# Effects of the Procedures of Body Compression on the Skin Temperature

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## 1. Introduction

Clothing pressure is an important factor in clothing comfort[1]. Generally, 40gf/cm$^2$ of pressure is regarded as hygienic allowance level of clothing pressure on the body. This value was derived from clothing pressure experiments by Obi[2,3]. The level of comfort varies with part of the body and compressed area[4,5,6]. Similarly, it was suggested that those level are influenced by the clothing material[7,8]. This assumption was confirmed by our experiments using two different procedures of body compression[9].

In this study, the skin temperature was compared among several different procedures of the body compression.

## 2. Methods

1) Subjects

Five healthy female students participated in this study. Their ages were 21–22 years old. Table 1 presents their physical characteristics. During the experiment, the subjects wore undershorts, brassiere, training shirt and training pants. The total insulation site of the clothing was about 0.76 clo[10,11].

2) Site of compression

Clothing compression has a direct influence on the neck, under breast, waist, abdomen, arm and legs. Therefore the left forearm was compressed, as in the previous experiment.

3) Application of compression

The pressure applied in this study was: 0mmHg, 30mmHg (≒40.8gf/cm$^2$), 40mmHg (≒54.4gf/cm$^2$), 50mmHg (≒68.0gf/cm$^2$) with reference to the results of Kawao[2] and our study[9]. A blood pressure cuff (width 13.8cm×length 47.0cm) was used for compressing the left forearm. The left forearm was compressed for intervals of 10, 30, or 60 sec for 10 min.

4) Measurement sites of skin temperature

The compression of the body decrease blood circulation[12]. Honda et al[13] reported that if the room temperature and the body temperature were kept constant, the skin temperature reflects the degree of the blood flow.

In this study, we measured the skin temperature during 4 types of body compression. The

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Table 1 Measurements of the subjects

| Subject | Stature (cm) | Weight (kg) | Rohrer# index | Blood pressure (mmHg) | pulse (beat/min) | forearm girth (cm) |
|---|---|---|---|---|---|---|
| A | 160.0 | 51.0 | 124.5 | 108–64 | 78.3 | 22.0 |
| B | 158.5 | 50.5 | 126.8 | 99–60 | 75.0 | 22.3 |
| C | 162.8 | 54.0 | 125.1 | 99–58 | 62.5 | 22.6 |
| D | 162.0 | 52.0 | 122.3 | 107–55 | 83.0 | 22.0 |
| E | 159.0 | 53.0 | 131.9 | 120–70 | 83.1 | 23.0 |

Rohrer index#: (Weight,kg)$10^7$/(Stature, cm)$^3$

sites of measurement were ipsilateral fingers, contralateral fingers and 8 sites on the body for calculating the mean skin temperature. The site on the fingers was the back of the middle phalanx of the third finger, since preliminary experiments revealed that this site was stablity and the temperature corresponded to the mean temperature of the five fingers of the hand.

Fig. 1 shows the 8 sites measured to obtain the mean skin temperature[14].

$$\text{The mean skin temperature} = 0.07T_1\,(\text{forehead}) + 0.14T_2\,(\text{forearm}) + 0.05T_3\,(\text{palm}) + 0.17T_4\,(\text{back}) + 0.18T_5\,(\text{chest}) + 0.19T_6\,(\text{thigh}) + 0.13T_7\,(\text{leg}) + 0.07T_8\,(\text{foot}) \quad \cdots\cdots \quad (1)$$

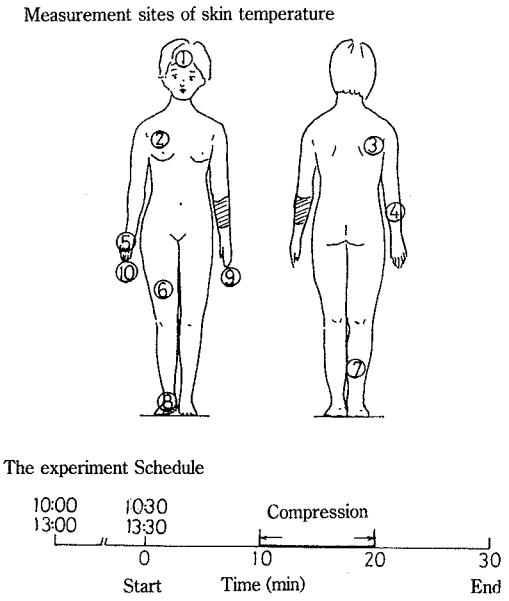


Fig. 1 Measurement sites of skin temperature and the experiment schedule.
The shadow part of left forearm was compressed.
Measurement sites: ①Forehead ②Chest ③Back ④Forearm ⑤Hand ⑥Thigh ⑦Leg ⑧Foot ⑨Ipsilateral Finger ⑩Contralateral Finger

In addition, the oral temperature was measured at the same time.

5) Instrument for measuring skin temperature

The skin temperature was measured by a thermocouple made from copper · constantan. The data were recorded by an instrument that record 12 temperature points at the same time (3087 type, YOKOGAWA HOKUSHIN). The skin temperature was calibrated by the correlation line between the temperature of the thermocouple and that of the standard thermometer.

6) Method of measurement

The experiment was carried out between meals with the subject lying in bed after a 30 min rest. Pressure cuff and thermocouples were set in place 10 min before the experiment.

The lower part of Fig. 1 shows the experimental schedule. The compression time for the left forearm was 10 min. The degree of compression was 30, 40 or 50 mmHg. This examination was repeated 3 times under the same conditions in a climate chamber at a constant temperature (27±1°C), constant humidity (50±5%RH), and air verocity (below 0.1 m/sec).

## 4. Results and Discussion

1) Skin temperature of the finger

Fig. 2 shows the changes in finger temperature during the compression of 0 mmHg and 50 mmHg. The ipsilateral skin temperature decreased in comparison with contralateral skin

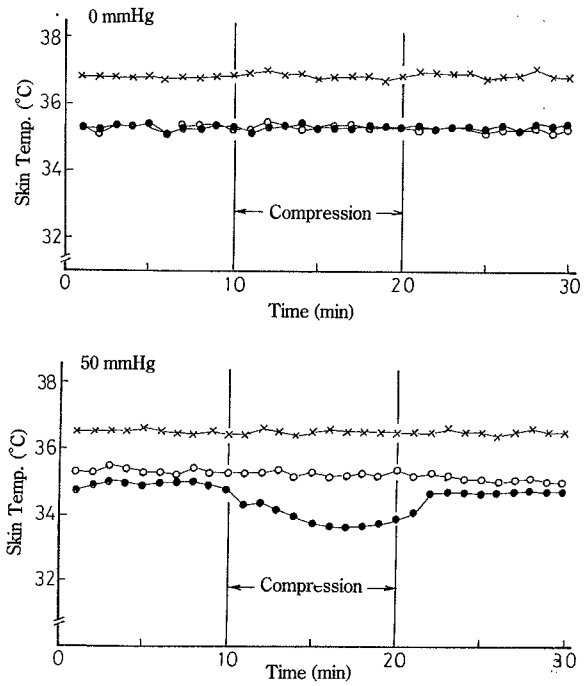


Fig. 2 The changes in finger temperature during compression.
—○—: Contrateral Finger —●—: Ipsilateral Finger
—×—: Oral Temperature

temperature at 50 mmHg. The change in skin temperature($\Delta T$) was calculated by subtracting the skin temperature 1 min to 5 min before compression from the temperature measured during and after compression of the left forearm. Oral temperature was almost never changed under these circumstances.

Fig. 3 shows the change in temperature of the ipsilateral finger. The horizontal line shows 10 min of compression and 10 min after compression. Compression at intervals of 10 sec caused a decrease in skin temperature of the ipsilateral fingers compared with no compression. The decrease in skin temperature with compression of 30 and 40 mmHg was below 0.2°C, and was stable in 5 min after compression. After cessation of compression, the temperature of the finger

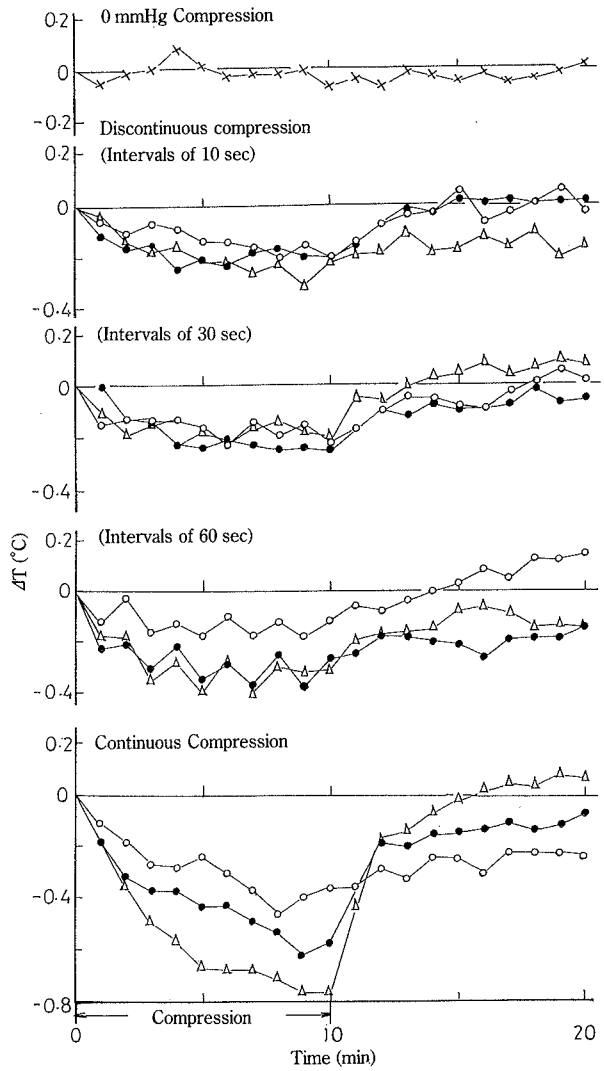


Fig. 3 The changes in temperature of ipsilateral finger.
—○—: 30 mmHg —●—: 40 mmHg —△—: 50 mmHg

immediately recovered to the temperature before compression. With 50 mmHg of compression, the skin temperature was slowly decreased during compression. After 10 min of compression, the decrease in the ipsilateral finger was about 0.3°C. Compression at intervals of 30 sec caused a decrease in the temperature in the ipsilateral finger similar to that at intervals of 10 sec. With compression at intervals of 60 sec, temperature in the ipsilateral finger was decreased and rose corresponding to the compression of the left forearm. With 30 mmHg, the temperature in the ipsilateral finger decreased about 0.2°C. With 40 mmHg and 50 mmHg, the decrease was 0.4°C.

With continuous compression of 30 mmHg, the temperature in the ipsilateral fingers decreased with compression, and was 0.5°C after 8 min of compression. With compression of 40 mmHg and 50 mmHg, the temperature decreased respectively to 0.6°C and 0.8°C.

Fig. 4 shows the relation between the compression and the change in temperature of the ipsilateral fingers. The plots of Fig. 4 are the arithmetical mean values, which were calculated by the skin temperature 9 min and 10 min during compression on the left forearm. The vertical bars indicate the 95% confidence interval.

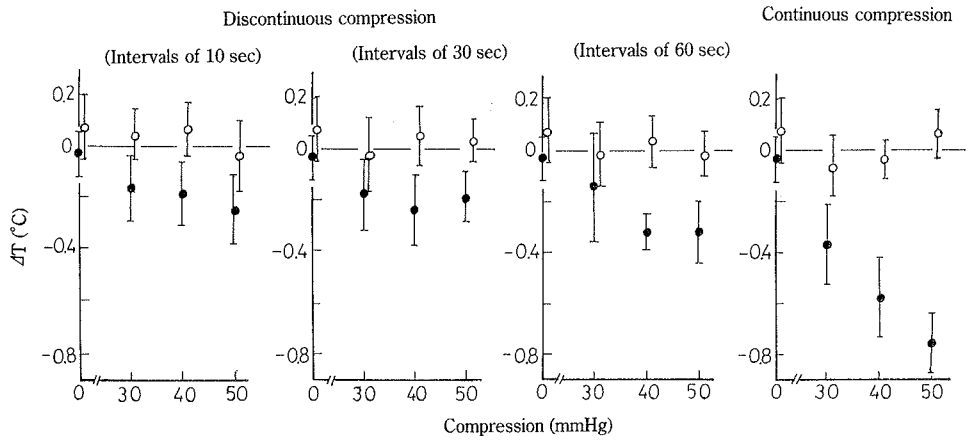


Fig. 4 The relation between compression and the temperature of ipsilateral finger.

When the forearm was compressed continuously at 60 mmHg, the temperature in contrateral fingers increased slightly.

In the ipsilateral fingers, a significant decrease was seen between no compression and discontinuous compression (for the interal of 10 and 30 sec $p<0.05$, for the interval of 60 sec $p<0.01$). However no significant decrease was noted at the same compression among discontinuous procedures. The decrease in temperature with discontinuous compression was larger at intervals of 60 sec than at 10 and 30 sec.

With continuous compression, a significant decrease was found for compression of 30 mmHg ($p<0.01$). The skin temperature decreased with the compression during all continuous compression time. These results showed that the skin temperature was more influenced by continuous than discontinuous compression.

Discontinuous compression of the body corresponds to the compression by clothing having low extensibility, and continuous compression is similar to that of highly extensible material.

Our results shows that the level of allowance and comfort of clothing pressure are higher during compression by material with low extensibility than with high extensibility.

2) The mean skin temperature of the body

Fig. 5 shows the mean skin temperature calculated from measurements at 8 sites of the body. The mean skin temperature increased slightly during measurement. In addition, the change in skin temperature increased with compression but not significantly.

Table 2 shows the individual correlation coefficients for the mean skin temperature at 8 sites and both finger temperatures. The mean skin temperature was significant correlation to the temperature of the forehead, forearm, back, thigh, leg and foot. As thigh temperature was highly correlated to the mean skin temperature (r=0.805), it was considered that the change of

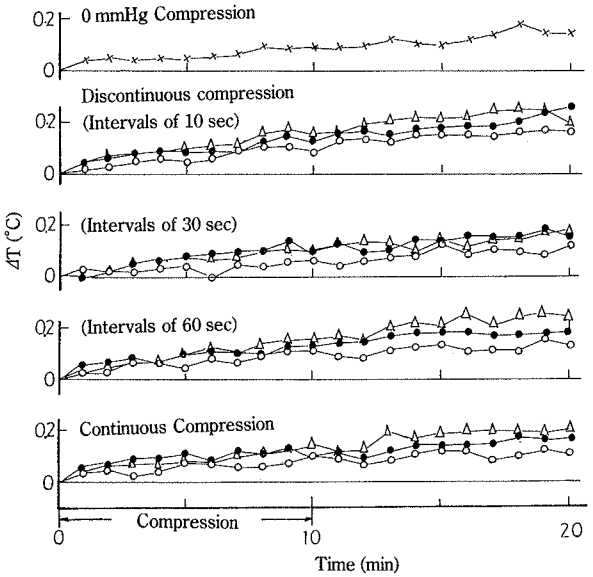


Fig. 5 The changes in mean skin temperature calculated from measurements at 8 sites of the body. —○—: 30 mmHg —●—: 40 mmHg —△—: 50 mmHg

Table 2 Individual Correlation Coefficients

| | Tm | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | Ti | Tc |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Skin Temp. | Tm | 0.289* | 0.451** | 0.150 | 0.709** | 0.535** | 0.805** | 0.773** | 0.491** | 0.077 | −0.106 |
| Forehead | T1 | | 0.007 | 0.124 | 0.107 | 0.378** | 0.153 | 0.100 | 0.051 | 0.168 | 0.074 |
| Forearm | T2 | | | −0.153 | 0.130 | 0.149 | 0.274** | 0.223* | 0.111 | −0.036 | −0.046 |
| Hand | T3 | | | | 0.114 | 0.143 | 0.001 | −0.025 | 0.094 | 0.446** | 0.247** |
| Back | T4 | | | | | 0.430** | 0.437** | 0.510** | 0.245** | 0.053 | −0.009 |
| Chest | T5 | | | | | | 0.351** | 0.187 | −0.028 | 0.008 | −0.000 |
| Thigh | T6 | | | | | | | 0.573** | 0.318** | 0.005 | −0.204* |
| Leg | T7 | | | | | | | | 0.371** | −0.010 | −0.143 |
| Foot | T8 | | | | | | | | | 0.044 | −0.093 |
| Ipsilateral Finger | Ti | | | | | | | | | | 0.437** |
| Contralateral Finger | Tc | | | | | | | | | | |

*significant at 0.05 level
**significant at 0.01 level

mean skin temperature depended on the change of thigh temperature.

Yoneda[2] found a 0.3°C increase of skin temperature, when the clothing pressure was applied the body. Similar results were obtained in our previous study[9] in which continuous and discontinuous compression of the forearm and leg caused a gradual increase of the mean skin temperature. The increase of skin temperature in the non-compressed parts was considered to be caused by a reflex mechanism in response to skin compression[15].

## 4. Summary

Changes in skin temperature were measured during 4 different compression procedures. The skin temperature in ipsilateral fingers decreased upon compression of the left forearm. The decrease with discontinuous compression was lower than that with continuous compression. The decrease with compression intervals of 10 and 30 sec was smaller than that with 60 sec of discontinuous compression. When the continuous and discontinuous compression was applied to the left forearm, the skin temperature of the contralateral fingers did not changed with these level of compression.

The mean skin temperature gradually increased during all compression procedures, and was dependent on the increase of the skin temperature in the thigh, leg and back. The increase of the mean skin temperature was higher with large compression.

These results show that extensibility of clothing and body condition are important parameters in deciding the level of allowance and comfort of with clothing pressure.

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