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SWEATING AND TYMPANIC TEMPERATURE DURING WARM WATER IMMERSION COMPARED BETWEEN VIETNAMESE AND JAPANESE LIVING IN HANOI

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The present study compared between Japanese and Vietnamese subjects living in Hanoi, the local evaporation rate by sweating and the tympanic temperature during legs immersion in warm water. Seven Vietnamese and seven Japanese (who had lived in Hanoi for 1-2 years) participated in the experiments, which were performed in April, 2001 in Hanoi (Vietnam). It was found that the tympanic temperature at which subjects started to sweat in the forearm was significantly higher in Vietnamese than in Japanese. In addition, the local amount of evaporation was significantly lower in Vietnamese subjects. We discussed the physiological reason for such different thermoregulatory responses in terms of different levels of set-point in the core temperature between Vietnamese and Japanese. It was concluded that the Vietnamese inhabitant commenced the sweating at higher tympanic temperature to identical warm stimuli and had lower sweating rate and higher tympanic temperature during the 40 min immersion of both legs to warm water than the Japanese inhabiting Hanoi for 1-2 years.
Key Words: evaporation by sweating; tympanic temperature; set-point; Vietnamese; Japanese; heat acclimatization

INTRODUCTION

It is well established that mammals adapted to high ambient temperatures (T_a) show high core temperatures (Schmidt-Nielsen et al., 1956; MacFarlane, 1968). In man, warm acclimatization associated with a higher body temperature has been discussed by many authors (Davy, 1850; Sundstroem, 1927; Mason, 1940; Renbourn, 1946; Adam and Ferres, 1954; Raynaud et al., 1976; Ladell, 1964). Li and Tokura (1996) reported that the rectal temperature in the subjects wearing skirts was shifted to higher levels as the season gradually became warmer from spring to summer in the months of April to June. Our previous study (Nguyen et al.,2001; Nguyen and Tokura, 2002) indicated that the daytime core temperatures in Vietnamese subjects acclimatized to a tropical climate was higher than those of Polish and Japanese subjects. These results led to the suggestion that the set-point of core temperature in people who are living in a tropical climate and who are repeatedly exposed to high ambient temperatures may be shifted toward a higher level. If this hypothesis is true, then sweating onset following heat stimulation will occur at higher tympanic temperature in these people compared to those living in a temperate climate. Therefore, the present study investigated if, following the local heat stimulation by immersing both legs and feet in warm water, the tympanic temperature threshold for the commencement of sweating would be higher in Vietnamese subjects compared to people inhabiting temperate regions. The present study also compared the physiological responses of Vietnamese subjects with those of Japanese, who had lived in Vietnam for 1-2 years, in order to investigate if any differences might disappear after living in the same tropical environment for such a period

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of time.

METHODS

Participants

Seven Vietnamese subjects (five males and two females: age, 20~22 years; weight, 54.4±0.9 kg; height, 166.3±1.9 cm; body surface area, 1.55±0.02 m^2, body mass index, 1.96±0.03) and seven Japanese (fours males and three females: 21~28 years; 55.7±2.7 kg; 163.7±2.7 cm; 1.55±0.04 m^2; body mass index, 2.07± 0.07) volunteered for this study. The home cities of the subjects in Vietnam and Japan were not checked in our experiment. No significant differences in physical characteristics between two groups were found. Body surface area (BSA) was calculated by the equation of Fujimoto et al. (1968); $BSA = W^{0.444} \times H^{0.663} \times 88.83 \times 10^{-4}$, and body mass index (BMI) was calculated by the following equation; $BMI = W/H^2 \times 10^3$, where W is weight (kg) and H is height (cm). The Japanese subjects had lived in Vietnam for at least a year and most for two years. All of them were drug-free students and refrained from heavy exercise, alcoholic or caffeine-containing drinks for at least 12 h before the start of each experiment. The general purpose of the experiment and its procedures were explained before they gave written consent. All female participants were studied in the follicular phase of their menstrual cycles.

Measurement

Measurements were performed in Hanoi, Vietnam during April, 2001. When the ambient temperature (T_a) was around 25° ~ 27° C, T_a was measured using a thermistor sensor (Gram Cooporation Thermistor Sensor, Japan, accuracy; ± 0.1° C), placed in the vicinity of the subjects. Skin temperatures were measured with thermistor sensors (Gram Cooporation Thermistor Sensor, Japan, accuracy; ±0.1° C) taped at four sites: chest (T_{chest}), arm (T_{arm}), thigh (T_{thigh}) and leg (T_{leg}). The temperatures were recorded every 2 min. Mean skin temperature (T_{sk}) was calculated by the following modification of the Ramanathan equation for four sites (Ramanathan, 1964): $T_{sk} = 0.3\ (T_{chest} + T_{arm}) + 0.2\ (T_{thigh} + T_{leg})$.

The tympanic temperature (T_{ty}) was measured every 2 min by the usage of infrared method (Biotex, Kyoto; accuracy; ±0.1 °C).

The evaporation rate (ER) by sweating at the forearm was measured every 2 min by a method based on estimation of the vapor pressure gradient in the air layer immediately adjacent to the skin (Nilsson, 1977) by humidity sensor (Servo Med, Sweden, range 0 ~ 300 g/m^2h, accuracy; ±2 g/m^2h) fastened on the surface of the forearm, which had been put on the table. Before the measurements were made, the sensor had been calibrated using three saturated salt solutions, K_2SO_4, $Mg(NO)_2$ and LiCl, at a constant temperature.

Experimental design

Each participant entered the experimental chamber at definite times of day (9:00 h, 11:00 h or 14:00 h), wearing a cotton T-shirt and short pants. The sensors for the skin temperature measurements and the humidity sensor for the measurements of ER at forearm were attached with adhesive tape. They sat quietly on a chair until 9:30 h, 11:30 h or 14:30h, respectively. Then, they were asked to immerse their legs into warm water at 43°C. The experiment finished 30 min after the onset of sweating (Figure 1).

We defined as the onset of sweating the time when an abrupt increase of ER was observed, which could be clearly judged.

Data analysis

The significance of the differences were tested by Student's unpaired *t*-test between the Vietnamese and Japanese subjects for tympanic (core) temperature at the time of onset of sweating, the

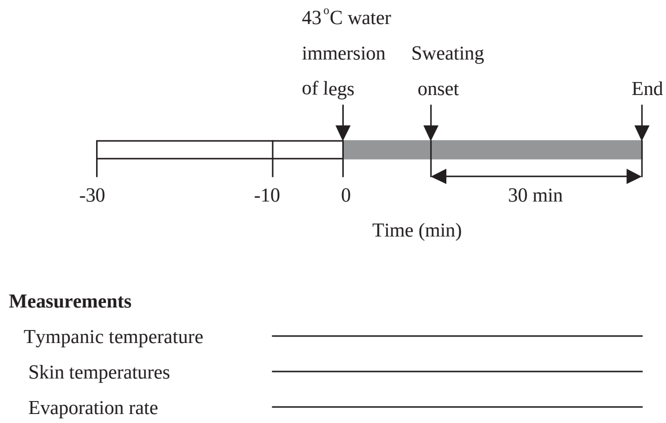

Fig. 1. Experimental schedule.

total amount of ER, and the time elapsed between water immersion and the onset of sweating.

The statistical significance of the differences between the two groups of subjects for T_{ty} and T_{sk} under the immersion of the legs in warm water was analyzed by a two-factor analysis of variance for repeated measures.

RESULTS

Figure 2 compares the ER by sweating during warm water immersion in the two groups. On average, the Vietnamese produced lower amounts of sweat, especially subject V4, V5 and V7, and most of the Vietnamese subjects commenced sweating later than the Japanese subjects. The subjects V1, V2, V3, V4 and V5 were males, while V6 and V7 were females. The subjects J1, J2, J3 and J4 were males, while J5, J6, J7 were females. These physiological parameters were not systematically different between males and females both in the Vietnamese and Japanese. Table 1 compares between the two groups the time elapsed for individual subjects until the sweating occurred after both legs were immersed in warm water between the two groups. The average time elapse was 12 ± 1 min and 8.3 ± 0.9 min in the Vietnamese and Japanese, respectively; which was significant statistically ($p<0.05$). Table 2 compared the amount of evaporation during 30 min from the time when sweating started to occur after legs were immersed in warm water. The total amount of ER by sweating was 1034 ± 88 g/m^2h in the Vietnamese group and 1271 ± 53 g/m^2h in the Japanese group during the 30 min after sweating started. The difference was significant statistically ($p<0.05$).

Figure 3 shows a comparison (Vietnamese *vs* Japanese) of regression lines for average ER *vs* T_{ty} during the 30 min after the commencement of sweating. The Vietnamese started sweating at higher T_{ty} than did the Japanese, which has been individually compared in Table 3. The average T_{ty} was 37.4 ±0.1°C for the Vietnamese and 36.7 ± 0.2°C for the Japanese. The difference was statistically significant ($p<0.05$). The average T_{ty} for 10 min before and for 34 min during the immersion has been compared (Figure 4a). As this figure shows, the average T_{ty} was significantly higher in the Vietnamese throughout the observation ($p<0.01$). The rise in T_{ty} produced by the immersion tended to be lower in the Vietnamese ($p<0.1$) (Figure 4b).

Figure 5 compares T_{sk} and skin temperature of the arm for 10 min before and for 34 min during the immersion. T_{sk} was not significantly different between the Vietnamese and the Japanese throughout the observation period. However, T_{arm} was significantly higher in the Vietnamese from 10 min (10 min before immersion) to 24 min (24 min after immersion) compared to the Japanese ($p<0.05$).

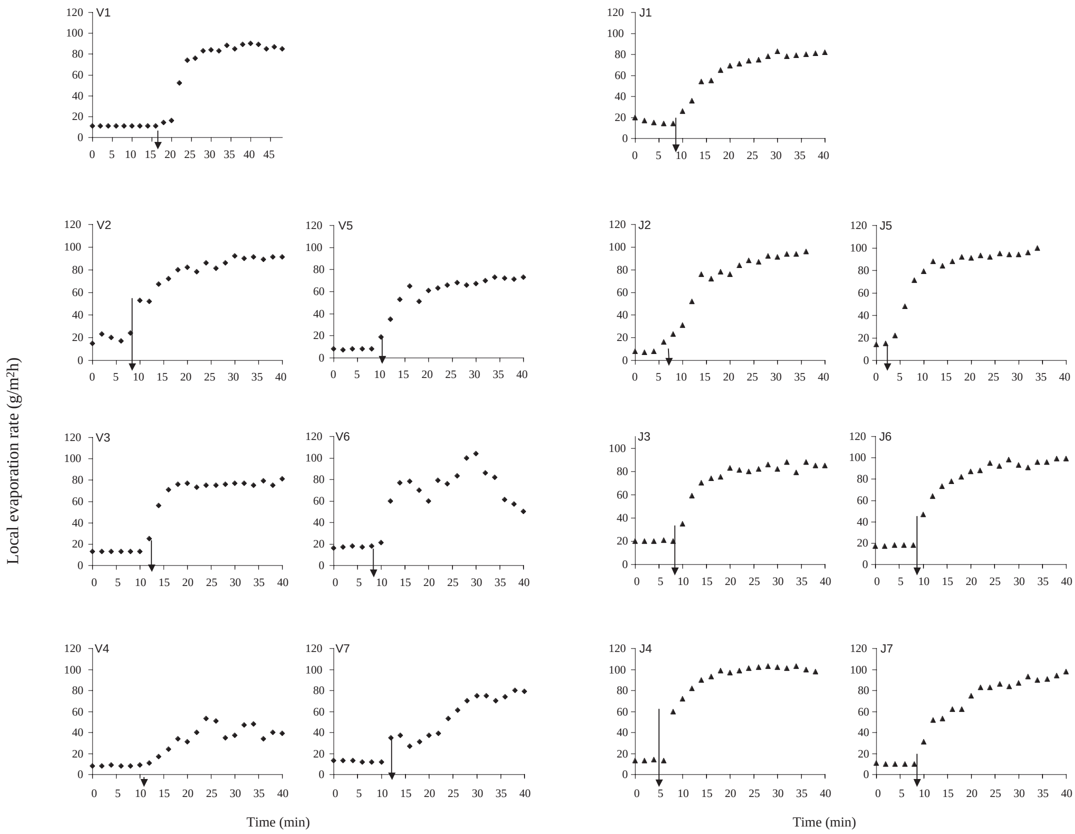

Fig. 2. A comparison of evaporation rate by sweating during immersion of the legs in warm water between the Vietnamese (V1, V2, V3, V4, V5, V6, and V7) and Japanese (J1, J2, J3, J4, J5, J6, and J7). ↓ : Onset of sweating. Ordinate: Local evaporation rate (g/m^{2}h). Abscissa: time (min). V6 and V7: females. J5, J6 and J7: females.

Table 1. A comparison of time elapsed (min) until the sweating onset between the Vietnamese and Japanese by immersion of both legs in warm water of 43°C.

Subject	Vietnamese	Japanese
1	18	10
2	10	6
3	12	10
4	12	8
5	10	4
6	10	10
7	12	10
Mean ± SEM	12 ± 1	8.3 ± 0.9*

*$P < 0.05$. Subjects 6 and 7 for the Vietnamese: females; subjects 5, 6, and 7 for the Japanese: females

Table 2. A comparison of evaporation rate (g/m^{2}h) by sweating between the two groups during 30 min after the sweating onset by immersion of both legs to warm water (43^{o}C).

Subject	Vietnamese	Japanese
1	1180	1086
2	1281	1150
3	1152	1232
4	587	1502
5	973	1327
6	1144	1378
7	927	1224
Mean ± SEM	1034 ± 88	1271 ± 53 *

* $P < 0.05$. Subjects 6 and 7 for the Vietnamese: females; subjects 5, 6, and 7 for the Japanese: females

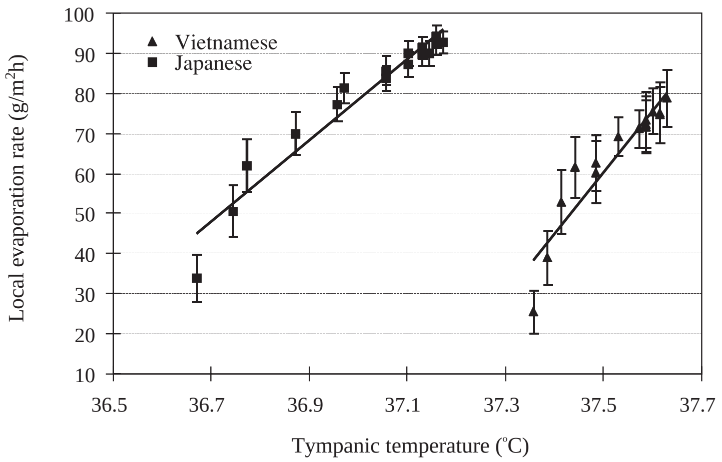

Fig. 3. A comparison of regressive lines for local evaporation rate *vs* tympanic temperature during the 30 min after sweat commencement. Each point (with SEM) is obtained by averaging the values of seven subjects. Closed squares: Japanese. Closed triangles: Vietnamese. Ordinate: local evaporation rate (g/m^{2}h). Abscissa: Tympanic temperature (^{o}C).

Table 3. A comparison of tympanic temperature (^{o}C) at sweating onset between the two groups when legs were immersed in warm water of 43^{o}C.

Subject	Vietnamese	Japanese
1	37.4	36.5
2	37.1	36.1
3	37.5	36.5
4	37.3	37.0
5	37.2	36.4
6	37.5	37.6
7	37.5	36.6
Mean ± SEM	37.4 ± 0.1	36.7 ± 0.2 **

** $P < 0.01$. Subjects 6 and 7 for the Vietnamese: females; subjects 5, 6, and 7 for the Japanese: females

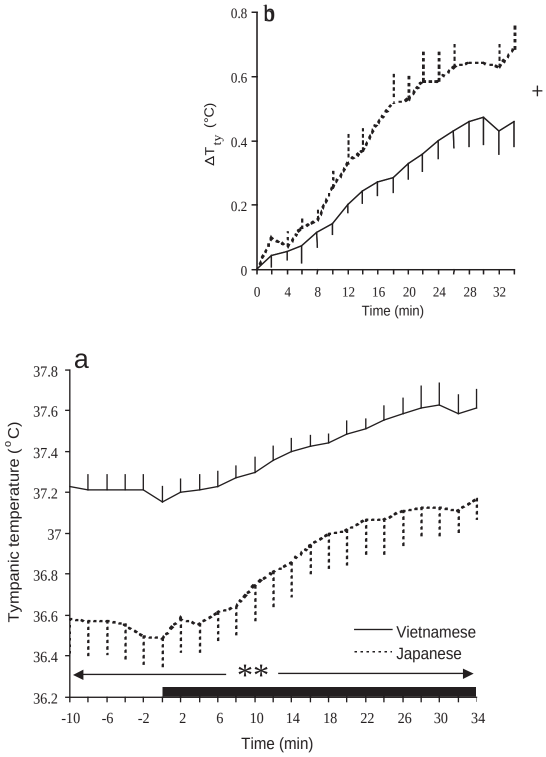

Fig. 4. a) A comparison of tympanic temperature (T_{ty} ,°C) between Vietnamese and Japanese for the 10 min before immersion in warm water and during immersion. Shaded area: during warm water immersion of legs. Values are mean and SEM (n = 7), ** $p<0.01$. b) A comparison of the rise in T_{ty} (ΔT_{ty} , °C) during warm water immersion between the Vietnamese and Japanese. Values are mean and SEM (n = 7), + $p<0.1$.The duration of experiment was shortest (34 min, see Fig. 4) in the Japanese, J5. The picture was drawn till this period, because T_{ty} could be obtained from all participants. (See also Fig. 5).

DISCUSSION

The most interesting finding in our study was that the onset of sweating occurred at higher T_{ty} in the Vietnamese. Also, the amount of ER was significantly lower in the Vietnamese. We have found that the core temperature during the daytime was significantly higher in the Vietnamese than in the Polish (Nguyen et al., 2001) and in the Japanese (Nguyen and Tokura, 2002), suggesting that the setpoint of core temperature was higher in the Vietnamese. We have confirmed this again in our present experiment (Figure 4). The reason why the sweating commenced at a higher T_{ty} in the Vietnamese is related to the higher setpoint value of core temperature in the Vietnamese. The reduced amount of ER and delayed sweating onset in the Vietnamese (Tables 1 and 2) is due to their higher skin temperatures in the Vietnamese (Figure 5) (Nguyen and Tokura, 2002), which accelerate dry heat loss with a reduction of the rate of sweating.

Higher body core temperature accompanying heat acclimatization has been noted by many authors (Davy, 1850; Sundstroem, 1927; Mason, 1940; Renbourn, 1946; Cisse et al., 1991; Ladell, 1964). Li and Tokura (1996) also found that warm acclimatization was characterized by a higher rectal temperature and lower amounts of sweating. A reduced rate of sweating might be significant

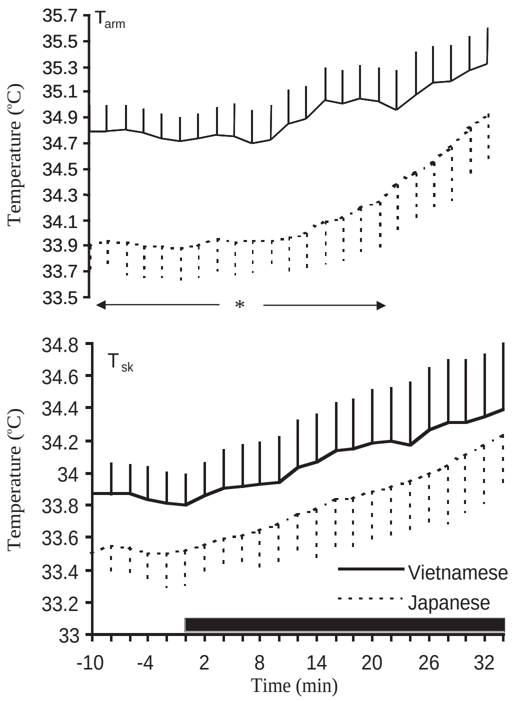

Fig. 5. A comparison of mean skin temperature (T_{sk}) and arm skin temperature (T_{arm}) for the 10 min before and during warm water immersion between the Vietnamese and Japanese. Shaded area: warm water immersion. Values are mean and SEM (n=7), * *p*<0.05.

for saving water. Similar finding was found in the camel, which markedly increased its rectal temperature when dehydrated, as part of an adaptation to the lack of water (Schmidt-Nielsen et al., 1956). Therefore, the higher setpoint value of core temperature could be an indication of heat acclimatization, with a reduction in the amount of sweating, being required to defend a higher setpoint of core temperature. The physiological mechanisms for establishing a higher setpoint in core temperature remain to be studied.

The increment of T_{ty} produced by warming tended to be smaller in the Vietnamese group (Figure 4b). This smaller increment of core temperature in a warm environment has been noted in heat-acclimatized people (Henane and Bittel, 1975; Nielsen et al., 1993).

Although the Japanese lived in Hanoi for more than one year, their physiology with regard to thermoregulation did not approach that of the Vietnamese, suggesting either that more than one year is not enough to elicit the thermophysiological characteristics of tropical inhabitants, or that the Vietnamese inhabitant has their inherited thermal characteristics. In other words, some genetic component might be involved in the different physiological responses between the Vietnamese and Japanese groups. However, it must be noticed that if the Japanese would stay in a tropical country within 3 years after birth in Japan, the numbers of active sweat gland could be almost identical to those of tropical inhabitant (Kuno, 1956). It is tempting to know how the physiological characteristics of sweating in the Japanese having moved to a tropical country within 3 years after birth in Japan would be. It is also well known that the tropical inhabitant has lower salt concentration of the sweat excreted from the active sweat gland in association with efficient evaporative heat loss (Kuno, 1956). We must study in future research program how the salt concentration of the sweat would be modified in the Japanese having stayed in a tropical country.

Thus, it is concluded that the Vietnamese inhabitant starts the sweating at higher T_{ty} to warm stimulus applied to legs than the Japanese inhabiting Hanoi more than one year.

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