Journal of Science and Medicine in Sport 17 (2014) 677–682

Contents lists available at ScienceDirect

Journal of Science and Medicine in Sport

journal homepage: www.elsevier.com/locate/jsams

Original research

Exercise-heat acclimation in young and older trained cyclists

Stuart Best[a,*], Martin Thompson[a], Corinne Caillaud[a], Liv Holvik[a], George Fatseas[b], Amr Tammam[a]

[a] Exercise Health and Performance Research Group, Faculty of Health Sciences, University of Sydney, Australia
[b] School of Medical Sciences, Faculty of Medicine, University of New South Wales, Australia

ARTICLE INFO

Article history:
Received 17 April 2013
Received in revised form
15 September 2013
Accepted 13 October 2013
Available online 31 October 2013

Keywords:
Ageing
Acclimatisation
Thermoregulation

ABSTRACT

Objectives: The purpose of this study was to investigate the effect of age on the capacity to acclimatise to exercise-heat stress. This study hypothesised that age would not affect body temperature and heat loss effector responses to short-term exercise-heat acclimation in trained subjects.
Design: Seven young subjects (19–32 years) were matched with 7 older subjects (50–63 years). Subjects were highly trained but not specifically heat acclimated when they exercised for 60 min at 70%VO_{2max} in hot-dry (35 °C, 40%RH) and thermoneutral (20 °C, 40%RH) conditions, pre and post 6 days of exercise-heat acclimation (70%VO_{2max}, 35 °C, 40%RH).
Methods: Rectal temperature (T_r), skin temperature (T_{sk}), heart rate (HR), cutaneous vascular conductance (CVC) and whole body sweat loss (M_{sw}) were measured during each testing session and T_r and HR were measured during each acclimation session.
Results: T_r, T_{sk}, %HR_{max}, CVC and M_{sw} were similar across age groups both pre and post heat acclimation. Following heat acclimation relative decreases and increases in T_r and M_{sw}, respectively, were similar in both subject groups. There was a significant reduction in heart rate (%HR_{max}) and increase in final CVC following the acclimation programme in the young group (all $p < 0.05$) but not the older group.
Conclusions: When comparing young and older well trained adults we found age affected the cardiovascular adaptation but not body temperature or whole body sweat loss to exercise-heat acclimation. These data suggest age does not affect the capacity to acclimatise to exercise-heat stress in highly trained adults undergoing short-term heat acclimation.

1. Introduction

Heat acclimation increases exercise time to fatigue,[1] decreases core temperature,[2,3] lowers skin blood flow and sweating thresholds[2,4] as well as reduces heart rate[2,4,5] during exercise in hot conditions. The attainment of an acclimated state is commonly defined by a plateau in core temperature, heart rate and sweat rate responses in consecutive bouts of thermal stress.[1,5,6]

Incidences of heat exhaustion and heat stroke in response to heat waves[7] and exercise-heat stress[8] increase rapidly with age from middle to old age. Heat acclimation reduces the thermoregulatory stress and therefore risk of heat exhaustion and heat stroke brought on by exercise-heat stress during athletic competition and/or physically demanding occupations. Therefore it is critically important to consider how age may affect the capacity to acclimatise to varying environmental conditions, particularly when subjected to exercise-heat stress.

Previous research has shown similar core temperature[9–11] and sweating responses[10,11] between young and older adults following heat acclimation. However, when compared to young adults there are also reports of increased core temperatures[12] as well as attenuated sweating[12,13] and skin blood flow[13] responses in older adults. These inconclusive results could be due to differences in protocols as some studies have failed to match testing conditions,[9] heat acclimation protocols[12] or similarly acclimated subjects[10,11] between age groups.

No study has compared body temperatures and heat loss effector mechanisms of similarly, un-acclimatised young and older adults, pre, during and post short-term exercise-heat acclimation. This investigation is critical in the development of heat acclimation regimes for older athletes or employees.

Thus, the purpose of the present study was to investigate the effect of age on the capacity to acclimatise to exercise in the heat. Specifically, this study would compare thermoregulatory responses of young and late middle-aged highly trained subjects when exercising at the same relative exercise intensity pre, during and post short-term exercise-heat acclimation. The response prior to and

* Corresponding author at: Institute for Exercise and Environmental Medicine, Texas Health Presbyterian Hospital, 7232 Greenville Avenue, Dallas, TX 75231, United States. Tel.: +1 214 345 6504; fax: +1 214 345 4618.
E-mail address: StuartBest@texashealth.org (S. Best).

1440-2440/$ – see front matter © 2013 Sports Medicine Australia. Published by Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jsams.2013.10.243

following heat acclimation would be referenced against the same exercise in a thermoneutral environment. We hypothesised there would be no difference between age groups in the rate of core temperature and heart rate adaptation during the heat acclimation. Furthermore there would be no relative differences between age groups in the ability to dissipate metabolic heat through sweating and skin blood flow prior to and post heat acclimation.

2. Methods

The study was approved by the University of Sydney Human Ethics Committee. Each participant gave written, informed consent prior to participation in the study in accordance with the standards set by the Declaration of Helsinki.

Fourteen highly trained cyclists aged 19–32 ($n = 7$), and 50–63 ($n = 7$) volunteered for the study. Each cyclist competed regularly for >2 years, and trained 4–5 sessions/week (1–2 h/session) for >6 months prior to participation in the study. Young and older subjects were matched for height, body mass and training volume. Testing was completed during winter to ensure participants were not heat acclimatised before the study.

Each participant completed medical and training history questionnaires prior to the study. A resting and exercise 12 lead ECG recording was examined by a medical practitioner for contraindications to exercise prior to participation in the study. Participants then completed a VO_{2max} test using a standard protocol[14] (20 °C, 40%RH).

Participant's then performed, in randomised sequence (range: 2–3 days between sessions), two 60 min stationary cycling bouts at 70%VO_{2max} in thermoneutral (20 °C, 40% RH), and heat (35 °C, 40% RH) conditions.[14] Following the initial thermoneutral and heat tests, participants rested for a minimum of 2 days (range: 2–11 days) before completing 6 consecutive heat acclimation sessions (60 min, 70%VO_{2max}, 35 °C, 40%RH). After one day of recovery following the heat acclimation, the heat test was repeated, followed by the thermoneutral test, with an additional days rest between testing sessions. Following a further days rest each participant completed another 60 min thermoneutral test (20 °C, 40%RH) in which each participant cycled at 200 W. The methods, results and discussion of the 200 W test are presented in the online-only Data Supplement.

Each test was identical in preparation and measures. Participants were asked to avoid strenuous exercise during the study and as close as possible repeat their food and fluid intake the day prior to each of the testing sessions. On the day of the test, prior to entering the climate chamber and following a minimum of 15 min of rest in a supine position, a 5 mL resting blood sample was collected. On entering the climate chamber the participant rested on the cycle ergometer for a total of 20 min allowing skin blood flow sensors to be attached and resting blood pressure to be measured.

Heart rate (HR), rectal temperature (T_r) and skin temperatures were measured continuously during exercise. Blood pressure (BP, sphygmomanometer), VO_2, cardiac output (Q) and cutaneous vascular conductance (CVC) were measured at 10, 20, 40 and 60 min. Venous blood samples (5 mL) were collected at 10 and 60 min. Three fans, placed directly in front of the bike (2 m), provided airflow (1.78 m/s, 6.4 km/h) during all testing and acclimation sessions. Each participant received one water bottle (6 mL/kg) to drink ad lib. during the hour of exercise but participants were required to ingest all the water by 55 min.[14] Sweat loss (M_{sw}) was calculated as the difference in pre and post exercise nude body mass (Mettler ID1s digital scale), corrected for fluid intake and respiratory water loss.[15]

During the heat acclimation sessions participants were weighed before exercise. Throughout each heat acclimation session T_r and HR were measured continuously and participants were able to drink water ad lib. with no restrictions on the total volume of fluid ingested.

An electromagnetically braked cycle ergometer (SRM) was used for all testing and acclimation sessions. HR was measured using a Polar heart rate monitor (T31, Polar, Kempele, Finland) and recorded using SRM software (SRM Training System Ver6.33.06, Germany). Expired respiratory gas was collected via Douglas Bags. Oxygen and Carbon Dioxide concentrations were later measured using Servomex (Crowborough, England) PM1111E Paramagnetic and IR1507 Paramagnetic Transducers, respectively. Total gas volume was measured using a Harvard (Holliston, MA, USA) SO-6162 Dry Gas Meter. Q was determined through a CO_2 rebreathing method[16] and stroke volume (SV) was calculated as SV (mL) = ($Q \times 1000$)/HR.

T_r and skin temperatures were measured using copper–tungsten thermocouples (Mallinckrodt, Inc., St. Louis, MO, USA). The T_r thermocouple was placed inside a thin latex sheath and inserted 10–12 cm inside the rectum. Thermocouples for skin temperature were taped over the mid-point of the tibia, mid-thigh, deltoid and the chest and mean skin temperature (T_{sk}) calculated.[17] Mean body temperature (T_b) was calculated as $T_b = (0.8 \times T_r) + (0.2 \times T_{sk})$. Skin blood flow (SkBF) was recorded at the forearm using a Moor Instruments (Devon, England) Laser Doppler Blood Flow Monitor (MP1-V2 skin probe) and later analysed (MoorSoft for Windows/moorLAB v1.31). CVC was calculated as: CVC (AU/mmHg) = SkBF/MAP where MAP = mean BP.

Each blood sample was immediately analysed for hematocrit and haemoglobin (Sysmex KX-21N Hematology Analyser, Kobe, Japan) and these values were used to calculate estimated changes in plasma volume.[18]

Metabolic heat production (M) was calculated using standard partitional calorimetry equations[19]:

$$M\,(\text{W m}^{-2}) = \frac{(\text{EE} \times \text{VO}_2 \times t)/(t \times 60)}{A_d}$$

$$\text{EE}\,(\text{J LO}_2^{-1}) = (0.23 \times \text{RER} \times 0.77) \times 21,166$$

where EE is the energy expenditure, t is the time (min), A_d is the body surface area (m^2), RER is the respiratory exchange ratio, 21,166 is the energy equivalent of oxygen (J LO_2^{-1}).

Repeated-measures ANOVA (group × pre–post acclimation × temperature × time) were used to analyse the data. Greenhouse–Geisser corrections were used in the event that sphericity was violated. Post hoc analyses were conducted using Tukey post hoc comparisons. One-way ANOVA were used to compare singular means and Pearson's correlation coefficient used to analyse linear correlations. In each analysis significance was set at $p < 0.05$. All 'final' values were measured at 60 min in the respective testing or acclimation session. All results are given as a mean ± SD.

3. Results

T_r and HR responses to the testing and acclimation sessions are shown in Fig. 1. All other body temperature, cardiovascular and sweating data for the thermoneutral and heat tests are shown in Table 1. Participant summary data (Table S1) and relative changes in key variables pre–post heat acclimation (Table S2) were reported in the online-only Data supplement.

VO_{2max} (L min^{-1}, $p = 0.008$) 70% power output ($p = 0.007$) and HR_{max} ($p = 0.010$) were significantly higher in the younger group than the older group but the relative intensity of the exercise was similar between age groups (69.5 ± 3.9%VO_{2max} and 70.4 ± 3.8%VO_{2max} for the younger and older groups, respectively, $p = 0.649$).