Seasonal Variation in Sweating Threshold of Men

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Sweating is an effective mechanism of temperature regulation in the heat. Sweating threshold has been examined in relation to heat tolerance (Hensel, 1982). In a previous report, we investigated the effects of the climate of native place on the sweating threshold which was determined by slow warming method in winter (Sato *et al.*, 1985). Then we seized an opportunity to carry out the same sweat response testings on the same subjects in summer. In the present report the sweating thresholds determined in summer were compared with those determined in winter.

METHODS

Sweat response testings were performed at Fukuoka in the winter (December 12-17) 1984 and in the summer (August 16 - September 13) 1985 on the same subjects. The subjects were eight Japanese males and one Taiwanese male, being healthy and not athletes. Table 1 shows their native cities where they were born and raised, and physical characteris-

tics. At the testing in the winter, all Japanese had been living in Fukuoka for at least eight months. Taiwanese came to Japan on April 1984 and had been living in Fukuoka since October 1984.

Sweat response testing procedure was described previously (Sato *et al.*, 1985). Briefly, after lying supine on a cot in the thermally neutral environment at air temperature (T_a) of 28°C and relative humidity (RH) of 50% with air movement less than 0.4m/sec for at least 30min, the subject wearing light trunks was exposed to a slow rise of T_a for 60min in a climatic chamber. T_a was raised linearly with a slope of 0.27°C/min keeping 50%RH, and reaching 44°C at 60min. When sweating was not observed, exposure time was prolonged until the onset of sweating with a constant T_a of 44°C after 60min. Sweating threshold was determined by a sharp decrease in the electrical resistance of neck skin above the middle of left clavicle. Rectal temperature (T_r), skin temperature of chest (T_{ch}), upper arm (T_{ua}), thigh (T_{th}) and lower leg (T_{ll}), and heart rate were measured every minute during expo-

Table 1. Subject profiles at the testing in the winter 1984.

Subj.	Age (yr)	Native City	August Mean Temp. (°C)	Height (cm)	Weight (kg)	BSA (m ²)	BSA/Weight (cm ² /g)
SM	21	Ono(Fukui Pref.)	26.3(Fukui)	179.0	63.7	1.75	0.275
SH	19	Tokyo	26.7(Tokyo)	187.5	74.7	1.94	0.260
KH	20	Kasugai(Aichi Pref.)	26.8(Nagoya)	169.8	80.9	1.88	0.232
HN	19	Kyoto	27.5(Kyoto)	175.5	58.2	1.66	0.285
HT	20	Souja(Okayama Pref.)	26.9(Okayama)	174.3	59.4	1.67	0.281
WT	20	Matsuyama(Ehime Pref.)	27.0(Matsuyama)	177.7	64.2	1.75	0.272
IK	26	Fukuoka	27.3(Fukuoka)	170.8	59.4	1.65	0.278
MK	23	Minamata(Kumamoto Pref.)	27.5(Kumamoto)	173.2	55.2	1.61	0.292
HJ	27	Dow Lyau(Taiwan)	28.3(Taipei)	178.0	64.8	1.76	0.272

BSA: Body surface area which was calculated from the equation of Fujimoto et al.(1968). August mean temperature was based on Tokyo Tenmondai(1984).

sure period. Mean skin temperature ($\bar{T}_s$) was calculated as $\bar{T}_s = 0.3(T_{ch} + T_{ua}) + 0.2(T_{th} + T_{tl})$, and mean body temperature ($\bar{T}_b$) as $\bar{T}_b = 0.8T_r + 0.2\bar{T}_s$.

In the paired *t*-test and correlation analysis, *P* values less than 0.05 were considered significant.

RESULTS

At 0min of the exposure period $\bar{T}_s$ was higher in the summer (mean 33.8°C, range 32.9-34.7°C) than in the winter (32.7°C, 32.2-33.5°C), while there was no significant difference in T_r between summer (37.19°C, 36.78-37.67°C) and winter (37.01°C, 36.66-37.44°C).

In winter, T_r always decreased slowly during the first 30-45min of the exposure period, and then remained constant for some time before rising. On the other hand, there were some variations in the change of T_r in summer. T_r decreased until 20-45min and then rose gradually in five subjects. In two subjects T_r decreased until 15-25min and then remained almost constant. No change until 25min and subsequent increase of T_r was observed in subject WT, and no change of T_r during the exposure period in MK. At the onset of sweating T_r was below its initial value in all subjects both in winter and in summer except in WT in summer. $\bar{T}_s$ rose gradually almost in parallel with T_a in all testings. In both seasons heart rate tended to fluctuate during the first half and increase during the second half of the exposure period.

Sweating thresholds were determined in terms of the exposure time, T_a , T_r , $\bar{T}_s$ and $\bar{T}_b$. The means and ranges of the sweating thresholds in winter and in summer were presented in Table 2. The threshold time exceeding 60min was observed only for MK and HJ in winter. The threshold time was shorter and threshold T_a was lower in summer than in winter, while threshold T_r was higher in summer. There were no significant differences in threshold $\bar{T}_s$ and $\bar{T}_b$ between two seasons. Between the values of sweating threshold in winter and summer, no significant correlations were observed.

To examine the effects of the climate of native

Table 2. Comparison of sweating threshold between winter and summer.

Sweating Threshold	Winter		Summer	
	Mean	Range	Mean	Range
Exposure Time(min)	54	37-66	34**	14-45
$T_a(^{\circ}\text{C})$	41.0	38.1-44.2	38.4**	33.6-42.5
$T_r(^{\circ}\text{C})$	36.83	36.36-37.30	37.09*	36.64-37.75
$\bar{T}_s(^{\circ}\text{C})$	36.5	31.9-37.9	35.9	35.2-37.2
$\bar{T}_b(^{\circ}\text{C})$	36.8	35.5-37.3	36.8	36.4-37.6

** Significantly different from values in winter at $P < 0.01$.

* Significantly different from values in winter at $P < 0.05$.

place on the sweating threshold, August mean temperature was consulted for each native city, if not available, for the nearest city (Table 1). The threshold time significantly correlated with August mean temperature in winter ($r = 0.797$, $P < 0.05$), and not in summer ($r = 0.292$, $P > 0.05$) (Fig. 1). The thresholds in other terms didn't correlated with August mean temperature in either season.

No significant correlations were observed between sweating threshold values and physical characteristics variables in both seasons.

DISCUSSION

Although Iwanaga *et al.* (1983) reported higher T_r

Fig. 1 Relationship between the sweating threshold time and August mean temperature of the native city in winter and summer.

at thermally neutral environment in summer as compared with T_r in winter, initial T_r was almost the same for winter and summer in the present study. For heart rate there was no significant difference in the values at 0min and at sweat onset between winter and summer.

It has been demonstrated that the latent period for onset of sweating was shorter in summer than in winter (Iwanaga *et al.*, 1983; Hori and Tanaka, 1985). The present result confirmed this general tendency. Sweating threshold T_r was higher in summer than in winter, which may be due to the fact that early decrease in T_r always found in winter was not always observed in summer. This result disagree with the finding of Midorikawa (1981), who showed lower T_r at sweat onset in summer than in winter. This discrepancy may be explained by the differences in testing procedure and subject. Her tests were performed on trained male students (native places were undescribed) at the hot environment with constant T_a of 40°C for 1 hr.

The most noticeable result in the present study was that significant correlation observed between the climate of native city and the sweating threshold time in winter became insignificant in summer. The short-term heat acclimatization in summer appears to mask the long-term acclimatization in infancy, since Henane and Bittel (1975) have reported an increased sensitivity of sweating with marked quickening of sweat by passive heating for 9 successive days. From the cluster analysis of physiological measurements in heat and cold tolerance tests on two groups of the residents of Okinawa, Inoue *et al.* (1985) found that the tests carried out in winter revealed more clearly the differences in response to tests between native Okinawan and migrants from the main Japanese islands than the tests carried out in summer. Hori *et al.* (1976) reported that the seasonal variation of adaptability to heat was different between native Okinawan and migrants in Okinawa from one of the main Japanese islands. Season of testing should be taken into account when

heat tolerance is investigated.

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