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REPEATED SAUNA BATHING EFFECTS ON MALES' CAPACITY TO PROLONGED EXERCISE-HEAT PERFORMANCE

Aleksander Tyka[1(A,B,C,D,E,F,G)], Tomasz Pałka[1(B,C,D,E,F)], Anna K. Tyka[2(B,C,D,E,F)], Zbigniew Szyguła[1(B,C,D,E,F)], Tomasz Cisoń[1(B,C,D,E,F)]

[1] Institute of Human Physiology, University of Physical Education, Cracow, Poland
[2] Pedagogical Institute, PWSZ, Nowy Sącz, Poland

Abstract

Introduction: Exercise in a hot and humid environment causes several changes in human body; these include deterioration in the circulatory, thermoregulatory and endocrine systems which have negative impact on athletes' performance. In order to compensate for such conditions, humans use various coping strategies.

The aim of this study was to investigate the effect of repeated sauna bathing on males' capacity to exercise at higher ambient temperature.

Methods: Various measures of work, both anaerobic and aerobic, have been used to measure power, work and exercise capacity. Maximal anaerobic power (MAP) and total work (TW) were measured in Wingate test (1) while maximal oxygen uptake ($\dot{V}O_2max$), total work (TW_{ST}), total work to threshold of decompensated metabolic acidosis (TW_{TDMA}) were measured in exercise test to exhaustion. The primary experiment (I) occurred two days before the first sauna bathing while the secondary (II) experiment occurred three days after the last heat exposure. Rectal (Tre) and thympanic temperatures (Tty), body water loss (ΔBM) and sweating rate (SR) were collected and evaluated during sauna bathing. Subjective perception of inconvenience during exercise test to exhaustion was evaluated by the Borg's scale (2).

Results: Repeated sauna bathing influenced subjects' ability to prolonged exercise; in particular we observed increases of total TW_{ST}, TW_{TDMA} and prolonged exercise duration (DE). This study showed no significant differences in MAP and TW in Wingate test.

Conclusion: Repeated heat exposure caused significant increase in capacity to prolonged exercise at higher ambient temperature.

Key words: *sauna bathing, thermoregulation, maximal oxygen uptake, maximal work load, anaerobic threshold*

Introduction

Thermoregulation principles and theories have varied within last twenty years (3) with little consensus. However, classical notions are still relevant and valid (4-14). This approach states that no matter the origin of heat stress (endogenous or exogenous), organisms strive to maintain homeostasis, protecting the organism from thermal disorder such as heat exhaustion and stroke. The risk of such disorders are not only possible during physical exercise in warm (25-30°C), humid (70-90%) and hot environment (31-40°C) but also when the organism is affected by exogenous heat such as: high temperature, solar radiation during sweltering days or sauna bathing. The symptoms of the organism's acclimation to this changeable environmental conditions include: increased need for hydration (15), decreased heart rate (16), increased sweating rate (7,17) and slower rise in temperature during incremental exercise (11). Some hormonal changes also occur to compensate for these metabolic demands (18-20). Improvement of thermoregulatory mechanisms via thermal passive treatment or physical exercise training may bring different effects (11,21).

Moreover, despite enhancement in a system's thermoregulation there is no improvement in an exercise oxygen uptake ($\dot{V}O_2max$) (11). However there is a possibility that it contributes to a decrease in pace of metabolic rate during exercise (22), and consequently, it may lead to an increase in performance. It is doubtful if it is going to affect anaerobic power level. The second mechanism is of less efficiency (21).

Finally, the purpose of this study was to examine the influence of repeated sauna bathing on the body's response to prolonged exercise. Specifically, to investigate the possible relationship of sauna to acclimation and if it was possible to find out what is the smallest number of sauna bathing needed to initiate crucial adaptive changes.

Methods

Participants

Twenty two men, 20 to 22 years of age were selected. Subjects had similar body composition and were divided at random into two even groups: experimental (E) and control (C). Physical characteristics of the subjects are given in Table 1. The study protocol was approved by the local Ethics Committee. Participants consented to take part in the study. They had been familiarized with the study's purpose, methods, risks and side effects, their participation was voluntary.

Table 1. *Subjects' physical characteristics as mean values (± SD)*

	Age (years)	Body heigh (cm)	Body mass (kg)	Body surface area	%Fat	Lean body mass
Group C	20-22	178.2 ± 4.02	71.6 ± 5.3	1.79 ± 0.009	12.55 ± 3.42	62.65 ± 6.5
Group E	20-22	176.0 ± 3.98	69.6 ± 4.7	1.78 ± 0.008	13.47 ± 3.67	60.18 ± 4.9

This included explanation of the study's purpose, methods, risks and side effects.

Procedures

Sauna bathing effects on subject's performance were measured twice. The first exercise tests (I) occurred two days before the first heat exposure, the second tests (II) three days after the last sauna bathing.

In both series body height (BH), body mass (BM), percentage of fat (PF) and lean body mass (LBM) were recorded. It provided a possibility to quantify the percentage of fat (PF) and lean body mass (LBM) according to Slaughter's formula (22). Furthermore, participants performed Wingate test on cycloergometer 854E Monark/Sweden (1). On the next day they were subjected to exercise test to exhaustion also on cycloergometer - 900ER Jaeger (Germany). At first they had to warm up within two minutes (WU) at 110 Watts power, after that exercise intensity has been extended every second minute by adding 20 Watts more. Exercise testing proceeded until the person could no longer pedal with regular rhythm (RPM) 60 turns per minute. The Borg's scale (2) was used to measure subjects' perceived inconvenience. Furthermore every 30 seconds the following respiratory parameters were collected: VO_2, V_E, VCO_2, $FeCO_2$, RQ, $V_E \cdot VCO_2^{-1}$ as well as those collected by using Ergospirotest OY M9427 Medikro (Finland). This procedure helped to assess maximal oxygen uptake ($\dot{V}O_2max$) as well as threshold of decompensated metabolic acidosis (TDMA) (23,24). Other factors that have been recorded every minute during exercise were: heart rate (HR) with Sport Tester S610i™ Polar Electro (Finland), rectal (Tre) and thympanic temperature (Tty) with electrothermometer TE-3F Ellab (Denmark). Both tests were conducted at ambient temperature 33± 0.5°C and humidity 50± 5%.

Thermal training

Subjects from the experimental group (E) participated in twelve sauna baths with a two days rest between each heat exposure. Participants spent a total of 45 minutes in sauna – this time was divided into three even parts (each 15 minutes) and separated by two 4-6 minutes showers to cool the body (water temperature 15±1.0°C).

Ambient temperature and relative air humidity either in sauna and climatic chamber have been supervised with thermohigrometer TH-2-4 Harvia (Finland). Temperature in sauna at chest level was pegged at 90±3°C and relative humidity was 5% at the beginning of sauna session, and 15% at the end of it.

Evaluation of body reaction to exogenous heat

Rectal (Tre) and thympanic temperature (Tty) were constantly measured during each sauna bathing. Heart rate (HR) and blood pressure (BP) data were collected every five minutes. Dehydration level (ΔBM) due to exercise and heat exposure was assessed by measuring body mass before and after sauna bathing with 1.0 gram accuracy using the F 1505–DZA weight - Sartorius (Germany). Sweating rate (SR) was measured and calculated by Allan's and Wilson's method (4) in the last (third) 15-minutes-heat exposure. Analytic weight WPA-60 Radwag (Poland) was used to measure how heavy sweat capsules were.

Statistics

Statistica 7.0 for Windows (StatSoft) was used to evaluate the data. Descriptive statistics such as: arithmetical average ($\bar{x}$) and standard deviation (SD) were calculated. Changes of analyzed variables due to thermal training were presented as means ± S.E.M. ANOVA test followed by: Fisher-Snedecor, Duncan, post-hoc and t-Student's tests for depending variables were performed. Statistical significance was set at $P < 0.05$.

Results

After twelve series of sauna bathing no significant changes in body mass (BM) and body composition (PF,LBM) were noticed in subjects from experimental group (E) compared to supervisory group (C). Thermal training did not affect maximal oxygen uptake ($\dot{V}O_2max$). However heat exposure influenced relevant capacity improvement (Table 2). It was observed in exercise test to exhaustion either by significant total work's extension (by more than 6%) and improvement of threshold of decompensated metabolic acidosis by 33% ($p<0.05$). In the control group (C) these factors did not vary in I and II series. Neither the experimental nor supervisory group had significant changes in maximal anaerobic power (MAP) (Table 2).

Rectal (Tre) and thympanic temperature's (Tty) evaluation recorded during last 15 seconds of each, third heat exposure led to distinction between temperature's falling (F) and stabilization (S) phase (Fig. 1). Falling phase of changes in body temperature was observed from first to fifth sauna bathing however

Table 2. *Maximal oxygen uptake ($\dot{V}O_2max$), total work (TWmax), threshold of decompensated metabolic acidosis (TW_{TDMA}) in exercise test to exhaustion and maximal anaerobic power (MAP), total work (TW) in men before first (I) and after last heat exposure (II). * statistically significant differences (P<0.05)*

PARAMETERS	GROUP	SERIES	$\bar{x}$± SD	Δ
$\dot{V}O_2max$ ($l \cdot min^{-1}$)	E	I	3.23±0.48	+0.13
		II	3.36±0.51	
	C	I	3.29±0.59	-0.15
		II	3.14±0.52	
$\dot{V}O_2max$ ($ml \cdot kg \cdot min^{-1}$)	E	I	46.4±3.89	2.26
		II	48.70±3.67	
	C	I	45.87±4.21	-1.64
		II	44.23±4.32	
TW_{ST} (kJ)	E	I	186.4±11.80	11.5*
		II	197.9±14.70	
	C	I	178.5±16.10	-0.6
		II	177.9±15.32	
TW_{TDMA} (kJ)	E	I	66.9±2.76	22.90*
		II	89.8±2.87	
	C	I	67.2±2.84	1.30
		II	65.9±3.08	
MAP ($W \cdot kg^{-1}$)	E	I	10.85±1.82	0.03
		II	10.88±1.73	
	C	I	10.86±1.35	-0.10
		II	10.76±1.57	
TW ($J \cdot kg^{-1}$)	E	I	249±14.51	-0.04
		II	245±12.78	
	C	I	251±11.18	-0.03
		II	248±15.31	

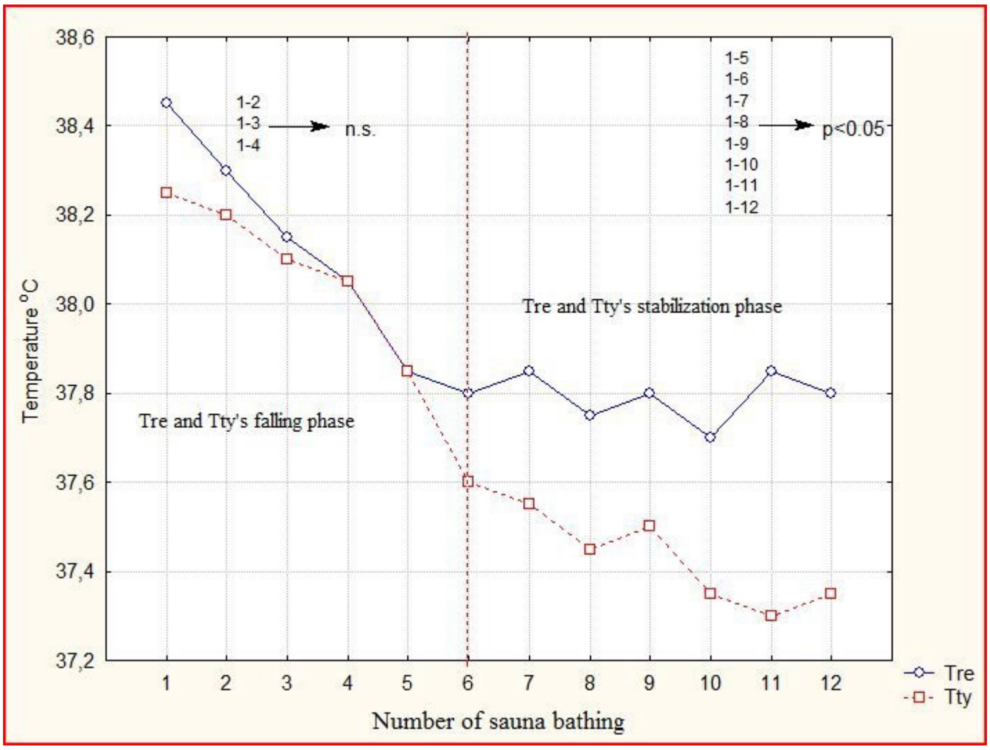

Fig. 1. *Changes of rectal (Tre) and thympanic temperature (Tty) recorded during 12 sauna bathing*

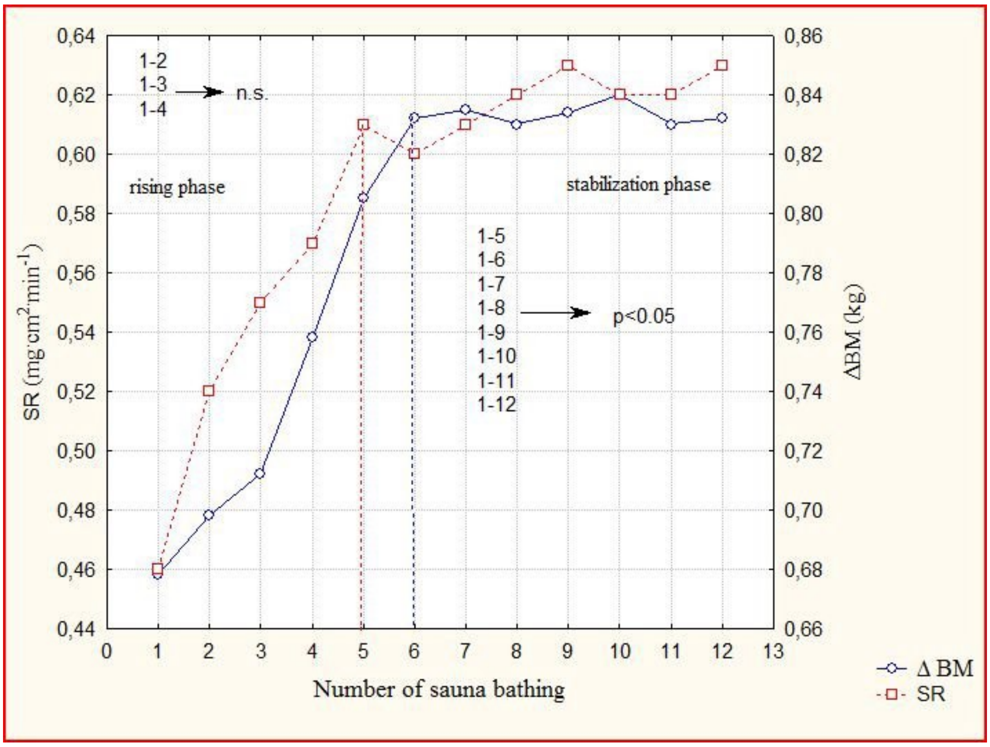

Fig. 2. *Changes of sweating rate (SR) and body dehydration (ΔBM) in 12 sauna bathing*

after sixth heat exposure rectal temperature remained at similar level – stabilization phase. The increase in Tre and Tty was significantly lower in sixth and further heat exposures comparing to the first sauna bathing.

Changes in sweating rate and body dehydration during heat exposures also had two phases (Fig. 2). From first to fifth sauna bathing SR and ΔBM had been intensively growing (about 22%) – rising phase, while after sixth one they remained relatively stable – stabilization phase.

Discussion

Thermal acclimation is more efficient when people reside at higher ambient temperatures compared to those living in cooler and less humid surroundings. When both exogenous and endogenous thermal stress factors are affecting human body at the same time acclimation can become even more efficient (5). Each factor separately can also accelerate pace of acclimation (21). Sauna bathing should be the inseparable part of training when preparing to contests in hot climate. Such knowledge is popular among coaches who use it in order to optimize professional sportsmen's trainings especially before important contests in hot climate (10). Some research (25) proves that people treated with thermal acclimation do not achieve thermoregulatory mechanisms' improvement until after 3-4 heat exposures. This statement was confirmed by other authors whose researches took place in warm and humid environment as well as in the sauna (16). For example, in a study on Caucasian men it was observed that acclimation process to tropical climate is divided into phases like in our research. The highest acclimation level can be achieved after 10-11 days after arrival to tropical zone. The effect of improvement in toleration to exogenous heat during sauna bathing can be noticed after 5-6 heat exposures (11). In this study, changes occurred in rectal and thympanic temperatures were observed from first to fifth sauna bathing. Within a few days the temperature remained relatively stable. A decrease in changes of temperature was accompanied by sweating rate's increase until the fifth sauna bathing and body dehydration's growth until sixth heat exposure what contributed to thermoregulation mechanisms' improvement. According to Kubica et al. (16) the best thermoregulation mechanisms' determinant is time of Tre elevation by 1.2°C during exercise of 53% $\dot{V}O_2max$ in ambient temperature 33°C and relative humidity 70%. Changes in analyzed parameters observed in the research show that after 5-6 sauna bathing thermoregulation mechanisms become more efficient and such information may be extremely important both for competitors and coaches. Interesting thing is whether acclimation changes were accompanied by parallel performance's ability changes. Earlier investigations (7) revealed that thermal trainings in sauna did not affect increase in $\dot{V}O_2max$ and own research stands for this statement. However it is possible to distinguish couple of acclimation changes in order to improve exercise at higher ambient temperature, these are: slower increase in Tre and HR in exercise test to exhaustion. It was also observed by other researchers (21). Adaptation changes after sauna bathing sessions in men from experimental group were seen as improvement of capacity to prolonged exercise in higher ambient temperature.

It was followed by significant total work's increase in exercise test to exhaustion (TW_{ST}) and increase of total work to threshold of decompensated metabolic acidosis (TW_{TDMA}).

Conclusion

Thermal training is a useful tool for preparation of athletes who compete in endurance-related sports that can improve performance in a warm (25-30°C), humid (70-90%) and hot (31-40°C) climate as well as in moderate environments. The acclimation process is rapid, with adaptation changes occurring after 5-6 sauna heat exposures. The effects include improvements in thermoregulation mechanisms and significant increase in capacity to prolonged exercise.

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Address for correspondence:
Aleksander Tyka
31-571 Kraków, Al. Jana Pawła II, 78
e-mail: wftyka@cyf-kr.edu.pl
tel.: +48(12) 683 14 01

e-mail addresses to co-authors:
Anna Tyka: aniatyka@yahoo.co.uk
Tomasz Cisoń: tomekcison@wp.pl
Tomasz Pałka: wfpalka@wp.pl
Zbigniew Szyguła: wfszygul@cyf-kr.edu.pl

Author's contribution
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection