

PERIPHERAL THERMAL THRESHOLDS AND THERMOEFFECTORS THRESHOLD ZONE IN MALAYSIAN AND JAPANESE MALES

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INTRODUCTION

Heat acclimatization is triggered as a response to a complex of environmental factors in hot climate. A number of studies on heat acclimatization have been reported in terms of physiological adaptation (such as body temperature and sweating responses) (Saat et al., 2005; Saat & Tochihara, 2008), while studies on heat acclimatization in cutaneous thermal sensitivity are relatively rare. It is known that long term changes in a thermal environment can reach the central nervous system either directly, by deviation of core temperature, or indirectly, via thermoreceptors (Hensel, 1982). Cutaneous thermal receptors transmit information about the temperature of the external surface of the body (Iggo, 1970), and mediate the autonomic temperature regulation, and the experiences of thermal comfort and discomfort (Hammel, 1968; Hardy, 1961; Hensel, 1982; Nadel et al., 1973). These experiences motivate our thermoregulatory behaviour. The purpose of this study was to investigate: 1) differences in cutaneous warm and cool sensations between Malaysian and Japanese males; 2) peripheral thermoeffector zone estimated from an inter-threshold zone between cool and warm sensations in two ethnic groups.

METHODS

Ten Malaysians (MY) and ten Japanese (JP) young males participated in this study (JP: 21±1yr in age, 168.9±4.5cm in height, 62.6±5.3kg in weight, 1.75±0.09m² in BSA, 14.1±2.8%bodyfat, 41.8±4.8ml min⁻¹ kg⁻¹ in VO₂max, 24.2±4.7g hr⁻¹ m⁻² in insensible body mass loss, 0.77±0.05kcal min⁻¹ m⁻² in resting metabolism; MY: 22±2yrs, 167.9±5.4cm, 65.2±11.1kg, 1.77±0.15m², 19.0±5.7%BF, 39.6±3.6ml min⁻¹ kg⁻¹, 24.1±4.3g hr⁻¹ m⁻², 0.82±0.11kcal min⁻¹ m⁻²). Ten Malaysian males were invited from Malaysia to Fukuoka, Japan to participate in the present study as volunteers. Each subject stayed in Fukuoka for two weeks for the participation.

Peripheral warm and cool thresholds were measured on 12 body regions (the forehead-FH, chest-CH, abdomen-AB, back neck-NK, upper back-BK, forearm-FA, hand-HD, palm-PM, thigh-TH, calf-CF, instep-IT, and sole-SL on the left side of the body), using a stimulator with a thermo-electronic probe and a push-button switch (Intercross-200, Intercross, Japan). The surface area of the probe in contact with the skin was 25×25mm (6.25cm²). The speed of

warming and cooling of the probe was set at $0.1^{\circ}\text{C}\cdot\text{sec}^{-1}$. All subjects were instructed to push the timer-switch the moment they felt a ‘slightly warm’ or ‘slightly cool’ sensation from their thermal neutral state. The surface temperature, the change of surface temperature, heat flux on/through the surface of the probe, etc. were simultaneously recorded. Skin temperatures (T_{sk}) were recorded every second on the adjacent 12 body regions of the thresholds measurement body sites (LT-8A, Gram Ltd, Japan). Mean skin temperature (mean T_{sk}) was estimated from a modified Hardy-DuBois’ equation. Rectal temperature (T_{re}) was monitored at a depth of 13cm from the anal sphincter every second (LT-8A, Gram Ltd, Japan). Subjects had laid supine on a bed for at least two hours. Insensible body mass loss was estimated by the difference between body mass before and after the experiment. Resting energy metabolism (M_{rest}) and VO_2max were measured on different days. The climatic chamber was maintained at an air temperature of 28°C with 50%RH. Each subject wore only shorts. Body hairs on the calf and thigh were shaved beforehand, as large as $4\times 4\text{cm}$ each. Subjects had laid supine on a portable net bed equipped in the climatic chamber. After 30min-stabilization on the net bed, thermal threshold measurement was conducted. All measurements were repeated three times and were done between 14:00-18:00PM. Before measuring, careful instructions were provided in the subject’s own language and all subjects were pre-adapted to thermal threshold measurements.

Throughout the present study, the detectable temperature range (DTR) was defined as the rise/fall of skin temperature once the subject initially detects a warm/cool sensation during the warming/cooling of the body skin, starting from thermal neutral state of the skin. Inter-threshold’s zone was defined as the distance of DTR between a ‘slightly warm’ and ‘slightly cool’ sensation. Peripheral thermoeffector threshold zone (PTTZ) represents the inter-threshold’s zone as a sum of DTR to warmth and coolness. Weighted means of T_{sk} at the warm/cool thresholds, DTR on 12 regions, and PTTZ were calculated with the same coefficients of Hardy & DuBois’ 7-point mean- T_{sk} equation: $\text{Weighted mean PTTZ} = 0.07(\text{PTTZ}_{\text{forehead}} + \text{PTTZ}_{\text{neck}})/2 + 0.35(\text{PTTZ}_{\text{chest}} + \text{PTTZ}_{\text{abdomen}} + \text{PTTZ}_{\text{upper back}})/3 + 0.14(\text{PTTZ}_{\text{upper arm}} + \text{PTTZ}_{\text{forearm}})/2 + 0.05\text{PTTZ}_{\text{hand}} + 0.19\text{PTTZ}_{\text{thigh}} + 0.13\text{PTTZ}_{\text{calf}} + 0.07\text{PTTZ}_{\text{foot}}$. A regional sensitivity coefficient was defined as a ratio of thermal sensitivity normalized by the baseline calf sensitivity coefficients, in terms of detectable temperature range. The value was calculated in the following manner (e.g., Warm *insensitivity* coefficient of the forehead = Detectable temperature of the forehead/Detectable temperature range of the calf; Warm sensitivity coefficient = Warm *insensitivity* coefficient⁻¹). ANOVA was conducted to test the differences by two ethnic groups and 12 body regions. Duncan’s Post-hoc test was carried out on the items that showed significant differences in body regions after ANOVA. A significance was set at $p < 0.05$.

RESULTS

No difference was found in resting mean T_{sk} between MY ($33.9 \pm 0.4^{\circ}\text{C}$) and JP ($34.2 \pm 0.2^{\circ}\text{C}$), but the forearm, palm, hand, instep, and sole skin temperatures were significantly lower in MY than JP (Fig.1). Resting T_{re} was higher in MY than in JP ($37.1 \pm 0.3^{\circ}\text{C}$ for MY, $36.8 \pm 0.2^{\circ}\text{C}$ for JP; $p < 0.05$) and rectal-to-skin temperature gradient was greater in MY than JP ($3.2 \pm 0.3^{\circ}\text{C}$ for MY, $2.6 \pm 0.3^{\circ}\text{C}$ for JP; $p < 0.01$). For T_{sk} at the warm threshold, MY perceived a warm sensation at a higher T_{sk} on the forehead than those of JP ($p < 0.05$, Fig.2). MY also showed a tendency of perceiving cool sensation at a lower T_{sk} on the hand, palm, instep, and sole (Fig. 2). The weighted mean of T_{sk} at cutaneous warm/cool sensations were $37.5 \pm 0.8/33.6 \pm 0.7^{\circ}\text{C}$ for JP and $37.7 \pm 0.9/33.4 \pm 1.3^{\circ}\text{C}$ for MY.

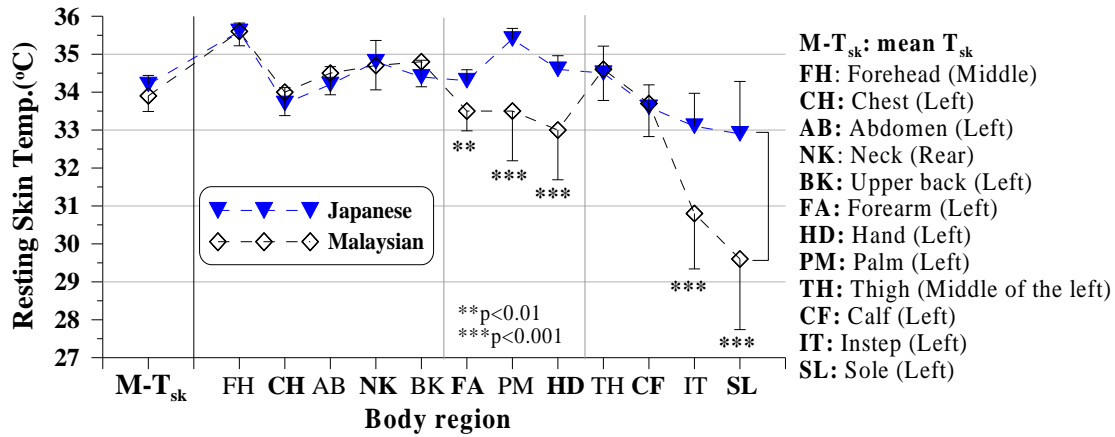


Fig. 1. Resting mean T_{sk} and body regional T_{sk}.

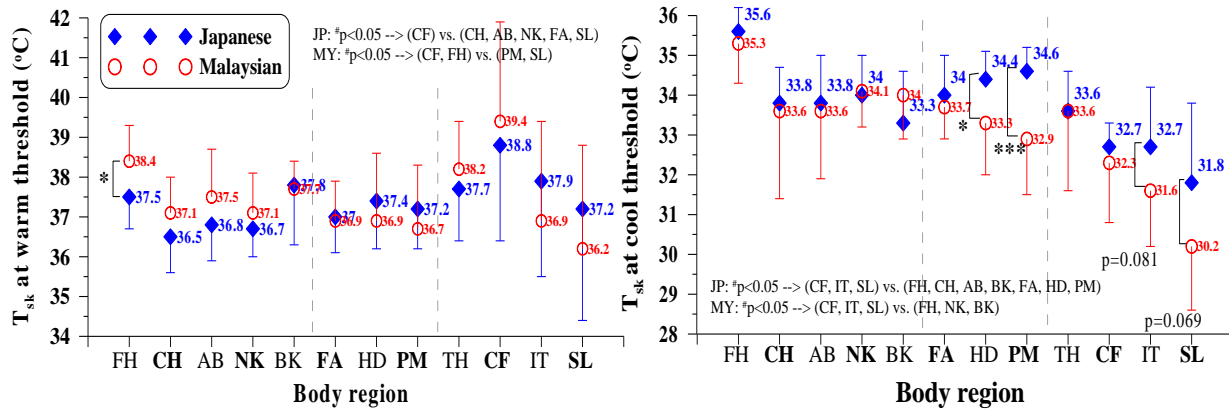


Fig. 2. Skin temperatures at warm and cool thresholds (*p<0.05, ***p<0.001).

Overall, DTR of cutaneous warm sensations was greater in MY than JP, but the ethnic difference was not significant due to great individual variations (SD) (Fig. 3). The weighted mean of the DTR of cutaneous warm/cool sensation were $1.98 \pm 0.65 / -1.29 \pm 0.68^\circ\text{C}$ for JP and $2.32 \pm 0.85 / -1.49 \pm 1.11^\circ\text{C}$ for MY.

Warm sensitivity coefficients normalized by the calf sensitivity had a tendency of being greater in JP than in MY (Table 1). That is, when the calf sensitivity was set as the baseline (value=1), the forehead for MY was 2.89 times more sensitive to warm sensation than that of the calf (p<0.05), while the JP's forehead was 8.69 times more sensitive to warm comparing to the thermal sensitivity of the calf (these ratios were consistent with the results using reaction times to warmth and coolness). For JP, the forehead among 12 regions was the most sensitive to both warming and cooling, while for MY the neck and the forehead were the most sensitive sites to warming and cooling, respectively (Table 1).

PTTZ that expressed in terms of the detectable temperature range (DTR) had a tendency of being wider in MY than in JP (Fig. 3 and 4). The ethnic difference was marked on the forehead ($1.95 \pm 1.22^\circ\text{C}$ for JP, $3.16 \pm 1.61^\circ\text{C}$ for MY, p=0.075; Fig. 3). The forehead-PTTZ was discriminated from the PTTZ on the calf, instep and sole for JP; from the calf and sole PTTZ for MY (p<0.05). The calf had the widest PTTZ among 12 body regions ($6.16 \pm 2.76^\circ\text{C}$ for JP,

7.11±3.08°C for MY). The weighted mean of PTTZ was 3.9±1.4°C for JP and 4.3±2.0°C for MY. The actual range of PTTZ in terms of skin temperature was the widest on the calf (32.7-38.8°C for JP; 32.3-39.4°C for MY) and the smallest on the forehead (35.6-37.5°C for JP; 35.3-38.4°C for MY) (Fig. 4).

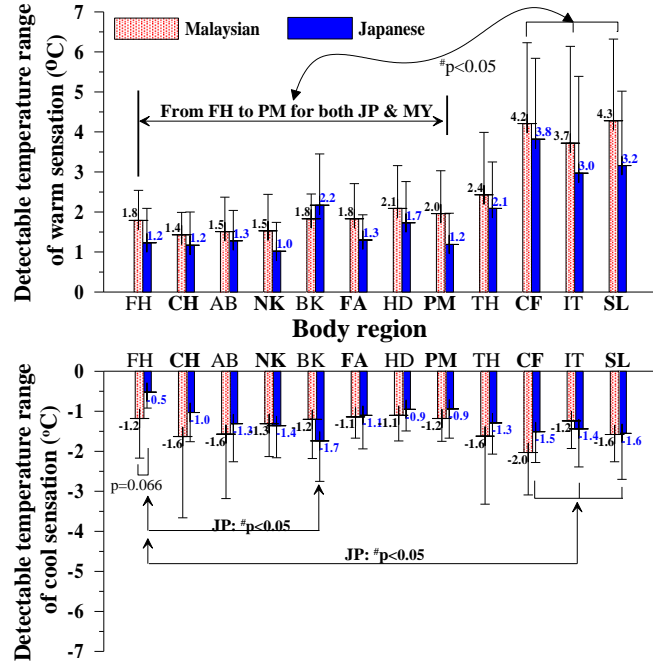


Fig. 3. Detectable range of warm and cool sensations.

Table 1. Sensitivity coefficients normalized by the calf thermal sensitivity

	Warm sensation		Cool sensation	
	Japanese	Malaysian	Japanese	Malaysian
Forehead	8.69 ^c ±11.5	2.89 ^{bcd} ±2.17	5.26 ^b ±6.47	2.68 ^b ±2.86
Chest	7.48 ^{bc} ±13.1	3.17 ^{cd} ±1.37	2.92 ^a ±3.97	2.50 ^{ab} ±2.91
Abdomen	4.45 ^{abc} ±3.61	3.64 ^{cd} ±2.36	1.68 ^a ±1.22	1.68 ^{ab} ±1.12
Neck	5.61 ^{abc} ±5.58	3.94 ^d ±2.82	1.48 ^a ±0.95	1.62 ^{ab} ±0.60
Back	2.48 ^{abc} ±1.54	2.43 ^{abcd} ±1.17	1.03 ^a ±0.51	1.97 ^{ab} ±0.92
Forearm	4.01 ^{abc} ±4.03	2.56 ^{abcd} ±1.23	1.70 ^a ±1.04	1.92 ^{ab} ±0.95
Hand	4.43 ^{abc} ±6.80	2.53 ^{abcd} ±1.53	1.86 ^a ±1.26	2.52 ^{ab} ±2.22
Palm	5.14 ^{abc} ±5.49	2.80 ^{bcd} ±1.96	2.40 ^a ±1.87	1.78 ^{ab} ±0.68
Thigh	2.10 ^{ab} ±1.27	2.19 ^{abc} ±1.35	1.48 ^a ±0.91	1.64 ^{ab} ±0.89
Calf	1.00^a ±0.00	1.00^a ±0.00	1.00^a ±0.00	1.00^a ±0.00
Instep	1.97 ^{ab} ±1.72	1.34 ^{ab} ±0.66	1.40 ^a ±0.76	2.09 ^{ab} ±1.69
Sole	1.75 ^{ab} ±1.45	1.10 ^a ±0.65	1.75 ^a ±1.88	1.35 ^{ab} ±0.62

All values are Mean±SD; The sensitivity coefficient was the ratio of the detectable temperature of each region to that of the calf unit (unit=°C/°C); ^{a,b,...,d} group differences among 12 regions.

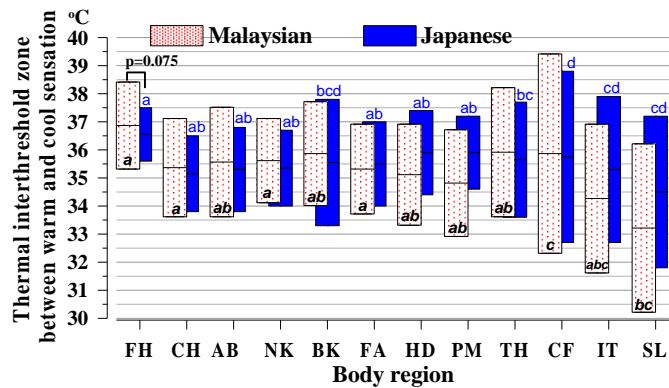


Fig. 4. Peripheral thermal neutral zone on 12 body regions (*:a,b,c,d group differences among 12 regions).

CONCLUSIONS

We examined differences in cutaneous thermal thresholds and the peripheral thermoeffector threshold zone (PTTZ) between Malaysian (MY) and Japanese males (JP). We found that MY had a tendency of being less sensitive to detect warmth than JP. Peripheral thermoeffector threshold zone (PTTZ) had a tendency of being wider in MY than JP. In particular, the ethnic differences were marked on the forehead. The most sensitive body region of JP was the forehead for both warming and cooling, but the regional thermal sensitivity of MY was less differential than that of JP. The present results suggest that peripheral thermal perception projects heat acclimatization. In particular, it is important to note the wider PTTZ of MY than JP on the forehead. The forehead acted like an index to reflect the level of heat habituation in cutaneous thermal threshold. Something to be considered is that there were great inter-individual deviations in thermal threshold measurements. Many ethnic differences in thermal thresholds were not statistically significant due to the individual variations, except several body parts such as the forehead, hand, and foot.

ACKNOWLEDGEMENTS

We would like to express our thanks to Trifon Metodiev, Mutsuhiro Fujiwara, and Shizuka Umezaki for their academic advices and technical supports. This study was supported by a Grant-in-Aid for Scientific Research (No.21247040) from the Japan Society for the Promotion of Science.

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