

Thermal Responses to Heat in Female Athletes and Non-athletes

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Abstract

Thermoregulation in five female athletes and five nonathletes was studied. The subjects rested by immersing their legs up to knee in a stirring water bath of 42°C in a climatic chamber (32°C, 45% rh) for 60 minutes. Thermoregulatory and cardiovascular measurements were assessed. The principal differences between the two groups concerned the sweating responses; the athletes had a much lower sweat onset threshold, and higher sweating capacity. The increment of rectal temperature and heart rate was smaller in the athletes than in the nonathletes. These modifications are similar to those derived from heat acclimation under heavy work load could act on the thermoregulatory function in a way similar to heat acclimation.

INTRODUCTION

Our knowledge of the human temperature regulation in heat has been derived mostly from experiment with male subjects. The few investigations comparing women with men show that women have less sweat rate than men; as the onset threshold for sweating is high; internal temperature is higher during heat exposure (4, 6, 8, 21).

Strenuous exercise, especially endurance exercise, is limited by some factors such as the metabolic heat load (19), and the heat gain by solar radiation (20). These factors tend to increase internal temperature to a critical level (16, 17). As a result of habituation of their exercise, therefore, the improvement of heat-dissipating function in athletes has been reported in the previous studies (5, 9, 14). With a few exceptions, however, all these have been derived from male subjects. Drinkwater et al. (3) have reported that women's athletes showed superior capacity for heat dissipation by increasing peripheral blood flow to that of nonathletes. Although their study was conducted using relative work load, expressed as a %VO₂ max, for comparing both athletes and nonathletes, comparison of thermoregulatory responses to work in heat is complicated by other factors such as lean body mass and body water content.

The purpose of the present study was to determine whether daily exercise under heavy work load does play a role in ameliorating of temperature regulation in heat in female. For the purpose, the study was designed to compare the thermal responses in athletes and nonathletes at rest when exposed to heat.

METHODS AND PROCEDURES

Ten university female students, five competitive athletes and five sedentary students (non-athletes), volunteered for participation. The mean values of the physical characteristics of the subjects are presented in Table 1. Athletes were defined as those who participated in endurance type of sports for many years, and nonathletes were those who did not regularly participate in any vigorous physical exercise.

The study was carried out between 8 A.M. and 10 A.M. in a climatic chamber. On the day of the experiment the subjects reported to the laboratory in the post prandial state. They then were weighed nude, inserted a rectal thermocouple to a depth of 10 cm, and donned a two-piece swimsuit. Thereafter, the subjects entered the climatic chamber maintained at 28°C (45% rh), and sat quietly for a 60-min. At the end of the period, all base-line data were re-croded. The room temperature was then rapidly raised to 32°C. Immediately after the room temperature reached to the target, the subject's legs immersed in a bath of stirred water at 42°C to the knee. Tolerance time was determined when the subject complained her condition as intolerable and was accompanied by any of nausea, headache, and dizziness. In addition to the subjective judgement, the experiment was designed to terminate when rectal temperature reached 39°C or when heart rate reached 190 bpm. The scheduled length of heat exposure was a 60-min period. No fluids or food were supplied during the experimental period.

Copper-constantan thermocouples and a multi-channel recorder (Okura) were used to record skin temperatures at three sites and rectal (Tre) temperature. Mean weighed skin temperature (\bar{T}_{sk}) was calculated by standard procedures (15). Heart rate (HR) was obtained from standard ECG leads every five min. Sweat rate (SR) was made on the basis of the Ohara's filter paper discs method (12). In brief, sweat was collected with filter paper discs in a capsule attached with a collodion solution on the chest (above nipple) and back (above scapula) in a skin area of 12.6 cm² and at a collection interval of 20-min. The sweat rate was measured by weighing the filter paper discs. Sweating onset was measured by a starch-iodin method located on the forearm.

Table 1. Physical characteristics of subjects

Subj.	Age yr	Height cm	Weight kg	BSA m ²
Athletes (n=5)	20.0 (±1.1)	160.1 (± 5.1)	54.8 (±3.5)	1.57 (±0.06)
Nonathletes (n=5)	19.5 (±0.8)	159.9 (± 8.5)	51.0 (±9.0)	1.53 (±0.18)

Values are means ± SD

RESULTS

All of the subjects completed the 60-min experiment of heat exposure. Temporal sequences of the changes in mean values of T_{re} and \bar{T}_{sk} are illustrated in Fig. 1. There was no significant difference in two pre-exposure temperatures between the two groups. During the heat exposure, T_{re} of athlete group was lower than that of nonathlete group. The terminal T_{re} (37.67) of athlete group was significantly lower than that (37.98) of nonathlete group ($P < 0.05$). T_{sk} rose immediately and sharply in contrast to T_{re} as heat stress commenced and levelled off in the two groups. Fig. 2 illustrates the HR response of the two groups during heat exposure. The initial HR of athlete group was significantly lower than that of nonathlete group ($P < 0.05$) and remained significantly lower than that of the nonathlete group during the 60-min exposure.

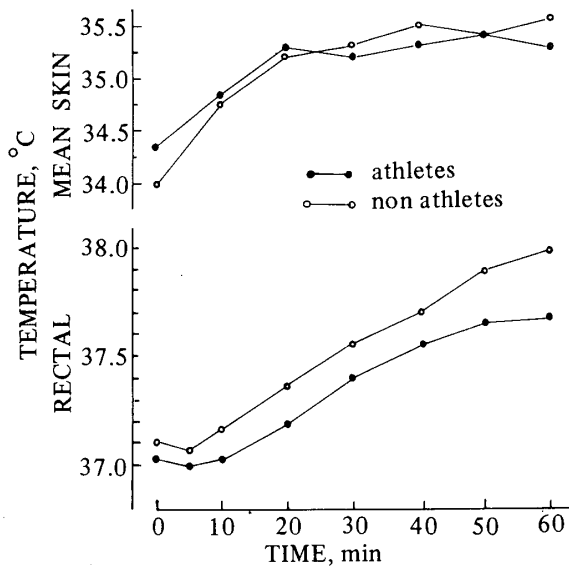


Fig. 1. Means of rectal temperatures and mean skin temperatures of two groups during 60-min of rest in the heat.

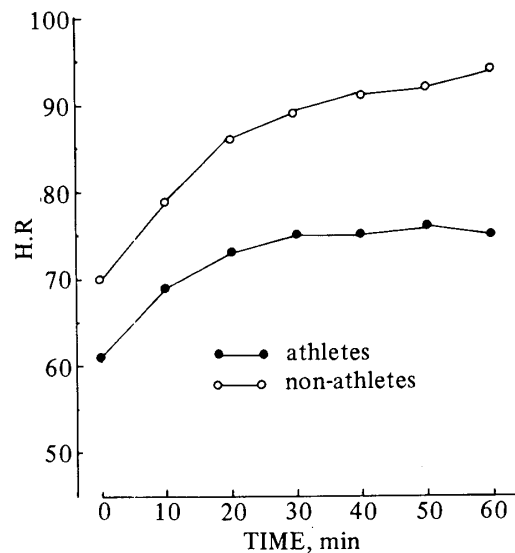


Fig. 2. Means of heart rates of two groups during 60-min of rest in the heat.

The mean value of T_{re} threshold for sweating measured by the starch-iodin method for athlete and nonathlete groups was 37.08°C and 37.41°C , respectively, showing that the former was significantly lower ($p < 0.01$) than the latter. Sweat rates as related to T_{re} of the two groups are shown in Fig. 3. The slope of the regression line of sweat rate (Y) response to T_{re} (X) for athlete group was not actually different from that of nonathlete group. Due to the lower onset of T_{re} sweating threshold in athlete group, the slope of the sweat SR/ T_{re} relations shifted toward lower temperature.

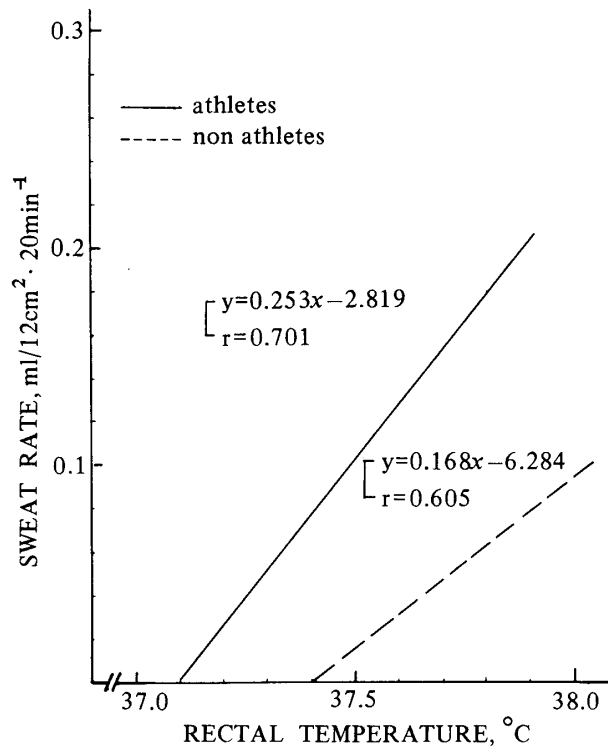


Fig. 3. Sweat rate as a function of rectal temperature.

DISCUSSION

The present study shows some modifications of temperature regulation to heat stress by physical training. Sweating threshold was reduced by 0.3°C in athlete group compared to nonathlete group. This results in the sweat rate for internal temperature (Fig. 3) of athlete group being generally higher than that of nonathlete group. These beneficial thermoregulatory responses observed in the athletes could be ascribed to daily physical conditioning whereby metabolic hyperthermia is induced and acts as an internal stimulus for thermal adaptation. The improvement of thermoregulatory functions in female athletes is in good agreement with those reported by previous studies comparing male athletes and nonathletes at rest (1, 9) and work (5, 14).

Nadel et al. (11) have demonstrated a decrease in sweating threshold and a parallel shift of the slope of the SR/T_{re} by heat acclimation, whereas our data indicates such a downward shift of the sweating response due to physical training. This means that the long-duration physical conditioning produces modifications in the sweating mechanism which are not different from those produced by heat acclimation. A similar result has been obtained by endurance conditioning in competitive athletes (7). The authors of the study stated that athletes responded to heat stress as if they were partially heat acclimatized.

The most commonly observed difference between males and females in hot environments is that females do not sweat as much as males (4, 6, 18). Furthermore, the heart rates as well as core temperatures of females are considerably higher than in males performing work in heat (2, 10, 21). Consequently these results have led to the assumption that a lower heat adaptation for females than males. However, male subjects in the studies reviewed, were usually more physically fit than the female subjects. The lower heart rates and rectal temperatures during work in heat were observed in females, as compared with their counterparts, in the previous studies (13, 18), in which the females appeared more fit than the males. A probable explanation of the lower sweat output for untrained females could be the social mores whereby sweating is considered undesirable in females and is generally avoided by them. Therefore, it is natural to see that female athletes can react to heat stress as males do.

In conclusion, the improved thermoregulatory responses observed in athletes in the present study could logically be ascribed to daily strenuous and long-duration physical conditioning, inducing metabolic hyperthermia and acting as an artificial heat acclimation. Such mechanisms do not differ from those demonstrated by male athletes.

女子運動鍛練者及び非鍛練者の暑熱適応

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身体鍛練によって暑熱に対する適応性が高まることがこれまでの研究によって明らかにされている。しかし、それらの多くは男子を対象とするもので、女子を対象とした報告はきわめて少ない。そこで、本研究は長時間にわたる激しい運動量と伴うスポーツの鍛練者と非鍛練者の暑熱応答と比較検討したものである。

それぞれ5名の鍛練者及び非鍛練者が室温32℃(比湿45%)の人工気候室で椅座位と保って42℃の浴槽に両脚を膝まで浸し60分間の安静位と続けた。その間、直腸温、皮膚温(3点)及び心拍数が記録され、これ以外に、胸部及び背部から12.6cm²にわたって発汗量が測定された。

実験の結果、暴露中の鍛練者の直腸温と心拍数は有意に低く、耐暑性の大きいことが観察された。また鍛練者の発汗に対する閾値温は非鍛練者のそれよりも低く、さらに、単位深部体温当りの発汗量は鍛練者において大きかった。これらは鍛練者の発汗に対する感受性の大きいことを示すものと考えられる。そして、この結果はこれまでに男子を対象として報告された結果と類似したものであった。女子は男子と比べて、身体的に不活発であり、汗を出すことをむしろ避けるような生活習慣を持つために、男子と比較した場合、発汗応答がおそく、発汗量も少ないものと思われる。

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