Effect of Native Place on Sweating Rate at Rest and during Exercise in Dry and Humid Heat

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Thermal sweating is one of the effective methods for the regulation of body temperature, and depends on surface and deep body temperatures (Nadel et al., 1971). It is well known in our experience that sweating is related to climatic factors such as ambient temperature, humidity and air current. And sweating responses can be varied by climatic acclimatization (Hori et al., 1976).

The purpose of the present study is to measure the interaction of sweating rates and body temperatures at rest and during exercise in heat, and to investigate the individual differences based on native place.

METHODS

Eight male students in good physical conditions were served as subjects. All of them lived in Chiba prefecture, and were divided into two groups based on their native places. Group A (MM, SS, KS and SO) were born and grown up in Kanto or Tohoku districts. Group B (YN, HS, YM and SR) came from South Kyushu area or Formosa one or two years ago.

Table 1 lists their ages, heights, weights, body surface areas (BSA), mean skinfold thickness (MSF) and body densities (D). BSA, MSF and D were calculated by the prediction equations as previously described (Katsuura et al., 1982). There were no significant differences between these physical characteristics in the two groups.

All experiments were performed in a climatic chamber. The set points of air temperature and relative humidity were 25°C—50%, 40°C—25% and 40°C—75%.

After rest for 45 minutes, they performed two successive exercises by bicycle ergometer at load of 50W and 100W for 15 minutes, respectively. Sweating rate, rectal temperature and skin temper-

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age (yr)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>BSA (m²)¹</th>
<th>MSF (mm)²</th>
<th>D (g/ml)³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>MM</td>
<td>23</td>
<td>176.5</td>
<td>75.9</td>
<td>1.875</td>
<td>23.6</td>
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<tr>
<td>SS</td>
<td>22</td>
<td>175.0</td>
<td>55.8</td>
<td>1.626</td>
<td>9.4</td>
<td>1.073</td>
</tr>
<tr>
<td>KS</td>
<td>23</td>
<td>171.5</td>
<td>51.7</td>
<td>1.551</td>
<td>4.8</td>
<td>1.080</td>
</tr>
<tr>
<td>SO</td>
<td>22</td>
<td>173.5</td>
<td>67.8</td>
<td>1.763</td>
<td>12.8</td>
<td>1.061</td>
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<td>Group B</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YN</td>
<td>19</td>
<td>166.0</td>
<td>56.1</td>
<td>1.574</td>
<td>8.4</td>
<td>1.076</td>
</tr>
<tr>
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<td>19</td>
<td>180.0</td>
<td>69.3</td>
<td>1.824</td>
<td>9.4</td>
<td>1.075</td>
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<tr>
<td>YM</td>
<td>21</td>
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<td>72.3</td>
<td>1.845</td>
<td>7.7</td>
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<td>60.1</td>
<td>1.610</td>
<td>15.9</td>
<td>1.057</td>
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<td>63.6</td>
<td>1.709</td>
<td>11.5</td>
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<tr>
<td>S.D.</td>
<td>3</td>
<td>5.3</td>
<td>8.3</td>
<td>0.124</td>
<td>5.5</td>
<td>0.009</td>
</tr>
</tbody>
</table>

¹ Body surface area  ² Mean skinfold thickness  ³ Body density
ature were measured every 3 minutes during the last 15 minutes of rest period and during exercise.

Volume of sweat was measured by a filter paper ($\phi$ = 5.5 cm) on the right chest (Ohara, 1968).

Mean skin temperature was calculated from the equation of Ramanathan (1964).

The experiments were undertaken in Chiba during autumn and winter.

RESULTS AND DISCUSSION

Figure 1 shows the changes of sweating rate in eight subjects. At 25°C–50%, sweating was hardly observed at rest and during 50–W exercise, but increased with the passage of time during 100–W exercise. At 40°C–25% and −75%, sweating was found in all periods of experiments. Sweat rates in these hot conditions didn't tend to change at rest, but increased during exercise. The large individual differences were, however, observed at high temperature and high humidity (40°C–75%).

Figure 2 shows the changes of rectal temperature and mean skin temperature. Rectal temperatures rose during exercise, and those at the end of exercise tended to be higher at 40°C than at 25°C. The maximum value tended to be found at 40°C–75%.

Mean skin temperatures increased slightly at 40°C, although those changes at 25°C were not uniform. There was little correlation between sweating rate and physical characteristics, that is, body surface area, mean skinfold thickness and body density. But significant correlations were observed between sweating rate and mean skin temperature and between sweating rate and rectal temperature.

So a multiple regression equation among sweating rate (SR: mg/23.75 cm²/2 min), mean skin

![Graph showing sweating rate changes](image-url)

**Fig. 1** Changes of sweating rate (SR) in eight subjects. △: 25°C-50%, □: 40°C-25%, ○: 40°C-75% 0-15 min: rest, 15-30 min: 50-W exercise, 30-45 min: 100-W exercise.
temperature (Ts: °C) and rectal temperature (Tr: °C) was obtained.

$$SR = -2510.5 + 15.937Ts + 53.597Tr$$ (R = 0.743)

where R is a multiple correlation coefficient, and was statistically significant (p < 0.01). This conformed to the result of Nadel et al. (1971).

As for the individual difference based on native place, sweating rate and rectal temperature (initial value and maximum value) tended to be lower in group B than in group A at any ambient condition. This indicates that the heat loss in group B is more efficient than that in group A. But there was little difference between mean skin temperatures in these groups.

Each multiple regression equation was shown as follows.

Group A: $$SR = -2128.7 + 22.280Ts + 37.592Tr$$ (R = 0.768)

Group B: $$SP = -2058.1 + 11.972Ts + 45.132Tr$$ (R = 0.688)

Both of the multiple correlation coefficients were significant (p < 0.01 in group A, p < 0.05 in group B).

The proportions of Ts and Tr in group A were significantly different from those in group B. This suggests that the influence of surface temperatures and deep temperatures on the sweating rate may be varied by the factors of native place.

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REFERENCES


Nagoya Med. J., 14: 133—144.


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