

SWEAT GLAND FUNCTION IN THAI AND JAPANESE MALES IN RELATION TO PHYSICAL TRAINING

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Introduction

Elucidation of the heat dissipation mechanism in tropical natives is important for countering the increased risk of heat stroke posed by global warming. We have previously reported that heat loss in Thai natives living in a tropical climate, as compared with Japanese living in a temperate climate, depends more on cutaneous vasodilation than on sweating and that the lower rate of sweating in Thai natives is attributable to lower sweat output per gland and not to a lower number of activated sweat glands (1). It is known that tropical natives in general have a suppressed sweating function (2-4), and that sweat responses are modified by exercise intensity, aerobic fitness and other factors (5, 6). However, these findings derive mainly from comparison between tropical and temperate people during passive heating or pharmacological stimulation, while sweating response has only been measured during light exercise in tropical and temperate residents with similar VO_{2max} (4). To know in detail the characteristics of sweat function in residents of a tropical climate zone (the effects of long-term heat acclimation), we need to examine the sweat gland responses during exercise at moderate and heavy intensities and under pharmacological stimulation in relation to physical training.

In this study, we compared the exercise- and acetylcholine-induced sweat gland responses in physically trained (Thai-T) and untrained (Thai-U) Thai males and in physically trained (Jpn-T) and untrained (Jpn-U) Japanese males, to test the hypothesis that peripheral sweat gland function is suppressed by long-term heat acclimation regardless of aerobic fitness.

Methods

This study involved two tests: an exercise test and an acetylcholine (ACh) iontophoresis test. Forty-seven volunteers (15 Thai-T, 15 Thai-U, 9 Jpn-T, and 8 Jpn-U) participated in the exercise test, and 58 volunteers (16 Thai-T, 15 Thai-U, 14 Jpn-T, and 13 Jpn-U) participated in the ACh iontophoresis test. Except for gymnastics lessons, the Thai-U and Jpn-U had not performed regular physical activity in the previous 3 years. The Thai-T and Jpn-T had participated in endurance sports for more than 6 years. The subjects wore a minimal amount of clothing in both tests. The maximal O_2 uptake (VO_{2max}) for each subject was estimated in a submaximal step-load cycle exercise test, performed on a day other than that of testing. After explanation of the study methods and goals the subjects signed an informed consent. The study was approved by the Osaka Int'l University and the Chiang Mai University ethics committee. The experiments were conducted in September and October in Japan and between March and May in Thailand.

Exercise test. Each subject maintained a sitting position in the testing room (28-29°C and 50-60%RH) for at least 30 min, then performed a continuous graded cycling exercise at intensities of 35, 50, and 65% of VO_{2max} for 20 min each without rest between intensities. The exercise intensities of each subject were determined from the data of VO_{2max} test. During the exercise test, the local sweat rate (SR) was measured on the forehead, chest, and forearm using the ventilated capsule method with a capacitance hygrometer. The number of activated

sweat glands (ASG) on chest and forearm was determined at a site adjacent to the sweat capsules by the starch-iodide technique during three exercise periods, 15-20, 35-40, and 55-60 min. The sweat output per gland (SGO) at chest and forearm was calculated by dividing the respective SR by the respective number of ASG. The rectal (T_{re}) and skin temperatures at five sites were measured continuously, and the mean skin temperature (T_{sk}) and mean body temperature (T_b) were calculated. The heart rate (HR) was measured continuously with a HR monitor.

Acetylcholine iontophoresis test. Axon reflex-mediated (AXR) sweating and directly activated (DIR) sweating responses to iontophoretically applied ACh were determined in Thai-T, Thai-U, Jpn-T and Jpn-U. All subjects were administered 10% ACh solution on the forearm and thigh using iontophoresis technique (2 mA, 5 min). The iontophoresis was performed on the skin surface (2.613 cm^2) of the forearm and thigh under air conditions of 26°C and 50% RH. During the 5-min iontophoresis, the onset time (AXR_{onset}), maximal value (AXR_{max}), and sweat volume (AXR_{sv}) of AXR sweating were determined from the AXR sweating curve. The DIR sweating was studied for 7 min immediately after the iontophoresis current was stopped. The mean SR (DIR_{SR}) was calculated using the data for the last 5 min of measurement. Immediately after the DIR_{SR} measurement, the activated sweat gland (DIR_{ASG}) density was determined using the starch-iodide technique, and the sweat output per gland (DIR_{SGO}) was calculated by dividing DIR_{SR} by DIR_{ASG} . The oral (T_{or}) and skin (T_{si} ; at the forearm and thigh) temperatures were measured using thermistor probes immediately before the test.

Statistics. The main effects of long-term heat acclimation and physical training status were determined using analysis of variance (ANOVA). When the F value was significant, Tukey's *post-hoc* test identified differences among group means. All data are reported as means \pm SEM. Statistical significance was set at $p < 0.05$.

Results

Exercise test. The Thai-T ($53 \pm 3 \text{ ml/kg/min}$) and Jpn-T ($57 \pm 2 \text{ ml/kg/min}$) groups had significantly higher VO_{2max} values than the Thai-U ($37 \pm 1 \text{ ml/kg/min}$) and Jpn-U ($45 \pm 1 \text{ ml/kg/min}$) groups, respectively. No ethnic difference in the VO_{2max} was observed between Thai-T and Jpn-T, while Thai-U had lower VO_{2max} than Jpn-U.

The T_{re} , T_b , and HR values increased significantly with increment of exercise intensity in each group. There were no group differences in the T_{re} , T_b , HR values at rest or at the end of exercising at 35, 50, and 65% of VO_{2max} . The T_{sk} in Thai-T and Thai-U was significantly lower than in their corresponding Japanese groups regardless of exercise intensity, although no group differences were observed for the Thai-T vs. Thai-U and Jpn-T vs. Jpn-U.

Figure 1 shows SR, ASG, and SGO on chest during cycling exercise at 35%, 50%, and 65% VO_{2max} in each group. The SR on forehead, chest and forearm increased significantly with exercise intensity in all groups. The SR was significantly lower in the Thai-T than the Jpn-T group on the forehead and forearm at the exercise intensity of 50% VO_{2max} , and on all three sites at 65% VO_{2max} . The SR was also significantly lower in the Thai-U than the Jpn-U group on the forehead and chest at 50% VO_{2max} , and on all three sites at 65% VO_{2max} . The SR was significantly greater in the Thai-T than the Thai-U group on the chest and forearm at 35% VO_{2max} , and on all three sites at 50% and 65% VO_{2max} . The SR was also significantly greater in the Jpn-T than the Jpn-U group on the chest and forearm at 50% VO_{2max} , and on all three sites at 65% VO_{2max} .

No marked group differences were observed in the ASG number at the chest and forearm (not measured on forehead) at the exercise intensities of 50% and 65% VO_{2max} , although that at both sites was significantly lower in the Thai-U than the Thai-T at 35% VO_{2max} . The SGO

increased significantly with exercise intensity in all groups. The SGO was significantly lower in the Thai-T than the Jpn-T group on the chest and forearm at 65% $\text{VO}_{2\text{max}}$. The SGO was also significantly lower in the Thai-U than the Jpn-U group on the chest at 65% $\text{VO}_{2\text{max}}$. The SGO was significantly greater in the Thai-T than the Thai-U group on the chest and forearm at 50% and 65% $\text{VO}_{2\text{max}}$, and also in the Jpn-T than the Jpn-U group on the forearm at 50% $\text{VO}_{2\text{max}}$, and on the chest and forearm at 65% $\text{VO}_{2\text{max}}$.

Acetylcholine iontophoresis test. No group differences were observed in the $\text{VO}_{2\text{max}}$ for the Thai-T vs. Jpn-T (50 ± 2 vs. 50 ± 3 ml/kg/min) and Thai-U vs. Jpn-U (35 ± 1 vs. 36 ± 2 ml/kg/min), although Thai-T and Jpn-T groups had greater $\text{VO}_{2\text{max}}$ than their corresponding untrained groups.

Though there were no group differences in the T_{or} and T_{sl} on forearm in the iontophoresis test, the Thai-U group exhibited a lower thigh T_{sl} than the other groups.

$\text{AXR}_{\text{onset}}$ was significantly longer in Thai-U than Jpn-U on the thigh but not significantly different between Thai-T and Jpn-T groups. No long-term acclimation effects were observed in the forearm $\text{AXR}_{\text{onset}}$. AXR_{max} was significantly lower in Thai-T and Thai-U groups than the corresponding Japanese groups on the thigh but not on the forearm. AXR_{sv} was significantly lower in Thai-T than Jpn-T on the forearm, and in Thai-T and Thai-U than the corresponding Japanese groups on the thigh. However, both Thai-T and Jpn-T groups tended to show greater AXR_{max} on the thigh (but not on the forearm) than the corresponding untrained groups.

Figure 2 shows DIR_{SR} , DIR_{ASG} and DIR_{SGO} on forearm and thigh in each group. Thai-T showed lower DIR_{SR} than Jpn-T on the thigh (but not on the forearm), although there was no significant difference between Thai-U and Jpn-U on either body site. DIR_{SR} was significantly greater in Thai-T and Jpn-T on both forearm and thigh than the corresponding untrained groups. No differences were seen in DIR_{ASG} among the four groups. Thai-T had lower DIR_{SGO} than Jpn-T on the forearm, and both Thai-T and Thai-U had

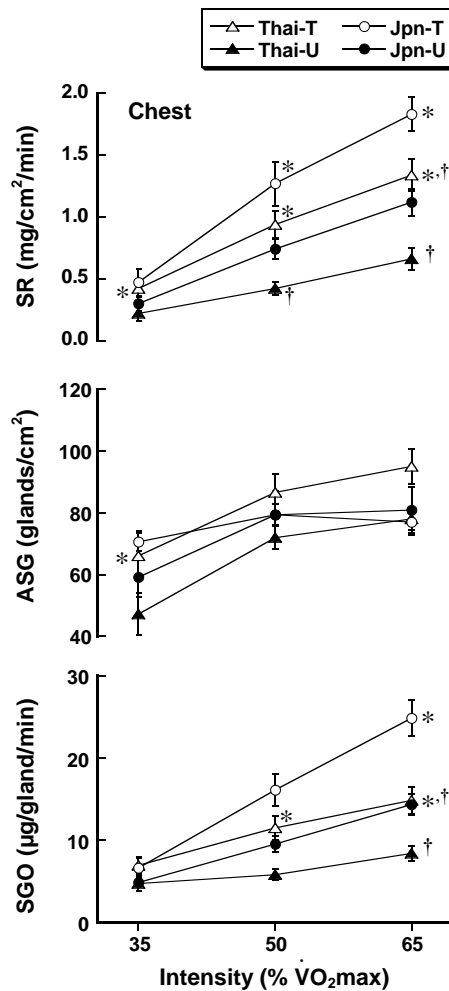


Figure 1. Sweat rate (SR), active sweat glands (ASG), and sweat gland output (SGO) on chest during cycling exercise at each intensity (35%, 50%, and 65% $\text{VO}_{2\text{max}}$) in physically trained (Thai-T) and untrained (Thai-U) Thai males and in physically trained (Jpn-T) and untrained (Jpn-U) Japanese males. Values are means \pm SEM.

*significantly different between trained and untrained for each race, $p < 0.05$. † significantly different between race groups for each training statuses, $p < 0.05$.

lower DIR_{SGO} on the thigh than the corresponding Japanese groups. DIR_{SGO} was significantly greater in Thai-T and Jpn-T on the forearm and thigh than the corresponding untrained groups.

Discussion

The main findings of exercise test were as follows. First, long-term heat acclimation suppresses the exercise-induced SR regardless of aerobic fitness. Second, long-term physical training enhances SR in both tropical and temperate residents. Finally, the suppression of SR by long-term heat acclimation and the enhancement by long-term physical training were mainly attributable to changes of SGO and not to changes in the number of ASG.

Sato and Sato (7) reported that the sweat glands of subjects judged to be poor sweaters were smaller, showing lower secretion activity and decreased cholinergic sensitivity than glands from physically fit subjects. Based on this result, it has been suggested that long-term heat acclimation suppresses the size or cholinergic sensitivity of sweat glands, and physical training enhances the size or cholinergic sensitivity of sweat glands even in people whose sweat function has been suppressed by heat acclimation. This suggestion was supported by the results of the ACh-induced DIR sweating responses in this study. That is, the effects of long-term heat acclimation or physical training on DIR_{SR}, DIR_{ASG} and DIR_{SGO} in the ACh iontophoresis test were similar to the findings induced from SR, ASG and SGO in the exercise test.

ACh-induced sweating responses can be measured from the DIR (sweating activity mediated by the muscarinic receptor of the eccrine sweat gland) and AXR (sweating activity mediated by the sudomotor axon reflex via the nicotine receptor) separately by using iontophoresis method (8). Low et al. (8) have reported that ACh-induced DIR and AXR sweating may reflect the elements of the sweat gland itself (cholinergic sensitivity and size of eccrine glands) and of postganglionic sympathetic axons strongly. The ACh-induced AXR sweating was also suppressed by long-term heat acclimation regardless of aerobic fitness, but not enhanced markedly by physical training. Therefore, the suppressed sweating function with long-term heat acclimation observed in the exercise test may be due to modification of the action in postganglionic

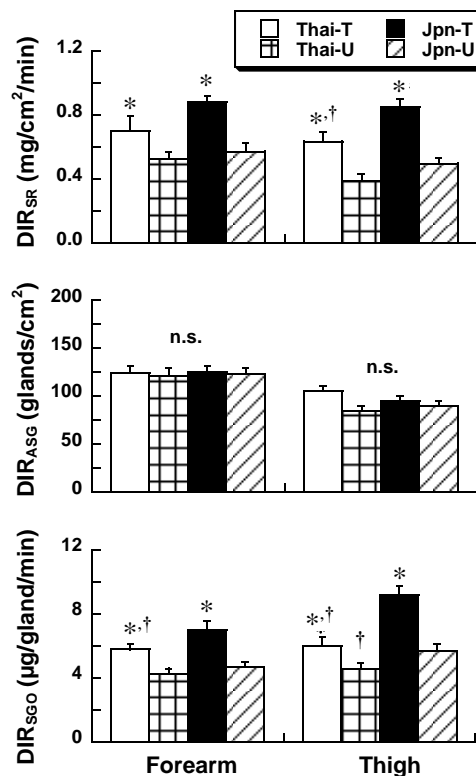


Figure 2. Sweat rate (DIR_{SR}), active sweat glands (DIR_{ASg}), and sweat gland output (DIR_{SGo}) on the forearm and thigh during the acetylcholine iontophoresis test in physically trained (Thai-T) and untrained (Thai-U) Thai males and in physically trained (Jpn-T) and untrained (Jpn-U) Japanese males. Values are means ± SEM. * significantly different between trained and untrained for each race, $p < 0.05$. † significantly different between race groups for each training statuses, $p < 0.05$.

sympathetic axons, together with the modification of the size and cholinergic sensitivity of sweat glands. The improvement of peripheral sweat mechanisms by physical training may be due to modification of the size and cholinergic sensitivity of sweat glands rather than the action of postganglionic sympathetic axons.

Conclusions

Measurement of exercise-induced SR, ASG, and SGO and Ach-induced AXR and DIR sweat responses demonstrated that 1) long-term heat acclimation might suppress sweat gland function peripherally regardless of aerobic fitness, 2) the suppressed function was due to not only lower DIR (suggesting suppressed size or cholinergic sensitivity of the sweat gland itself) but also lower AXR (suggesting suppressed action of postganglionic sympathetic fibres), and 3) the enhancement of sweat gland function by long-term physical training was observed even in people acclimated to a tropical climate due to the enhanced DIR rather than AXR.

Acknowledgments

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