The upper arm also showed a decrease of approximately 0.25 °C. On the forearms, the skin temperature remained almost constant, although there was some variation. The reason why the skin temperature of the hands and upper arms decreased is thought to be because the supine position caused a change in the direction of gravity to the side of the blood flow, which reduced blood flow.

Focus on the whole-body average. The skin temperature is stable up to 1800 seconds before the postural change but decreases from 1800 seconds after the postural change. Thus, as in Case 1, the skin temperatures of the hands, upper arms, and legs, which changed due to the supine position, were found to affect the whole-body average.

3.2 Blood flow

Figures 3 (a) and (b) show the blood flow rate in the hand in Case 1 and Case 2. The data shown in the figure is the average of all 11 subjects.

It was confirmed that the blood flow rate decreased by about 30 ml/min at once immediately after the posture change. Compared with the skin temperature of the hands shown in Figure 2, it was confirmed that the blood flow rate change corresponded to the skin temperature change.

Figure 3 (b) shows that the posture change from the sitting position to the supine position after 1800 seconds is noteworthy. A slight decrease in blood flow was observed immediately after the postural change. Comparing the two cases, in Case 1, a decrease in blood flow of about 30 ml/min was observed for a skin temperature change of about 1 °C. However, in Case 2, only slight fluctuations in blood flow were observed for a skin temperature change of approximately 0.75 °C.

The results verified the postural change affected on the blood flow and then the skin temperature. It means that the thermal sensation can be also changed by the posture. The thermal sensation of occupants needs to be evaluated depending on the occupants’ posture. For instance, occupant in patient’s bedroom in hospital mainly stay lying in bed. Japanese-style room expect occupant sitting on the floor. Thermal environment needs to be designed based on the typical posture of occupant in the environment.

4 Conclusion

To verify the change in skin temperature due to gravity, experiments were conducted on 11 subjects under two postural change conditions. The results confirmed the following.
1) The skin temperature of the hand showed the largest change of whole body by raising the hand in Case 1 while the upper arm and forearm showed a slower change than the hand.
2) The skin temperature change corresponded to the blood flow change in Case 1.
3) The postural change to the supine caused the skin temperature decreasing in the hands, upper arms, and foot, however that in the forehead and forearms did not change.
4) Both Case 1 and Case 2 confirmed that the local skin temperature change was large enough to affect the whole-body average.

It was confirmed that postural changes sufficiently affect skin temperature and blood flow. In conventional comfort evaluation, the six elements of the thermal environment, namely air temperature, radiant temperature, airflow, humidity, amount of clothing, and metabolic rate, have been taken into consideration. However, considering that changes in the posture of the human body alter blood flow and skin temperature, it is considered necessary to consider posture as the seventh element of the thermal environment.
Acknowledgement

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