PHYSIOLOGICAL RESPONSES DURING 60 MIN LEG IMMERSION IN JAPANESE AND MALAYSIAN MALES

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INTRODUCTION

A number of studies on heat acclimatization have been extensively reported and indicated differences between tropical and temperate natives in physiological responses such as rectal temperature, body temperature, and sweating responses (Kuno, 1956; Matsumoto et al., 1993; Nguyen and Tokura, 2003; Saat et al., 2005). Those studies reported that rectal temperature and skin temperature were higher in the tropical natives compared to the temperate natives. Tropical natives also sweat less and slower than the temperate ones.

However, most studies on ethnic differences in physiological responses to date were conducted with the same protocol but using different equipment at different places. The same protocol was applied in a study on sweating response between Thai (tropical natives) and Japanese (temperate natives) but this study was performed with different instruments at different places (Matsumoto et al., 1993). According to the previous research, less study was conducted by using the same equipment at the same place.

In this present study, we investigated the differences in physiological responses between Malaysian (tropical natives) and Japanese (temperate natives) by conducting this study in an environmental chamber at the same place in Fukuoka, Japan. In addition, heat tolerance between two ethnic groups was evaluated by using heat stress indexes to indicate heat strain occurs during passive heating.

METHODS

Ten healthy Japanese males (JP: 20.8±0.9 years; 64.0±4.9 kg; 168.9±4.5 cm; and 1.75±0.09 m^2 of body surface area) from Fukuoka, Japan and ten Malaysian males (22.3±1.6 years; 65.3±11.3 kg; 167.9±5.4 cm; and 1.74±0.15 m^2 of body surface area) from Kelantan Kotabaru, Malaysia participated in this study. There were no significant differences in physical characteristics between JP and MY subjects. Both groups of subjects were tested with the same experimental protocol during spring 2009 in Fukuoka, Japan. Each subject wore only shorts during the experiment. After staying in the testing chamber for 10 minutes, passive heating was induced by immersing lower legs in 42ºC hot water in an environment of Ta: 28º C, RH: 50% for 60 min.

Rectal temperature (T_{re}) was monitored throughout the test every two seconds by a thermistor probe (LT-8A; Gram Corporation, Japan) inserted 13 cm beyond the anal sphincter. Skin temperatures were monitored continuously at ten sites (forehead, upper back, chest, abdomen, upper arm, forearm, hand, thigh, calf, and foot) with thermistor sensors attached with surgical tape. Mean skin temperature ($\overline{T}_{sk}$) was calculated by using the modified of Hardy and DuBois' equation. Furthermore, local sweat rate ($\dot{m}_{sw}$) on the forehead, upper back, forearm, and thigh were measured continuously by using ventilating capsule methods (ATMO CHART SS-100II, KANDS Co. Ltd., Japan). Activated sweat gland (ASG) was determined at the four body sites adjacent to the sweat capsule using starch-iodine technique (Inoue, 1996) at 20, 40, and 60 min during leg immersion. The density of ASG was determined by the same investigator. Heart rate (HR) was simultaneously measured throughout the test using HR monitor (RS400, Polar Electro Oy, Finland). Sweating onset time was determined as the time at a prompt sweating after the commencement of leg immersion. Threshold T_{re} for sweating was determined correspondently to the sweating onset time. Body heat storage by Hardy and DuBois (Minard, 1970) and physiological strain index (PSI) (Moran et al., 1998) were calculated by using the following equations:

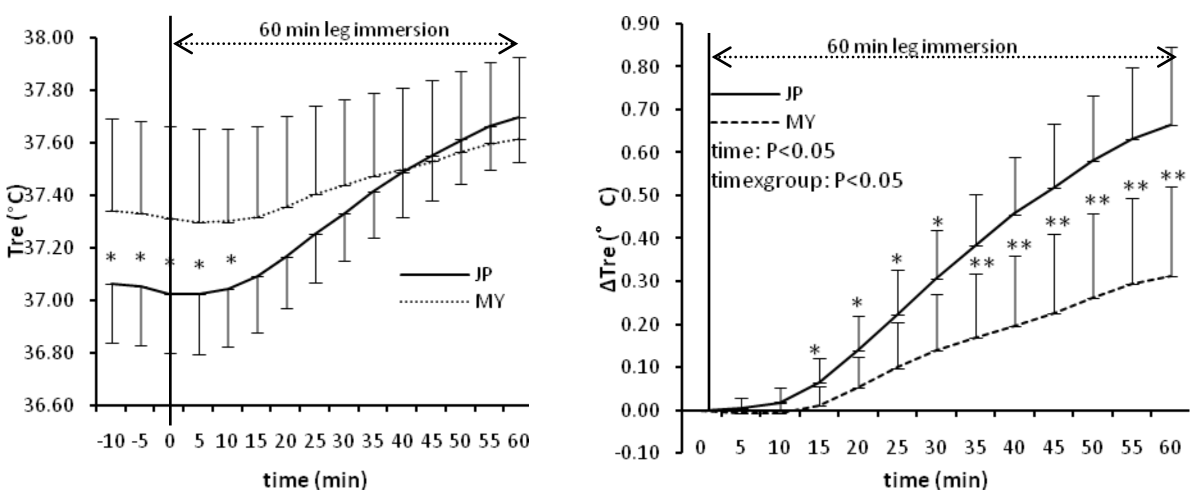
$$\text{Heat storage (kcal m}^{-2}\text{)} = 0.83 \times (0.8\Delta Tre + 0.2\Delta\overline{T}sk) \times \text{weight} \times BSA^{-1}$$

$$\text{Physiological strain index (PSI)} = 5 \times (T_{ret} - T_{re0}) \times (39.5 - T_{re0})^{-1} + 5 \times (HR_t - HR_0) \times (180 - HR_0)^{-1}$$

Statistical significant was assessed using a repeated two-way (time x group) analysis of variance and further analysis was tested using a paired *t*-test at various time points between two ethnic groups at 0.05 level, and the values are presented in mean±SD.

RESULTS

The average of T_{re} did not differ among JP and MY subjects. As shown in Fig 1.a, T_{re} in MY subjects was significantly higher than JP subjects from 10 min before leg immersion until 10 min during leg immersion, but after that there were no significant differences between JP and MY until the end of leg immersion.



a) b)

Fig 1. a) Rectal temperature (Tre) response from 10 min before immersion and 60 min immersion for all groups. b) the rise of rectal temperature (ΔTre) during 60 min immersion between JP and MY.
* significantly different at P<0.05, ** significantly different at P<0.01

The comparison of the rise in T_{re} (ΔT_{re}) between JP and MY during leg immersion is shown Fig 1.b. It can be seen that ΔT_{re} showed significant differences between JP and MY ($P<0.05$). During leg immersion, T_{re} increased rapidly in JP subjects compared to MY subjects.

Table 1 shows the summary of sweating responses (sweating onset time, threshold T_{re} for sweating, ASG and $\dot{m}_{sw}$) during 60 min leg immersion between JP and MY subjects. It can be seen that the sweating onset time in MY subjects was longer than that in JP subjects (Table 1). The sweating onset time at the three body sites (forehead, forearm, and upper back) did not differ among JP and MY subjects but there was a significant difference in the sweating onset time at the thigh between JP and MY ($P<0.05$). Correspondently to the sweating onset time, the threshold T_{re} for sweating at the forehead, forearm, and thigh showed significant differences between JP and MY, but no significant differences in the threshold T_{re} sweating onset time at the upper back area between JP and MY subjects was observed.

Table 1. Sweating responses (sweating onset time, threshold Tre for sweating, activated sweat gland (ASG), and sweat rate) during 60 min leg immersion between JP and MY

	Japanese (JP)			***Malaysian (MY)***		
Sweating Onset Time (min)						
Forehead	10.52±5.99			13.13±3.32		
Forearm	11.98±6.92			13.24±3.43		
Upper back	12.02±6.91			13.02±3.86		
Thigh	12.66±5.67			19.43±8.00 *		
Threshold Tre for sweating (ºC)						
Forehead	37.08±0.37			37.39±0.30 *		
Forearm	37.06±0.38			37.39±0.30 *		
Upper back	37.20±0.36			37.39±0.29		
Thigh	37.11±0.38			37.41±0.30 *		
ASG[1] (gland cm^{-2})	20th min	40th min	60th min	20th min	40th min	60th min
Forehead	199±54	208±40	181±73	125±42**	149±42**	141±37
Forearm	88±32	94±22	83+30	63±16*	80±23	66±27
Upper back	74±29	85±28	133±60	57±26	60±17*	60±17**
Thigh	41±16	46±12	46±13	26±7*	30±14*	30±12*
$\dot{m}_{sw}$ [2] *(mg cm^{-2} min^{-1})*	20th min	40th min	60th min	20th min	40th min	60th min
Forehead	0.81±0.57	1.25±0.63	1.13±0.73	0.34±0.15*	0.56±0.24**	0.66±0.30
Forearm	0.50±0.38	0.70±0.37	0.67+0.45	0.34±0.18	0.67±0.38	0.55±0.23
Upper back	0.72±0.59	0.95±0.60	0.91±0.62	0.52±0.33	0.81±0.58	0.87±0.80
Thigh	0.21±0.08	0.29±0.08	0.25±0.08	0.15±0.08	0.20±0.07*	0.21±0.08

[1] activated sweat gland at 20, 40, and 60 min during leg immersion, [2] sweat rate at 20, 40, and 60 min during leg immersion, * significantly different to JP subjects at $P<0.05$, ** significantly different to JP subjects at $P<0.01$

The density of ASG on the forehead at 20 min and 40 min after immersion were significantly higher ($P<0.05$) among JP (199±54 glands cm^{-2} and 208±40 glands cm^{-2} respectively) compared to MY (125±42 glands cm^{-2} and 149±42 glands cm^{-2} respectively) but no significant difference between JP and MY subjects in ASG on the forehead at 60 min was confirmed. The ASG on the upper back at 20 min after the commencement of immersion showed no significant difference between JP and MY subjects, but there were significant differences in ASG on the upper back at 40 and 60 min between JP (85±28 glands cm^{-2} and 133±6 glands cm^{-2} respectively) and MY subjects (60±17 glands cm^{-2} and 60±17 glands cm^{-2} respectively). The ASG on the thigh were significantly different between JP and MY subjects at 20, 40, and 60 min during immersion ($P<0.05$), while ASG on the forearm only significantly different ($P<0.05$)

between JP and MY subjects at 20 min during immersion and no significant differences between two groups were observed in ASG on the forearm at 40 and 60 min during immersion.

Correspondently to the density of ASG, the forehead $\dot{m}_{sw}$ of JP subjects was significantly greater than that of MY subjects at 20 min (P<0.05) and 40 min (P<0.01) during immersion. Moreover, the thigh $\dot{m}_{sw}$ at 40 min after the commencement of immersion was significantly higher in JP subjects compared to MY subjects (P<0.05). Overall, there were tendencies that $\dot{m}_{sw}$ of JP subjects on the four sites of body were higher than $\dot{m}_{sw}$ of MY subjects.

Heat storage and physiological strain index (PSI), indicating the heat strain based on T_{re} and heart rate (HR), showed that heat storage and PSI in JP subjects (20.44±4.17 kcal m^{-2} and 2.55±1.66 respectively) were significantly higher (P<0.05) than that in MY subjects (11.97±5.14 kcal m^{-2} and 1.14±0.59 respectively). Higher heat storage and PSI in JP subjects indicated that 60 min leg immersion was strenuous physiological conditions for JP subjects compared to MY subjects. It was indicated mainly by the higher raised of T_{re} during 60 min immersion in JP subjects.

CONCLUSIONS

In summary, the results of our present study suggest that the physiological responses during 60 min leg immersion differed between JP and MY subjects. The increase of rectal temperature (ΔT_{re}) of JP subjects were significantly higher than those of subjects (MY subjects) who already acclimatized to heat for long time. Sweat rate and activated sweat gland (ASG) at the several body sites among JP subjects were greater than that among MY subjects. That indicated that MY subjects possessed heat tolerance by using fewer amounts of sweat rather than JP subjects. This conclusion supported the notion that physiological responses to heat were differed by ethnic differences.

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