PERPUSTAKAAN KAMPUS KESIHATAN
UNIVERSITI SAINS MALAYSIA

RUJUKAN

LAPORAN AKHIR PROJEK PENYELIDIKAN

R & D

JANGKA PENDEK

"The effects of short-term aerobic training program in a hot and cold environment on thermoregulation, sweat secretion and composition"

Professor Madya Dr. Roland Gamini Sirisinghe

(304/PPSP/6131256)

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BAHAGIAN PENYELIDIKAN
PUSAT PENGAJIAN SAINS PERUBATAN

SALINAN :
Bhg. Penyelidikan, PPSP
Perpustakaan Perubatan, USMKK
RCMO

T/Tangan : .... Tarikh : 12/1/05

UNIVERSITI SAINS MALAYSIA

JABATAN FISIOLOGI
DEPARTMENT OF PHYSIOLOGY

22 hb December 2004

Puan Latiffah Abdul Latif
Penolong Pendaftar
Pejabat Pengurusan & Kreativiti Penyelidikan
Jabatan Canselori
Universiti Sains Malaysia 11800 Pulau Pinang

Melalui:
Dekan
Jawatankuasa Penyelidikan
Pusat Pengajian Sains Perubatan

Puan,

Laporan Akhir

"The effects of short-term aerobic training program in a hot and cold environment on thermoregulation, sweat secretion and composition (304/PPSP/6131256)"

Surat puan bertarikh 30 September 2002 adalah di rujuk.

Bersama-sama ini dilampirkan salinan laporan akhir projek yang bertajuk "The effects of short-term aerobic training program in a hot and cold environment on thermoregulation, sweat secretion and composition (304/PPSP/6131256)" untuk makluman dan tindakan puan.

Atas kerjasama puan selama ini saya ucapan ribuan terimakasih.

Sekian.

Yang benar,

Professor Madya Roland Gamini Sirisinghe
Jabatan Fisiologi,
Pusat Pengajian Sains perubatan

PUSAT PENGAJIAN SAINS PERUBATAN SCHOOL OF MEDICAL SCIENCES
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BAHAGIAN PENYELIDIKAN & PEMBANGUNAN
CANSELORI
UNIVERSITI SAINS MALAYSIA

Laporan Akhir Projek Penyelidikan Jangka Pendek

1) Nama Penyelidik: Professor Madya Dr. Roland G. Sirisinghe

Nama Penyelidik-Penyelidik Lain (Jika berkaitan) : Professor Rabindarjeet Singh

2) Pusat Pengajian/Pusat/Unit : Sains Perubatan

3) Tajuk Projek: The effects of short-term aerobic training program in a hot and cold environment on thermoregulation, sweat secretion and composition.

4) (a) Penemuan Projek/Abstrak

(Perlu disediakan makluman di antara 100–200 perkataan di dalam Bahasa Malaysia dan Bahasa Inggeris. Ini kemudiannya akan dimuatkan ke dalam Laporan Tahunan Bahagian Penyelidikan & Pembangunan sebagai satu cara untuk menyampaikan dapatan projek tuan/puan kepada pihak Universiti).

Kajian ini dilakukan terhadap acclimasi panas (HA) dalam jangkapendek, kehilangan acclimasi (DA) dan reacclimasi (RA) bagi subjek mendapat pendedahan secara pasif acclimasi panas. Enam belas subjek lelaki bersenaman selama 14 hari (1jam/hari) dalam panas untuk HA. Satu kumpulan subjek teruskan bersenaman dalam sejuk 1jam/hari pagi dan diidedahkan satu jam waktu petang (EXG n=8) selama empatbelas hari. Kumpulan lain hanya didedahkan dalam sejuk setiap 1 jam pagi dan petang (EPG n=8). Semua kembali senaman dalam panas 1jam/hari selama 10 hari bagi RA. Subjek diuji pada hari (1, 16, 21, 32, 36, dan 44) dengan berbasikal ergometer selama 60 min ditahap 60% VO_{2max} dalam panas. Semasa acclimasi peratus dehidrasi meningkat secara signifikan pada hari ke 16 berbanding hari 1. Selepas HA, pada paras rehat Hb, PCV, dan RBC menurun secara signifikan, $[Na^{+}]_{sweat}$ meningkat secara signifikan. Pada min ke 40 senaman, T_{re}, HR, RPE, TS, kepekatan plasma laktat, Hb, PCV, RBC dan WBC menurun secara signifikan tapi MCH dan serum osmolality meningkat secara signifikan bagi $[Na^{+}]_{sweat}$ dan T_{sk} tiada perubahan. EXG menunjukkan lebih tinggi DA dimana T_{re} 24% dan 35% serta HR 29% dan 35% pada hari 21 dan 32 berurutan. EPG menunjukkan DA iaitu 2% dan 9% bagi T_{re} manakala HR 17% dan 17%. Ketiadaan perubahan dan peningkatan 11% dalam T_{re} dan HR iaitu 12% bagi kedua-dua hari iaitu 36 dan 44 menunjukkan perlahan RA bagi EXG. RA lebihcepat bagi EPG dengan peningkatan 11% dan 47% dalam T_{re} serta HR 8% dan 38% pada hari ke 36 dan 44 berurutan. Kesimpulan selepas 14 hari wujud HA dimana kehilangan lebih cepat bagi kumpulan senaman dalam sejuk. Kumpulan terdedah dalam sejuk RA lebih cepat, bukti bagi perbezaan ini belum jelas. Kemungkinan ransangan terhadap HA tidak berlaku akibat senaman di tempat sejuk.

(b) Senaraikan Kata Kunci yang digunakan di dalam abstrak:

Bahasa Malaysia	Bahasa Inggeris
1. Komposisi peluh	Sweat composition
2. Kawalatur suhu	Thermoregulation
3. acclimasi panas	Heat-acclimation
4. Kehilangan acclimasi	Decay of heat acclimation
5. Reacclimasi	Reacclimation

5) Output Dan Faedah Projek

(a) Penerbitan (termasuk laporan/kertas seminar)
(Sila nyatakan jenis, tajuk, pengarang, tahun terbitan dan di mana telah diterbit/dibentangkan).

1. Percent Loss of Acclimatization During Exercise in and Exposure to Cold Environment. Pembentangan di 8th National Conference on Medical Sciences, May 8-9, 2003, USM, Health Campus, Kelantan, Malaysia

2. The Effects of Exercise in the Heat on Thermoregulation in Japanese and Malaysian Males. Pembentangan di 42nd Congress of the Japanese Society of Biometeorology, October 18-19, 2003, Kobe University, Japan

3. Decay of heat acclimation during exercise in cold and exposure to cold environment. Pembentangan di 50th Congress of the Japanese Society of Physiological Anthropology, October 25-26, 2003, Chiba University, Japan

4. Effects of Heat acclimation on Thermoregulation, Blood Parameters, Sweat Secretion and Sweat Composition of Tropical-Malaysians with Prolonged Passive Heat Exposure. Pembentangan di 52nd Congress of the Japanese Society of Physiological Anthropology, October 22-23, 2004, Tokyo University, Japan

5. Effects of Exercise in the Heat on Thermoregulation of Japanese and Malaysian Males

   Journal of PHYSIOLOGICAL ANTHROPOLOGY - (Submitted for publication on Nov, 1, 2004)

6. Effects of Short-term Exercise in the Heat on Thermoregulation, Blood Parameters, Sweat Secretion and Sweat Composition of Tropic-dwelling Subjects

   Journal of PHYSIOLOGICAL ANTHROPOLOGY - (Submitted for publication on Nov, 16, 2004)

7. Decay of heat acclimation during exercise in cold and exposure to cold environment

   European Journal of Applied Physiology - (Submitted for publication on Nov, 6, 2004)

(b) Faedah-Faedah Lain Seperti Perkembangan Produk, Prospek Komersialisasi Dan Pendaftaran Paten.
(Jika ada dan jika perlu, sila guna kertas berasingan)

TIADA

(c) Latihan Gunatenaga Manusia

i) Pelajar Siswazah:

1. Mohamed Saat Ismail

ii) Pelajar Prasiswazah:

iii) Lain-Lain :

Peralatan Yang Telah Dibeli:

TIADA

UNTUK KEGUNAAN JAWATANKUASA PENYELIDIKAN UNIVERSITI

kajian ini telah banyak membawa manfaat

Professor Zabidi Azhar Mohd. Hussin
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T/TANGAN PENGERUSI
J/K PENYELIDIKAN
PUSAT PENGAJIAN

REPORT FOR THE RESEARCH PROJECT

(The effects of short-term aerobic training program in a hot and cold environment on thermoregulation, sweat secretion and composition)

1. **Manuscript 1**

   Effects of Exercise in the Heat on Thermoregulation of Japanese and Malaysian Males

   Journal of PHYSIOLOGICAL ANTHROPOLOGY-Submitted for publication on Nov, 1, 2004

2. **Manuscript 2**

   Effects of Short-term Exercise in the Heat on Thermoregulation, Blood Parameters, Sweat Secretion and Sweat Composition of Tropic-dwelling Subjects

   Journal of PHYSIOLOGICAL ANTHROPOLOGY-Submitted for publication on Nov, 16, 2004

3. **Manuscript 3**

   Decay of heat acclimation during exercise in cold and exposure to cold environment

   European Journal of Applied Physiology – Submitted for publication on Nov 6, 2004

4. **Abstracts**

4.1 The Effects of Exercise in the Heat on Thermoregulation in Japanese and Malaysian Males

4.2 Effects of Heat acclimation on Thermoregulation, Blood Parameters, Sweat Secretion and Sweat Composition of Tropical-Malaysians with Prolonged Passive Heat Exposure

4.3 Percent Loss of Acclimatization During Exercise in and Exposure to Cold Environment

4.4 Decay of heat acclimation during exercise in cold and exposure to cold environment

5. **Approval letter from Research Creativity and Management Office**

6. **Consent form**

Manuscript 1

Effects of Exercise in the Heat on Thermoregulation of Japanese and Malaysian Males

Abstract The effect of low-intensity exercise in the heat on thermoregulation and some biochemical changes in temperate and tropical subjects under poorly and well-hydrated states was examined. Two VO_{2max} matched groups of subjects consisting of 8 Japanese (JS) and 8 Malaysians (MS) participated in this study under two conditions. They are poorly-hydrated (no water was given) and well-hydrated (3 ml. Kg^{-1} body weight of water was provided at onset of exercise, 15^{th}, 35^{th} and 55^{th} min of exercise). Experimental room in both countries was adjusted to a constant level (Ta: 31.5±0.03°C, rh: 72.9±0.1%). Subjects spent an initial 10 min rest, 60 min of cycling at 40% VO_{2max} and then 40 min recovery in the experimental room. Rectal temperatures (T_{re}) skin temperatures (T_{sk}), heart rate (HR), heat-activated sweat glands density (HASG), local sweat rate ($M_{sw\text{-}back}$) and percent dehydration were recorded during the test. Blood samples were analysed for plasma glucose and lactate levels.

The extent of dehydration was significantly higher in the combined groups of JS (1.43± 0.08%) compared to MS (1.15±0.05%). During exercise $M_{sw\text{-}back}$ was significantly higher in JS compared to MS in the well-hydrated condition. The HASG was significantly more in JS compared to MS at rest and recovery. T_{re} was higher in MS during the test. T_{sk} was significantly higher starting at the 5^{th} of exercise until the end of the recovery period in MS compared to JS.

In conclusion, tropical natives have lower $M_{sw\text{-}back}$ as a result of higher T_{sk} and T_{re} during test. However, temperate natives have higher $M_{sw\text{-}back}$ and thus both T_{sk} and T_{re}, were lower during experiments in the hot environment. This phenomenon occurs in both poorly-hydrated and well-hydrated states at low intensity of exercise in hot environment. The difference in

$M_{sw\text{-}back}$ T_{sk} and T_{re}, is probably due to vasodilation which occurred during passive heat exposure in tropical natives.

Keywords : tropical native, temperate native, poorly-hydrated, well-hydrated, thermoregulation, sweat secretion

Introduction

Regulation of body temperature is generally affected by variation in environmental air temperature, humidity, velocity of air, and physical activity. Adaptation of an individual to a short period of exposure to heat, and acclimatization of tropical natives to the prevailing climate was distinct from each other (Kuno 1956). Acclimatization to repeated exposure to heat has been extensively studied. Literature survey revealed a lesser degree of sweating among tropical natives with a less salt concentration than temperate natives (Kuno 1956; Yoshimura 1960; Hori et al. 1976; Ohwatari et al. 1983; Sasaki and Tsuzuki 1984; Fan 1987; Matsumoto et al. 1991, 1993, 1998). Studies on sweat responses to heat load among Japanese (temperate) and Thai (tropical) subjects under identical thermo-neutral conditions showed that, Thai subjects had longer sweating onset-time compared to Japanese subjects (Matsumoto et al. 1993). There are, however, no studies addressing the effect of low intensity exercise in the heat among temperate and tropical natives. Furthermore the effect of hydration status on thermoregulation and some biochemical changes in temperate and tropical natives during and after low intensity exercise also has not been studied.

Hence the objective of the present study was to elucidate the effect of low-intensity exercise in the heat on thermoregulation and some biochemical parameters among Japanese (temperate) and Malaysian (tropical) subjects in poorly-hydrated and well-hydrated states.

Methods

Subjects

Two VO_{2max} matched groups of subjects, 17-28 years old, 8 Japanese (JS) from Fukuoka Japan and 8 Malaysian-Malay (MS) from Kota Bharu, Malaysia participated for this study. Fukuoka is located in a temperate zone (33° 36'N:130° 23'E) with hot summers and cold winters while Kota Bharu is a tropical zone (6° 07'N:102° 15'E) with dry and wet weather (mean annual ambient temperature is 16.6^{0}C and 29.5^{0}C, respectively). The subjects were not previously trained in a hot environment but physically active with basic recreational activities. The subjects were briefed on the details of experimentation and a written consent from each was taken. The physical characteristics of the subjects are shown in Table 1.

Procedures

The subjects constituting Japanese and Malaysian were tested following initially in poorly-hydrated state represented as JSPH for Japanese and MSPH for Malaysian. Finally in well-hydrated state represented as JSWH for Japanese and MSWH for Malaysian. In the poorly-hydrated state water was not given during exercise and in the well-hydrated state 3 ml. Kg^{-1} body weight water (Yaspelkis and Ivy 1991) was provided at each of four stages: Onset of exercise, at 15, 35, and 55 min of exercise. The poorly-hydrated and well-hydrated experiments were done in the same subjects with an interval of one week in random order. Experimental procedures and sport attire comprised of shorts, socks and shoes were similar in both countries. The air temperature (Ta) and relative humidity (rh) of the experimental room in both countries, Japan and Malaysia, were adjusted to a constant level (Ta: 31.5±0.03^{0}C, rh: 72.9±0.14% and Ta: 31.6±0.02^{0}C, rh: 71.7±0.12%) respectively.

Prior to the experiment, each subject was required to cycle on the ergometer at 60 revolutions per minute (RPM) for four minutes at four different workloads (50, 80, 110, and 140 Watts) over period of 16 minutes. Expired gas was measured throughout the test, but only the values during the final minute of each 4-minute increment were recorded. This was based on the fact that a subject reached a steady state of VO_{2max} after cycling for four minutes. Subsequently, a VO_{2max} test was carried out to determine the subjects maximal oxygen uptake (VO_{2max}). For this the subjects were required to cycle on an ergometer at 60 RPM until exhaustion. During this test, initial workload was set at 50 Watts and it was increased by 16 Watts every minute until the subject reached volitional exhaustion i.e. being unable to maintain a pedaling speed of 60 RPM in a neutral environment (Ta: 24.2±0.18°C, rh: 66.4±1.4%) (Singh et al.1989). From the data obtained in the submaximal exercise test and the VO_{2max} test, the workload which would elicit 40% VO_{2max} of a subject was calculated.

For the experimental study, the subjects were required to abstain from strenuous exercise for at least 48 hours prior to each test. They were not allowed caffeinated drinks, alcoholic beverages, or any drugs and they were confined to bed before 2330 on the nights prior to the test days. Subjects reported to the laboratory two hours before testing. A standard breakfast consisting of two slices of white bread and 500 mL of plain water were given to subjects within 15 min of arrival to ensure a normal hydration state (ACSM 1996). The subjects then sat in a thermoneutral environment (Ta: 24.2±0.01°C, rh: 66.4±0.1%) and remained in a comfortable sitting position for 15 minutes before a Teflon venous catheter was inserted into a forearm vein and fitted with a three-way stopcock for blood sampling: This remained in place for the remainder of the test. Nude body weight was then recorded before and after the test using an electronic scale with an accuracy of ± 0.01 kg. The subjects were then asked to enter the hot experimental chamber (Ta: 31.5±0.03^{0}C, rh: 72.3±0.14%) and spent 110 minutes in the hot environment, an initial 10 min at rest, 60 min cycling, and 40 min of recovery. During the first ten minutes and the last forty minutes, the subjects rested on an electrically-braked bicycle ergometer. Between these periods, the subject pedaled the bicycle ergometer at a constant rate of 60 RPM for 60 minutes, with control workload to achieve an intensity of 40% $V0_{2max}$. All tests were carried out between 1000 to 1200 to avoid the influence of circadian rhythm.

Measurements

Rectal temperature (T_{re}) was monitored continuously by the thermistor probe (Gram Cooperation Thermistor Sensor, Japan; accuracy, ± 0.01^{0}C), which was inserted 12 cm beyond the anal sphincter. Skin temperature was measured with thermistors attached at seven sites (forehead, abdomen, forearm, hand, thigh, calf, and foot) with surgical tape throughout the experiment. Mean skin temperature (T_{sk}) was calculated by using Hardy and Dubois' equation (1937). Heart rate (HR) was monitored every 10 min using polar HR detector. Local sweat samples were collected every 10 minutes by pieces of filter paper (12.4 cm^2) attached on the lower part of the sub scapular region and then covered with a sheet of vinyl to prevent evaporation of the sweat. The local sweat rates on the back ($M_{sw\text{-}back}$) were calculated from the mass gained by the filter paper with the use of an electric balance accurate to 1 mg. The heat-activated sweat gland density (HASG) was measured by using the iodine and starch method at every 10 minutes interval during the experiment (Inoue 1996). Blood samples were collected 5 min before exercise, at 5, 20, 40 and 60 min during exercise and 20 and 40 min post exercise recovery and transferred into a tube containing Natrium Fluoride (NaF) for estimation of plasma glucose and lactate levels. The plasma was separated by bench-top centrifugation. The plasma was analyzed for glucose by using glucose kits enzymatic calorimetric method and the plasma lactate was analyzed by using lactate analyzer. The percent dehydration during the test was calculated using the following formula.

$$\text{Percent dehydration (\%)} = \frac{[(\text{BW before test}) - (\text{BW after test (kg)}] \times 100}{(\text{BW before test})}$$

(BW = nude body weight)

Statistical Analysis

The data was analyzed with repeated-measures analysis of variance (ANOVA) incorporating groups, treatments and time as factors using VisualState for windows Version 4.5 software. Through ANOVA, Tukey post hoc comparisons were used to assess significant main effects or interactions. P<0.05 was considered as the level of significant. Results were presented as mean ± Standard Error Mean (SEM).

Table 1 Physical characteristics of the subjects

	Japanese n = 8	Malaysian (Malay) n = 8
Age (years)	23.9 ± 0.9	17.1 ± 0.3 *
Weight (kg)	61.92 ± 1.63	52.71 ± 3.07 *
Height (cm)	168.5 ± 1.8	166.5 ± 2.4
Percent body fat (%)	18.5 ± 1.3	18.7 ± 2.4
VO_{2max} ($mL.Kg.^{-1}$ min^{-1})	43.0 ± 2.2	42.7 ± 2.5
Workload (Watt)	165 ± 14	156 ± 14

*, significantly different from Japanese at $p<0.05$

Results

Dehydration

The extent of dehydration was more among the JS compared to MS in poorly-hydrated (1.41±0.12%, and 1.13±0.06%) and in well-hydrated states (1.44±0.13%, and 1.17±0.11%) respectively but neither was significant. However, the combined group of JS (1.43±0.08%) was significantly higher in dehydration than the MS (1.15±0.05%).

Local sweat rate

The local sweat rate at lower part of sub scapular region ($M_{sw\text{-}back}$) during resting, exercise and recovery period is shown in Table 2. There was significant interaction among groups, treatments and time. At the resting level within 0-10 min $M_{sw\text{-}back}$ was significantly higher in JSPH (0.126±0.039 mg. cm.^{2} min^{-1}), JSWH (0.151±0.037 cm.^{2} min^{-1}) when compared to MSPH (0.029±0.015 cm.^{2} min^{-1}), MSWH (0.003±0.001 cm.^{2} min^{-1}) respectively. $M_{sw\text{-}back}$ in JSWH was significantly higher when compared to MSWH at any time during exercise period. Whereas, in poorly-hydrated state only significant was noted within 10-20 min period of exercise between JSPH (1.349±0.182 cm.^{2} min^{-1}) and MSPH (0.622±0.098 cm.^{2} min^{-1}). At any time during recovery period, there was significantly higher in JSPH when compared to MSPH. However, JSWH was significantly higher at two points (within 0-10 min and 10-20 min) when compared to MSWH.

Table 2 Local sweat rate on the back ($M_{sw\text{-}back}$) during during resting, exercise, and recovery period for all groups

Local sweat rate (mg.cm^2. min^{-1})											
	R 0-10	E 0-10	E 10-20	E 20-30	E 30-40	E 40-50	E 50-60	Re 0-10	Re 10-20	Re 20-30	Re 30-40
JSPH	0.126± 0.039	0.595± 0.093	1.349± 0.182	1.498± 0.286	1.574± 0.391	1.690± 0.378	1.420± 0.227	0.805± 0.152	0.525± 0.128	0.279± 0.045	0.170± 0.021
MSPH	0.029± 0.015*	0.320± 0.118	0.622± 0.098*	0.837± 0.147	0.900± 0.149	0.983± 0.274	1.115± 0.318	0.312± 0.101*	0.127± 0.050*	0.048± 0.017*	0.057± 0.022*
JSWH	0.151± 0.037	0.571± 0.109	1.249± 0.200	1.812± 0.364	1.924± 0.309	2.300± 0.441	2.357± 0.436	1.098± 0.151	0.457± 0.111	0.304± 0.087	0.159± 0.035
MSWH	0.003± 0.001#	0.165± 0.039#	0.527± 0.075#	0.657± 0.089#	0.914± 0.160#	0.794± 0.107#	0.829± 0.206#	0.245± 0.050#	0.206± 0.055#	0.133± 0.041	0.104± 0.031

*, significantly different from JSPH at $p<0.05$. #, significantly different from JSWH at $p<0.05$.
R, resting period (min); E, exercise period (min); Re, recovery period (min); JSPH, Japanese poorly-hydrated; MSPH, Malaysian poorly-hydrated; JSWH, Japanese well-hydrated; MSWH, Malaysian well-hydrated

Heat-activated sweat glands density

The heat-activated sweat gland density (HASG) during rest, exercise, and recovery is shown in Table 3. There was significant interaction among groups and time but no significant differences between treatments. The HASG was significantly higher during resting in combined groups of JS (34±5 glands.cm.$^{-2}$) compared to MS (7±2 glands.cm.$^{-2}$). At 40 min during the recovery period, HASG was also significantly higher in JS compared to MS (33±5 glands.cm.$^{-2}$ Vs 15±3 glands.cm.$^{-2}$).

Table 3 Heat-activated sweat gland density (HASG) during resting, exercise, and recovery period for combined group of Japanese and Malaysian subjects in poorly-hydrated and well-hydrated

Heat-activated sweat gland density (glands.cm^{-2})											
	R 10	E 10	E 20	E 30	E 40	E 50	E 60	Re 10	Re 20	Re 30	Re 40
JS	34±5	75±4	76±4	180±5	76±5	80±4	82±3	61±5	47±6	42±5	33±5
MS	7±2*	58±7	69±5	84±8	88±8	82±9	85±10	51±6	30±5	30±6	15±3*

*, significantly different from JS at $p<0.05$. R, resting period (min); E, exercise period (min); Re, recovery period (min)
JS, Japanese subjects; MS, Malaysian subjects

Rectal temperature

Changes in rectal temperature (T_{re}) during rest, exercise and recovery are shown in Fig. 1. There was significant interaction among treatments and time but no significant differences between groups. At the 10 min of resting level T_{re} was lower in JSPH (37.14±0.09^{0}C), JSWH (37.15±0.08^{0}C) when compared to MSPH (37.30±0.16^{0}C), MSWH (37.24±0.08^{0}C) states respectively. Also T_{re} the end of exercise was lower in the JS compared to MS in poorly-hydrated (38.02±0.12^{0}C, and 38.20±0.12^{0}C) and well-hydrated (37.80±0.14^{0}C, and 37.87±0.01^{0}C) states respectively but there was no significant differences between the groups. During the recovery period, T_{re} decreased faster (0.45^{0}C) in MS from 38.20±0.12^{0}C at the end of exercise to 37.75±0.10^{0}C at the end recovery period compared to the JS (0.19^{0}C) in poorly-hydrated treatments whereas in well-hydrated treatments both subjects followed a similar trend and the difference was smaller. The changes of T_{re} between resting level toward the end of exercise were calculated. The results were 0.88^{0}C, 0.93^{0}C, 0.67^{0}C and 0.63^{0}C for JSPH, MSPH, JSWH and MSWH respectively.

However, starting at 40th min of exercise until the end of recovery period the combined groups of JS and MS, the T_{re} was significantly higher for the poorly-hydrated than for the well-hydrated condition. For instance at the end of exercise the combined groups of JS and MS, the T_{re} was significantly higher for the poorly-hydrated (38.11±0.08^{0}C) than for the well-hydrated condition (37.84±0.08^{0}C).

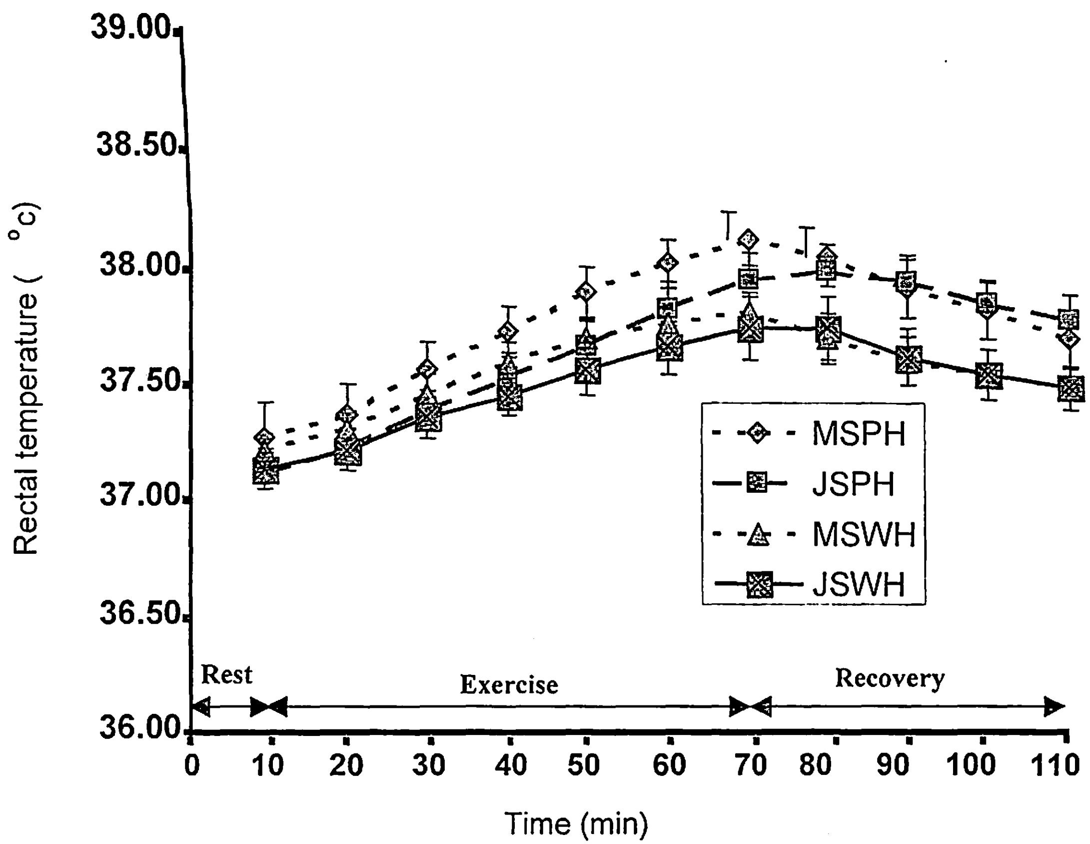

Fig. 1 Rectal temperature responses during resting, exercise and recovery period for all groups

Mean skin temperature

The change in mean skin temperature (T_{sk}) during rest, exercise and recovery was shown in Fig. 2. There was significant interaction among groups and time but no significant differences between treatments. At the 10 min of resting level T_{sk} was lower in JSPH (34.75±0.13^{0}C), JSWH (34.75±0.09^{0}C) when compared to MSPH (35.39±0.43^{0}C), MSWH (35.96±0.39^{0}C) states respectively. Also T_{sk} at the end of exercise was lower in the JS compared to MS in poorly-hydrated (35.64±0.20^{0}C, and 36.59±0.35^{0}C) and well-hydrated (35.51±0.18^{0}C, and 37.22±0.35^{0}C) states respectively. Toward the end of the recovery period T_{sk} was slightly drop from the end of exercise in both poorly-hydrated (36.59±0.35^{0}C to 36.16±0.35^{0}C) and well-hydrated (37.22±0.35^{0}C to 36.49±0.34^{0}C) for MS.

Moreover, in JS the T_{sk} has dropped lower than the resting levels in both states. The combined groups of JS starting at 5th min of exercise until the end of recovery period had significantly lower in T_{sk} than the MS. For example the combined groups of JS (35.55±0.24^{0}C) at the end of exercise had significantly lower T_{sk} than the MS (36.93±0.24^{0}C).

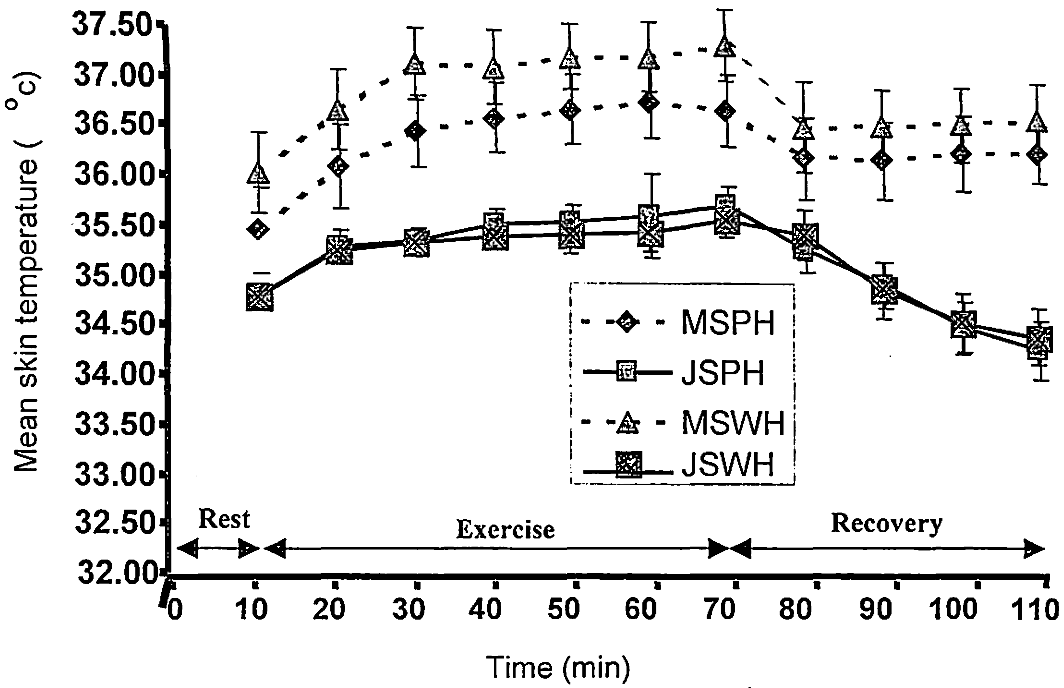

Fig. 2 Mean skin temperature responses during resting, exercise and recovery period for all groups

Heart rate

The HR during rest, exercise and recovery was shown in Fig. 3. There was significant interaction among treatments and time but no significant differences between groups. At the 10 min of resting level the HR was similar in both groups and treatments within 76±5 beats.min^{-1} to 83±6 beats. min^{-1}. The HR rate increase was also similar in JS and MS in poorly-hydrated treatments throughout the exercise reaching 142±5 beats. min^{-1} at the 60 min of exercise in JS and 140±6 beats. min^{-1} in MS. Subjects of well-hydrated at the end of 60 min exercise, showed a slightly lower HR than the poorly-hydrated subjects in both JS (134±5 beats. min^{-1}) and MS (133±6 beats. min^{-1}).

However, starting at the 10^{th} min of recovery until the end of experiment the combined groups of JS and MS, the HR was significantly higher for the poorly-hydrated than for the well-hydrated condition. For instance at the 10^{th} min in poorly-hydrated (100±4 beats. min^{-1}) and in the well-hydrated condition (90±4 beats. min^{-1}).

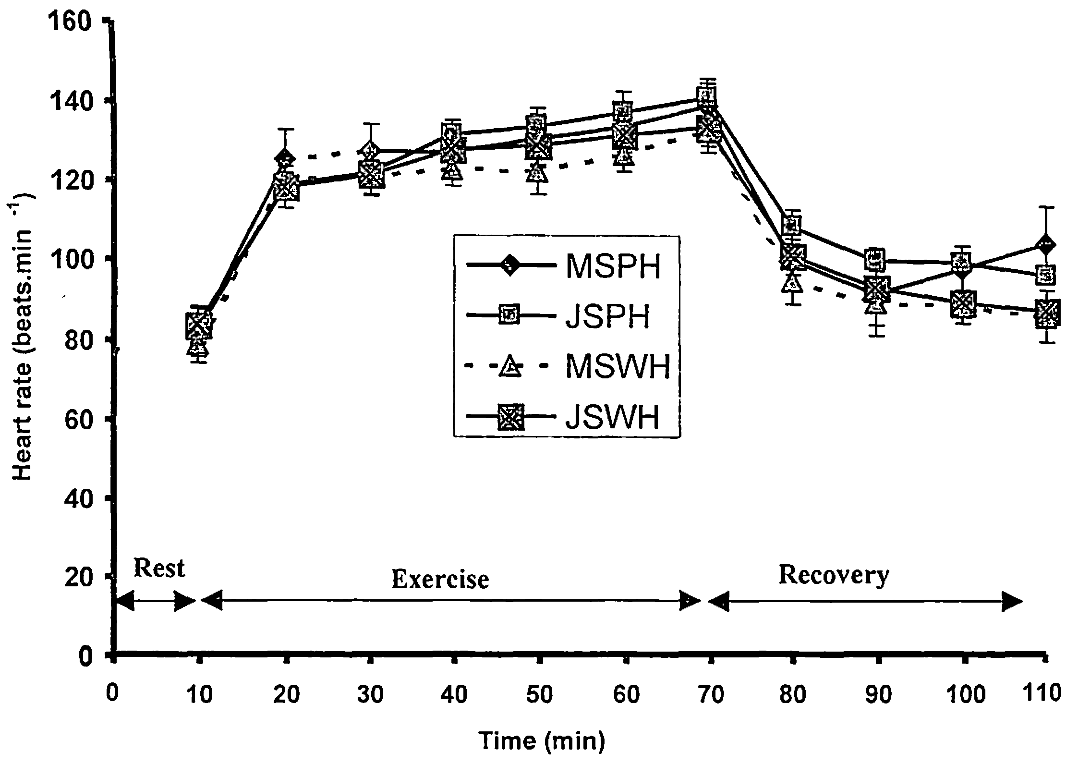

Fig. 3 Heart rate responses during resting, exercise and recovery period for all groups

Plasma glucose concentration

Plasma glucose concentration level was similar within the JS and MS, under resting conditions at the normal range between 5.10 to 5.71 mmol. L^{-1} (Fig. 4). There was no significant differences noted between groups, treatments and time. During exercise the plasma glucose concentration level fall between 4.0 to 5.24 mmol.L^{-1} but still within the normal range and between 4.41 to 5.31 mmol.L^{-1} during recovery period.

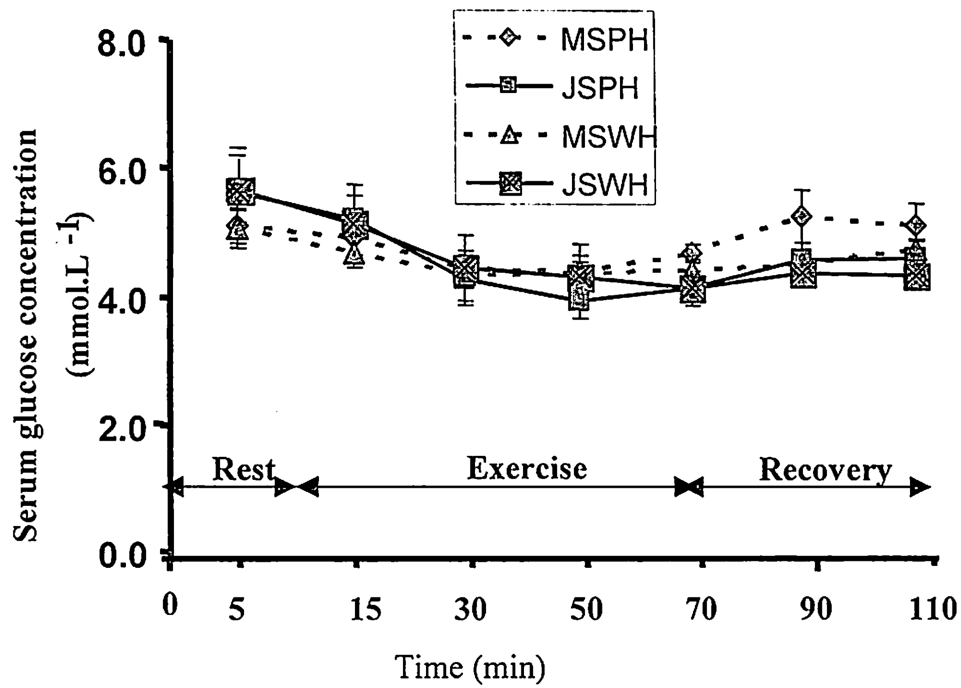

Fig. 4 Serum glucose responses during resting, exercise and recovery period for all groups

Serum lactate concentration

Serum lactate concentration level during rest, exercise and recovery was shown in Fig. 5. There was no significant differences noted between groups and treatments in serum lactate concentration. Serum lactate concentration was significantly higher initially in the MSPH when compared to JSPH and JSWH.

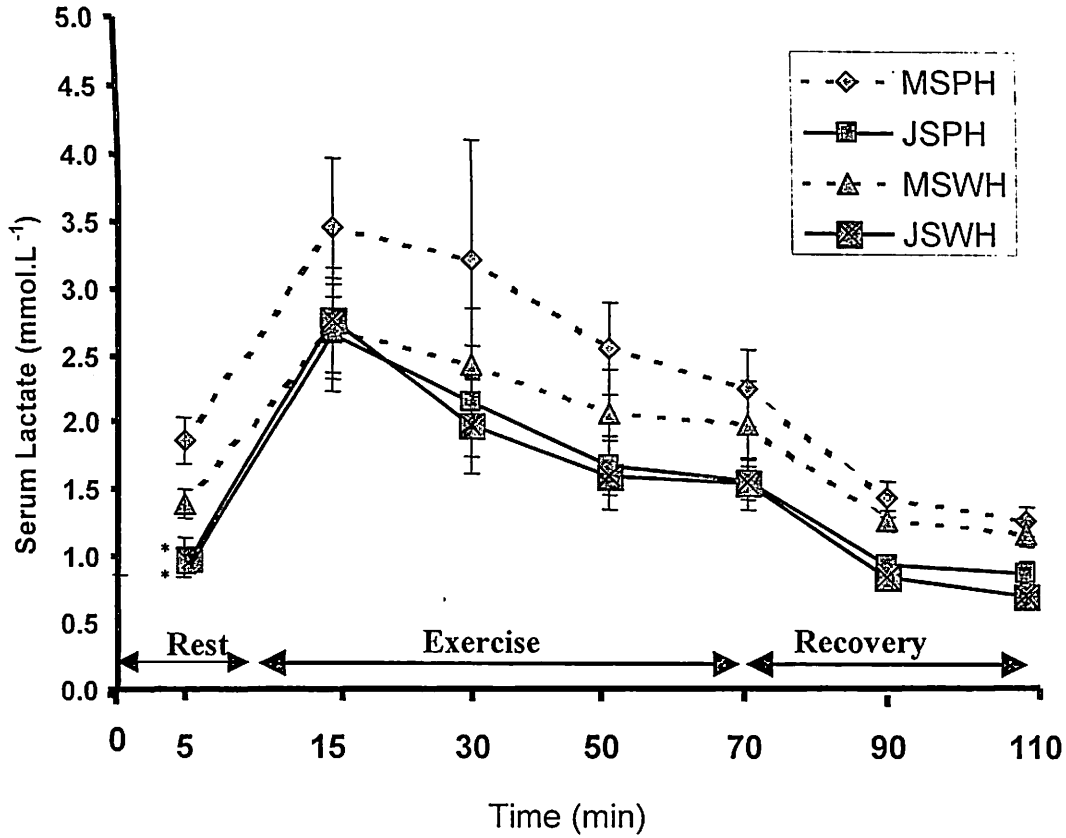

Fig. 5 Serum lactate responses during resting, exercise and recovery period for all groups. *, significantly different from MSPH at $p<0.05$

Discussion

Climatic exposure to heat results in gradual acclimatization, an adaptive physiological process leading to a decrease in body temperature, a decline in metabolic heat production and an improvement in heat abilities. This phenomenon generally occurs in tropical natives and they exhibit a better heat tolerance. There are a number of studies with regard to heat acclimatization (HA) responses in short-term physical and heat-stress conditioning, but those mentioning HA responses with prolonged passive heat exposure (HE) are scarce (Strydom et al. 1966; Shapiro et al. 1981; Chin et al. 1997). Passive HE is interpreted as living in a hot climate without performing intense exercise on a regular basis. Sweating is a mechanism of heat dissipation for humans when exposed to a hot environment. It is known that sweating response to heat is influenced by climate condition. In an area where there is a distinct seasonal fluctuation of ambient temperature like Japan, various physiological responses may change season by season. As to sweat responses to seasonal changes during summer, the sweat rate is higher, with a shorter latent period for sweat onset and lower salt concentration in sweat than in winter (Kuno 1956; Yoshimura 1960; Hori et al. 1976). However it is generally accepted that tropical natives having acclimatized to heat for a long time, sweat slowly than temperate natives and the salt concentration in sweat in the former is much lower than in the latter (Kuno 1956; Yoshimura 1960; Hori et al. 1976; Ohwatari et al. 1983; Sasaki and Tsuzuki 1984; Fan 1987; Matsumoto et al. 1991, 1993, 1998). Thus these suggest that smaller amounts of sweat in the warm ambient temperature give an indication of HA. Sweating will increase during exercise by increased sensitivity to the central sweating drive (Nadel et al. 1974). HA is transient and gradually disappears if not maintained by repeated heat exposure. It is believed that HA might be retained for 2 weeks after the last heat exposure but then be rapidly lost during the next 2 weeks (Lind 1964).

According to Matsumoto et al. (1993) the sweat response to heat load of natives tropical subjects (Thai) were significantly longer in sweat onset-time and smaller in local sweat volume on the chest when compared to Japanese. Tropical inhabitants possess heat-tolerance due to enhanced dry heat loss such as radiation, convection and conduction and possibly also due to an excessive sweat loss (non-evaporating, ineffective sweating), which was convenient to maintain body fluid and osmolarity (Matsumoto et al. 1997).

The factors which determine the set-point of body temperature were lower basal metabolism related to heat production and the physical constitution related to heat dissipation of tropical inhabitants (Hammel et al. 1963). Similarly heat tolerance was achieved by the lowering of threshold for sweating leading to enhanced sweating after short-term acclimatization (Nadel et al. 1974; Ogawa and Sugenoya 1993). Further acclimatization was associated with higher sweat rate and increased sweating response as the core temperature increases (Hammel 1968).

In the present study, $M_{sw\text{-}back}$ was significantly lower in the MS compared to the JS at rest, during exercise and recovery period in well-hydrated condition (Table 2). As a result the extent of dehydration was less in MSWH (1.17 ± 0.11%) compared to JSWH (1.44 ± 0.13%) and in the combined groups of MS (1.15 ± 0.05%) was significantly lower in dehydration than the JS (1.43 ± 0.08%). It might be of significance in terms of water saving, which increase their T_{re} markedly (Schmidt et al. 1956). The thresholds of temperature for sweating in MS were higher than those of JS, which indicate stronger heat tolerance in topical natives when compared to temperate natives. The HASG was significantly higher during resting and at the end of recovery in combined groups of JS compared to MS (Table 3) may have also contributed to