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HUMAN ACCLIMATION TO WORK IN WARM AND HUMID ENVIRONMENTS

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The aim of this study was to analyse the acclimation of male Europeans during a forty — one day stay in the hot and humid climate of Thailand. We also tried to examine the phases of acclimation which would eventually be used by trainers in the elaboration of the schedule of athletes' preparation to participate in competitions in a tropical climate. Twelve Polish male subjects ageing 21—38 years participated in these examinations. In Poland and Thailand the cycloergometric exercise test with the load of 53% of $\dot{V}O_2$ max was performed until a 1.2°C (ΔT_{re}) increase in rectal temperature was reached. The exercise test was executed in the same environmental conditions (i. e. $30 \pm 1^\circ\text{C}$ and $70 \pm 3\%$ of relative humidity). The duration of this exercise test (DE) was used as a criterion for the efficiency of thermoregulatory functions. During acclimation, three peaks of greater exercise thermoregulatory efficiency have been found, i. e. on the 4th—5th, 11th—12th and 29th—30th days of stay. These findings are particularly important for professional athletes who wish to prepare themselves for competitions held in hot and humid climates.

Key words: *Thermoregulation, acclimation, warm environment, physical exercise; rectal temperature, heart rate, hematocrit, dehydration, duration of exercise test.*

INTRODUCTION

The dynamic development of international sports competitions and professions turned physiologists attention to the necessity of better recognition of the mechanisms responsible for the efficiency of thermoregulation during exercise in high ambient temperatures.

The review of literature on thermal acclimation has shown that in the majority of cases its analysis has been based on the results obtained under simulated conditions in a climatic chamber which, according to Bexton et al. (1) and Zuckerman et al. (2), can lead to sensory deprivation. Some authors (3—5), on the basis of studies performed in climatic chamber, have drawn far-reaching conclusions which suggest that the competitors of long — lasting events (i. e. marathon runners), planning their competitions in a hot climate, should become acclimated at least five days before the start. This would be likely to produce better sports results. According to these authors, the effect of thermal acclimation in simulated conditions (for instance 3—4 hours in the

climatic chamber) could be quite different from that achieved during a day and night stay in the same climate.

Kubica et al. (6) found wide interindividual differences in the rate of internal temperature increase during exercise in the Polish population. This conclusion was confirmed by other authors in further studies (7—9), and the time of work necessary to reach the $1.2\text{ }^{\circ}\text{C}$ increase of T_{re} , has been approved as the good and simple index of the efficiency of thermoregulatory mechanisms during exercise in a hot environment.

The aim of these studies was to analyse the acclimation of physically efficient Europeans' in the naturally hot and humid climate of Thailand. We also tried to evaluate the changes in the phases of acclimation that could be utilized by trainers to frame the plan of agenda of departures in sports competitions of that geographical region.

MATERIALS AND METHODS

Twelve fit male subjects in the aged 27 ± 6.2 years were studied during a six — week experiment in thermal acclimation in Thailand, and one week in Singapore. Their mean body height was 175.4 ± 7.1 cm, body weight 73.65 ± 7.4 kg, and their body surface area 1.81 ± 0.05 m².

All experiments were carried out according to the scheme presented in *Fig. 1*.

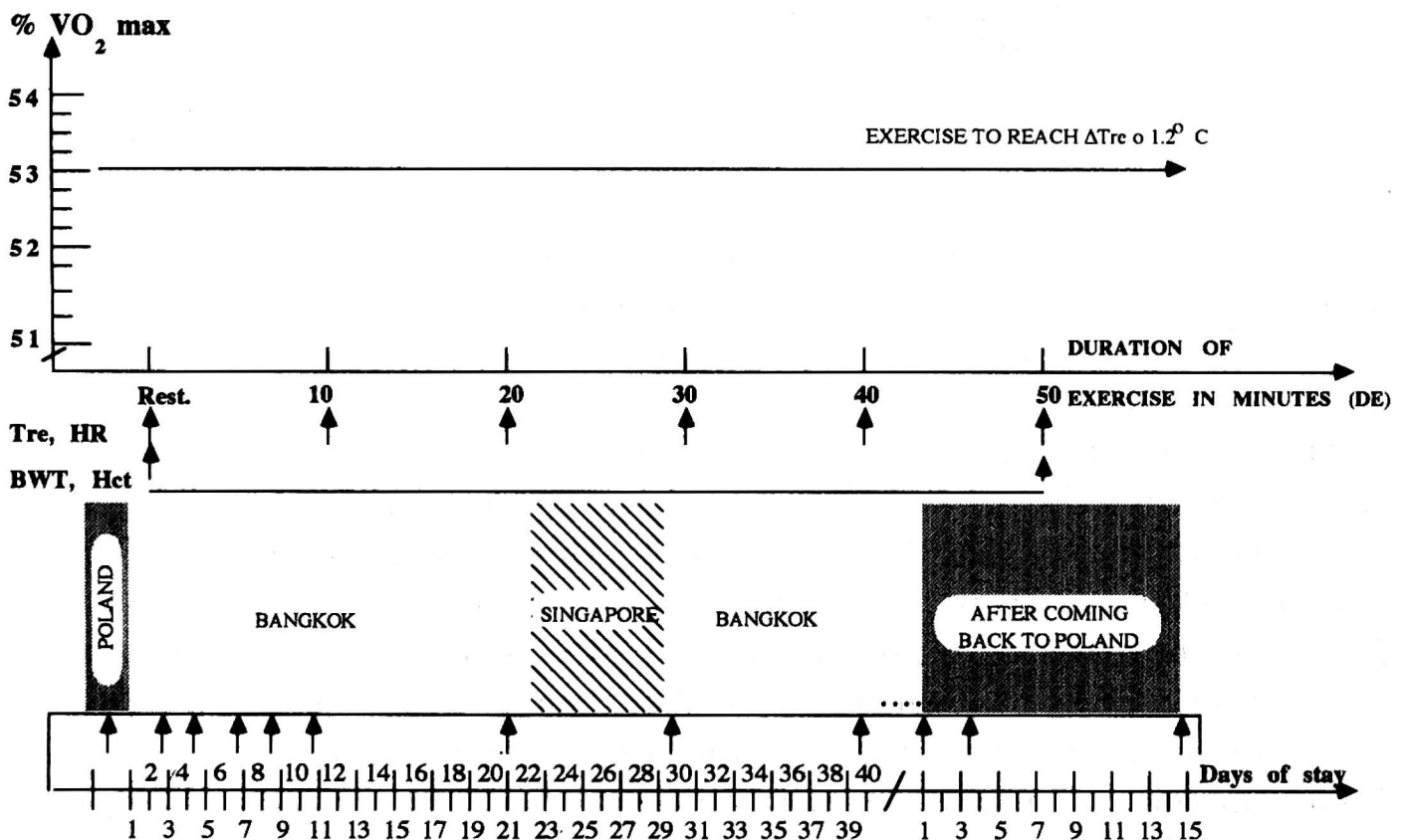


Fig. 1. The scheme of studies carried out in poland and in Thailand

The initial series, carried out in Poland before the excursion to Thailand consisted of determination of maximal oxygen uptake ($\dot{V}O_{2\max}$) by the method proposed by Nielsen et al. (10) and relative work load equal to 53% $\dot{V}O_{2\max}$ maximal power. Then the subjects performed the exercise at 53% $\dot{V}O_{2\max}$ in the climatic chamber (temperature $30 \pm 1^\circ\text{C}$), relative humidity $70 \pm 2\%$) every second day over a period of ten days. Exercise was continued until rectal temperature increased by 1.2°C (ΔT_{re}).

Duration of exercise (DE) necessary to reach $\Delta T_{\text{re}} 1.2^\circ\text{C}$ was used as an index of efficiency of thermoregulation, according to Kubica et al. (6).

Prolongation of exercise indicated an improvement in thermoregulatory processes, whilst its shortening indicated a change for the worse.

The results obtained during the last exercise test, just before leaving Poland were taken into analysis because the results in the initial series performed in our country were repeated.

Heart rate (HR), minute oxygen uptake ($\dot{V}O_2$), hematocrit (Hct), changes of body weight (ΔBWT in kg), as well as the rate of dehydration (BWT — ml per hour) were also analysed.

All measurements were performed in the morning, two hours after a light breakfast. During stay in Bangkok, the subjects were exposed to the exercise tests every second day over a twelve-day period, then before and after returning from Singapore, and just before leaving Thailand. All participants were given the same food as in Poland.

Rectal temperature by electrothermometer (Ellab-Denmark), and heart rate by Sport — Tester (Polar Electro-Finland) were tested every ten minutes. When an increase of 1°C of rectal temperature was reached, the measurements were made every minute. Minute oxygen uptake was measured in the above mentioned periods by MMC Beckman (USA) equipment.

Measurement of body weight (with an accuracy of 1 g) was carried out in Poland using Sartorius balance before and immediately after cessation of exercise (after previous evacuation of the bladder). In Thailand, body weight was measured by medical balance with an accuracy of 50 g.

Hematocrit in arterialized blood was analysed twice by hematocrit centrifuge before and after the exercise test. Taking into account the time difference between Poland and Thailand of six hours, the risk of a so-called "time debt" which changes the biological body clock could appear. For the purpose of faster debt repayment, a special diet (11—13) was given in Poland to all subjects before the expedition. It was prolonged to 30 days of the stay in Thailand.

Physiological examinations were completed by anthropological measurements. Their results were discussed in other paper.

The results were analysed using the statistical package (Stat View 1988) prepared by the Macintosh Company.

RESULTS

As it appears from *Fig. 2*, the DE taken as the basal index of the efficiency of exercise thermoregulatory mechanisms had changed during 6-week stay in a tropical climate, showing three peaks of acclimation. The first was found out between the 4th and 5th days of their stay in Bangkok, whereas the second became clearly visible between the 11th and 12th days. The 7-day stay in Singapore (29th—36th day in a hot climate) near to the equator (about $1^\circ 7'$ north latitude) caused the further improvement of thermoregulatory mechanisms which was indicated in the prolongation of DE. In the successive days after coming back to Bangkok, a visible worsening in acclimation was observed. It was manifested by the shortening of DE, which was kept, however, above the initial values noted in Poland.

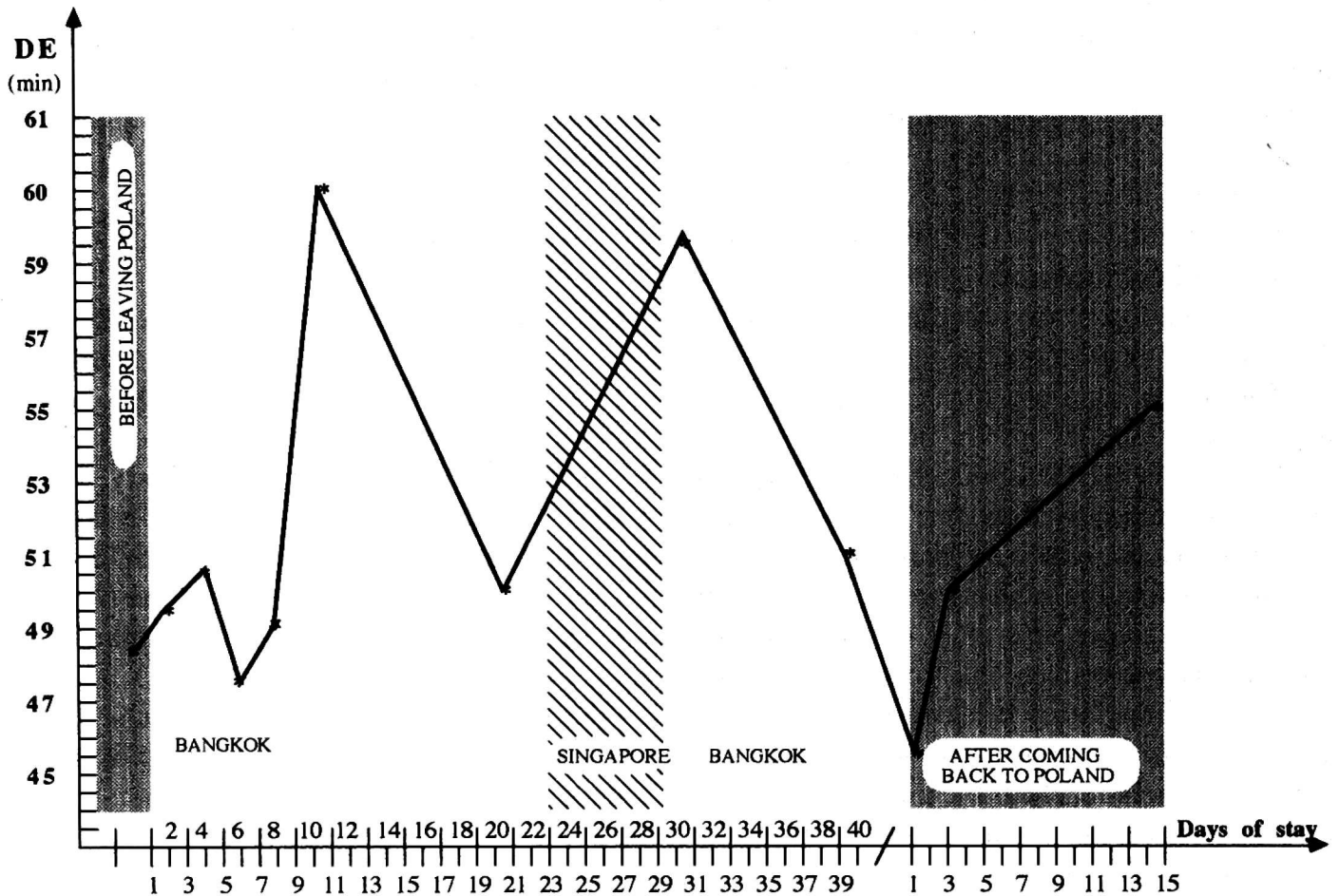


Fig. 2. Mean values of duration of the test exercise (DE) necessary to reach the 1.2°C increase of rectal temperature (ΔT_{re} of 1.2°C) before leaving Poland, during stay in the tropics and after coming back to Poland

In the first two days after coming back to Poland there was a consecutive decay in the efficiency of thermoregulatory mechanisms responsible for the heat balance. This was probably due to the effect of the time difference between Bangkok and Cracow, and of the different climate (i.e. lower temperature in Poland).

Successive exercise tests carried out on the 4th and 15th days after coming back to Poland showed an improvement of the thermoregulatory efficiency.

The results of the exercise duration (DE), were significantly higher on the 11th—12th and 29th—30th days of the stay in Thailand than the initial values ($p < 0.01$) noted in Poland. The difference between DE on the 4th and 5th day of the stay in Bangkok, and that in Poland was near to the statistical significance.

Heart rate (HR) values recorded when there was a 1.2°C rectal temperature increase on the 2nd and 3rd day of the stay in Bangkok were higher by about 12 beats per minute in comparison with values noted in Poland (Fig. 4).

In successive days while in Bangkok, HR values gradually decreased to a level of above 10 beats per min lower as compared to the initial values between the 11th and 12th days of stay, when thermoregulatory reactions were

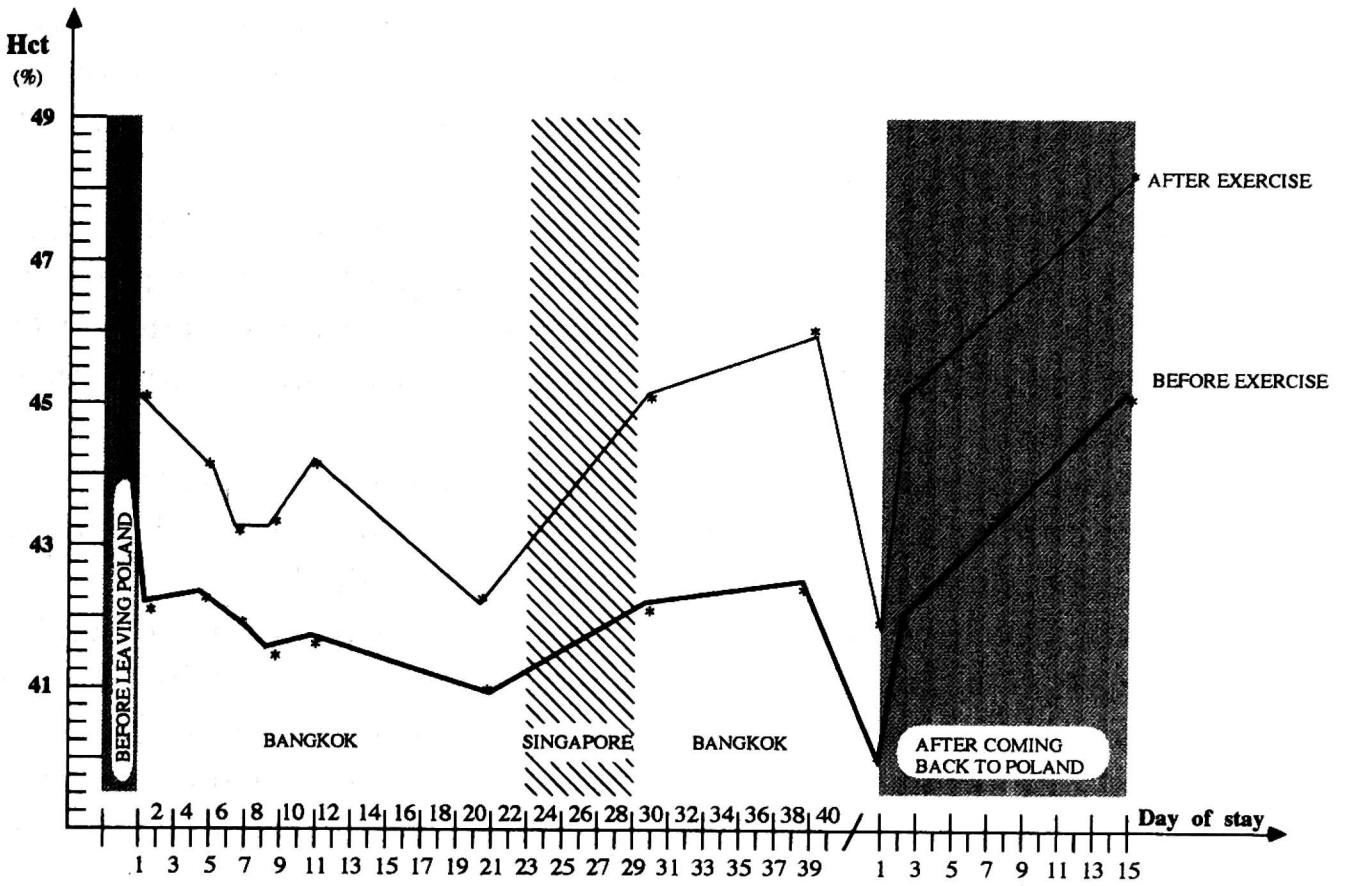


Fig. 3. Mean rest and post-exercise values of hematocrit (Hct) before leaving Poland, during stay in the tropics, and after coming back home

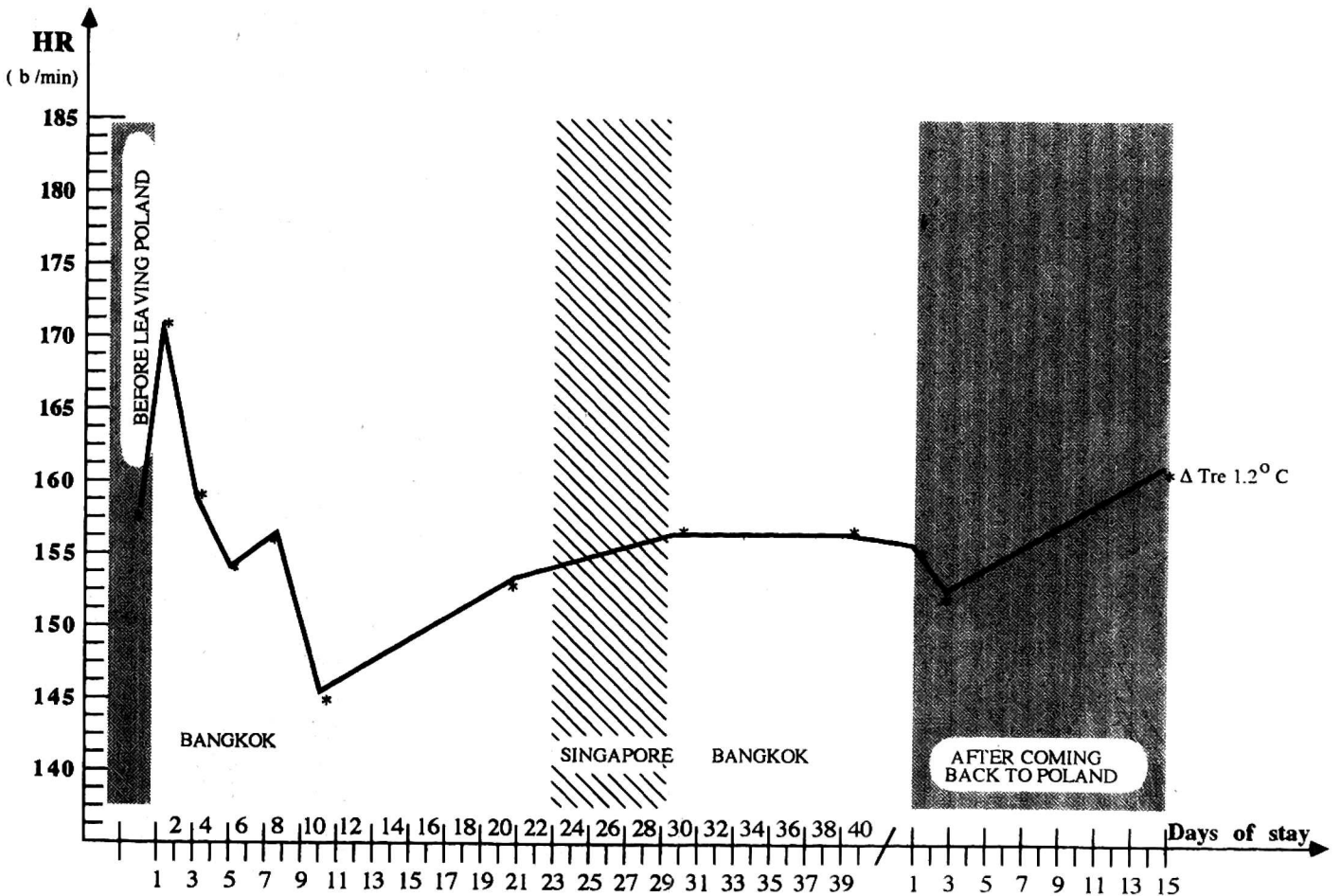


Fig. 4. Mean values of heart rate at the point when the ΔT_{re} reached $1.2^{\circ}C$ before leaving Poland, and during stay in the tropics and after coming back home

the best ($p < 0.01$). A prolonged stay in a hot climate caused an increase in exercise HR of above 5 beats per min on the 30th day as an effect of the heat load. The slight acceleration of HR was observed till the last day of stay when the level of HR reached 156 beats per minute.

Between the first and third day, after coming back to Cracow, HR attained during exercise became a little lower, than in Bangkok. It is important to realize that at that time the shortest DE was noted. Between the 14th and 15th day an increase in HR to a level slightly higher than before acclimation was registered.

In the first two days of the stay in Thailand, hematocrit resting values were approx. 3% lower than before leaving Poland (*Fig. 3*). In the days of relaxation that followed, the changes of values of Hct were negligible.

The hematocrit values measured after cessation of exercise decreased from the first to the 8th/9th day of the stay in a hot climate. On the 20th—21st day the reduction of Hct values was smaller, but after returning from Singapore (on the 30th day) the hematocrit resting and post-exercise values increased significantly ($p < 0.05$) as compared to the last results in Bangkok. However, on the 15th day after coming back to Poland they were almost the same as registered before leaving this country.

The forty – one – day stay of the subjects in a hot climate caused the lowering of their mean body weight from 73.65 kg to 66.97 kg, i. e. about 9.1%.

The magnitude of body dehydration, calculated from the difference of body mass before and after exercise test, showed differences resulting from the test

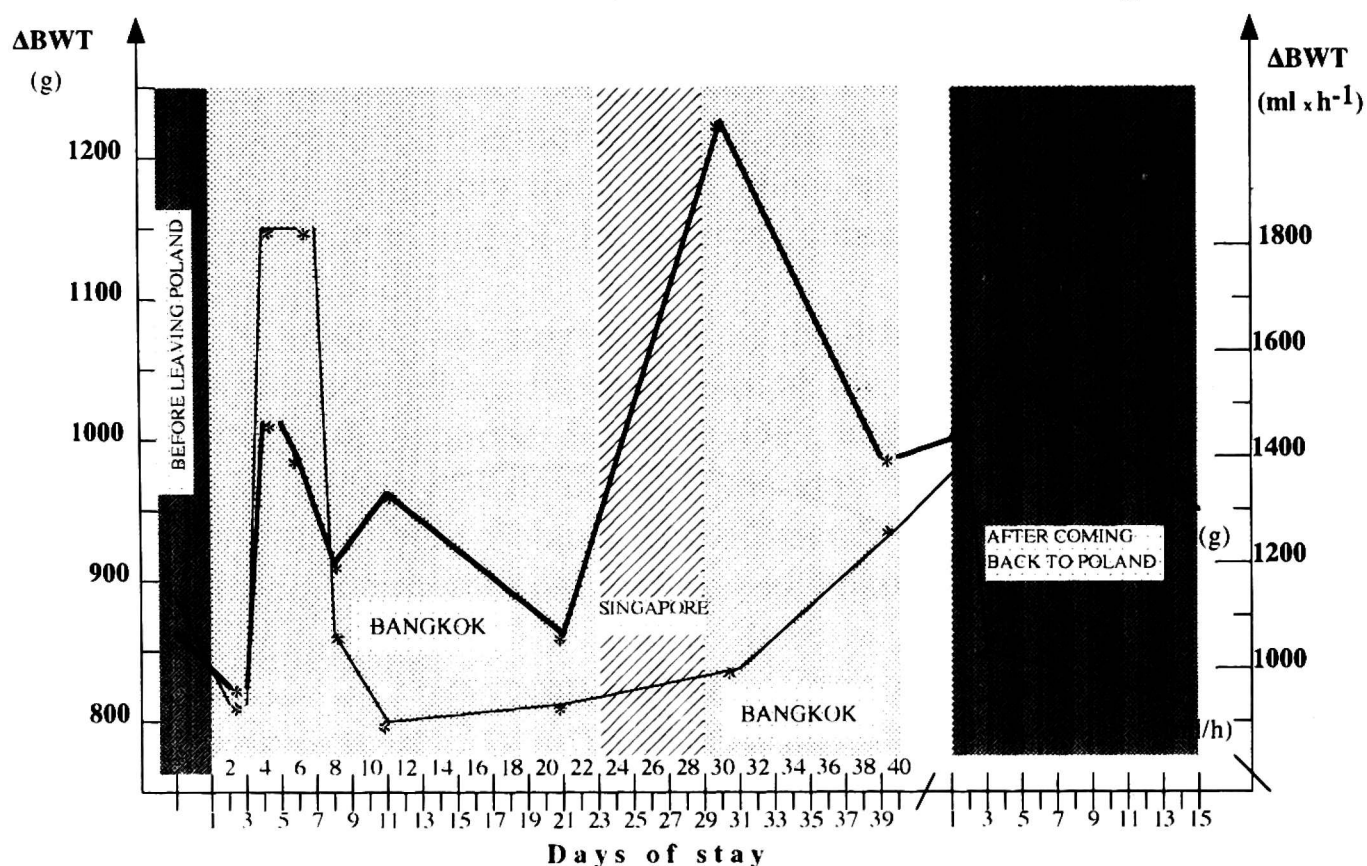


Fig. 5. Changes of the exercise dehydration (Δ BWT in g) and the rate of dehydration (Δ BWT in ml per h) before leaving Poland, during stay in the tropics and after coming back to Poland

exercise duration. The absolute values of Δ BWT before leaving Poland (Fig. 5) did not differ significantly with those in Thailand during first 22 days. Significantly greater body mass loss ($p < 0.01$) was observed just after the subjects came back from Singapore, i.e. on the 29th to 30th days of their stay in the Indochinese Peninsula, when Δ BWT values exceeded the level of 1200 g.

Attention should be paid to the fact, that at the same time, the rate of dehydration (Δ body water loss in $\text{ml} \times \text{h}^{-1}$) was as small as $1000 \text{ ml} \times \text{h}^{-1}$ (Fig. 5). In the period when the efficiency of thermoregulatory mechanisms was at its highest i.e. between 11th and 12th days, the level of this index was at its lowest — a little lower than $500 \text{ ml} \times \text{h}^{-1}$.

DISCUSSION

As it has been shown by Kozłowski et al. (14) Greenleaf et al. (15), Mostardi et al. (16) and Wilk et al. (17) rectal temperature rises very quickly during physical exercise in room temperature in the first 30 to 40 minutes, followed by a shorter or longer stabilization. The same exercise performed in the higher ambient temperature causes faster stabilization of rectal temperature. Sometimes its increase occurs during the whole exercise at an individual rate.

Hitherto some studies (6, 17, 18) carried out on male subjects at room temperature, have clearly shown the negative effect of temperatures higher than 38.3°C , combined with dehydration and electrolyte concentration decrease, on the physical work capacity. The extent of homeostasis disturbance was higher when the physical exercise was performed in a higher ambient temperature and relative humidity. In these conditions the combined effect of endogenic and exogenic heat on the organism has been observed.

Wyndham et al. (19—22) had studied the level of exercise thermoregulation in different races living in a hot climate; in white people from South Africa, Bantu, Bushmen and Aborigens. Comparative studies in people living in hot and humid temperatures and cold climates (Thais, Poles and Finns) were carried out by Tyka et al. (8, 9). The results of these studies indicated a better efficiency of thermoregulatory mechanisms in Thais as compare to Poles and Finns measured by DE. The better acclimatization of Thais to live in that climate was manifested in smaller dimensions of the body, particularly in higher body surface area to body weight ratio. This type of body structure creates the possibility of more efficient elimination of the excess of endogenic heat during physical exercise.

Examinations were carried out in Poland in a climatic chamber in the same thermal conditions of Bangkok (in the Dept. of Physiology, Mahidol University) i.e. in ambient temperatures equivalent to 30°C and relative

humidity kept at a level of 70%. During the stay of a Polish group in Thailand (February and March), climatic conditions were unusually strenuous for Europeans. The external temperatures raised until midday and then remained stable till the late night hours. High relative humidity (over 70%) increased discomfort and kept the subjects awake. In these conditions, the heat loss was severe and, in extreme cases, hyperthermia or even heat stroke became a risk.

The fourty – one – day stay of the subjects in a hot climate caused the lowering of their mean body weight about 9.1%. This phenomenon, although difficult to interpret, can be explained by the summation of so-called voluntary dehydration formed every day of a stay in a hot and humid climate.

Acclimation of men in high temperatures was mostly based on the analysis of thermoregulatory changes in climatic chambers. From the studies of Adams et al. (13), Frisancho (23), Meroza et al. (5), Seney et al. (4) and Wyndham et al. (19—22). It can be concluded, that the first effects of acclimation appeared between the 4th and 7th days and the prolongation of heat exposition can lead to full acclimation after 11 to 12 days. The above mentioned results were also in use in sports practice. Marathon runners wanting to achieve good results prepared themselves to participate in competitions performed in a hot and sunny environment, and adapted themselves to those conditions at least 5 days before the start. Acclimatization was most often linked with the adaptation of the cardiovascular system manifested in the augmentation of the functional cardiac reserve (6, 17, 18) and with the efficient function of organs responsible for the water — electrolyte balance (4, 17). Only a few scientists dealt with the problem of eventual phases in acclimation which can be very important for sport practice.

In the light of our own results, the existence a few peaks of acclimation can suggest, that for instance an athlete (trained in endurance sports events) who plan to participate in competitions which will take place in hot and humid climates, ought to arrive at the place at least 11 to 12 days earlier. At that time the rate of rectal temperature increase is the slowest and should not have a negative effect on one's body work capacity. When the sports event is based on anaerobic reactions (for instance 100 m, 200 m, 400 m and 800 m, or in light athletic technical competitions) the athlete can arrive a little later, i. e. 4—5 days before the competition.

Furthermore, the results obtained in these studies have shown that in general, athletes who have DE longer than 40 minutes are able to reach better results.

CONCLUSIONS

1. During thermal acclimation a few peaks can be noted. The first — in general shorter and lower — appeared between the 4th and 5th day of the stay in the tropic; the second — more visible — appeared between the 11th and 12th day of the stay in a hot climate; and the third between the 29th and 30th days.

2. The analysis of changes in internal body temperature during physical work in hot climates suggests that athletes (trained in endurance sports events) have to be subjected to 11—12 days of acclimation before the events begin. In strength — high — speed sports events, during which energy is drawn mainly from anaerobic processes, athletes should be adapted to the hot climate for a period of not less than 4 to 5 days.

3. The evaluation of people who enter into a contract with employers to perform work in a hot and humid climate should be preceded by an examination of their thermoregulatory efficiency according to the manner proposed by the authors, i. e. the time of a rectal temperature increase of 1.2°C during the test exercise.

4. The increase of voluntary dehydration in our subjects during their stay in a hot and humid climate, followed by the reduction of body weight, indicates the necessity of precise control of BWT, in sports events coupled with weight categories in particular.

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