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The effect of high versus low intensity heat acclimation on performance and neuromuscular responses

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ABSTRACT

This study examined the effect of exercise intensity and duration during 5-day heat acclimation (HA) on cycling performance and neuromuscular responses. 20 recreationally trained males completed a 'baseline' trial followed by 5 consecutive days HA, and a 'post-acclimation' trial. Baseline and post-acclimation trials consisted of maximal voluntary contractions (MVC), a single and repeated countermovement jump protocol, 20 km cycling time trial (TT) and 5 × 6 s maximal sprints (SPR). Cycling trials were undertaken in 33.0 ± 0.8 °C and 60 ± 3% relative humidity. Core (T_{core}), and skin temperatures (T_{skin}), heart rate (HR), rating of perceived exertion (RPE) and thermal sensation were recorded throughout cycling trials. Participants were assigned to either 30 min high-intensity (30HI) or 90 min low-intensity (90LI) cohorts for HA, conducted in environmental conditions of 32.0 ± 1.6 °C. Percentage change time to complete the 20 km TT for the 90LI cohort was significantly improved post-acclimation (−5.9 ± 7.0%; $P=0.04$) compared to the 30HI cohort (−0.18 ± 3.9%; $P<0.05$). The 30HI cohort showed greatest improvements in power output (PO) during post-acclimation SPR 1 and 2 compared to 90LI (546 ± 128 W and 517 ± 87 W, respectively; $P<0.02$). No differences were evident for MVC within 30HI cohort, however, a reduced performance indicated by % change within the 90LI ($P=0.04$). Compared to baseline, mean T_{core} was reduced post-acclimation within the 30HI cohort ($P=0.05$) while mean T_{core} and HR were significantly reduced within the 90LI cohort ($P=0.01$ and 0.04, respectively). Greater physiological adaptations and performance improvements were noted within the 90LI cohort compared to the 30HI. However, 30HI did provide some benefit to anaerobic performance including sprint PO and MVC. These findings suggest specifying training duration and intensity during heat acclimation may be useful for specific post-acclimation performance.

1. Introduction

The efficacy of heat acclimation (HA) to improve self-paced exercise performance in hot conditions has been well documented (Armstrong and Maresh, 1991; Lorenzo et al., 2010; Saat et al., 2005; Sunderland et al., 2008). Favorable reductions in cardiovascular, thermoregulatory and perceptual strain for a given work rate are conventionally used to explain performance gains (Chen et al., 2013; Sunderland et al., 2008), as such, the degree of acclimation achieved appears to be dependent on the dose of thermal strain administered (Maughan and Shirreffs, 2004). While this trend may point to the use of prolonged, repeated heat exposures to maximize adaptations in heat loss mechanisms (Houmard et al., 1990), pre-competition preparation time constraints often restrict long-term HA regimes (Petersen et al., 2010). Short-duration, high intensity exercise training has become a more recognized form of exercise training for enhanced physiological status and improved performance utilising a greater efficiency of time distribution. Consideration for applying an acclimation intervention should be given to the increased cumulative training load (Halson et al., 2002) and reduced rate of voluntary force recovery (Duffield et al., 2009) accompanying exercise- and environment-induced heat stress. Shorter periods of high-intensity HA have been reported to alleviate such concerns and yet still attain the desired increases in thermoregulatory efficiency and exercise performance (Chen et al., 2013; Houmard et al., 1990). Nevertheless,

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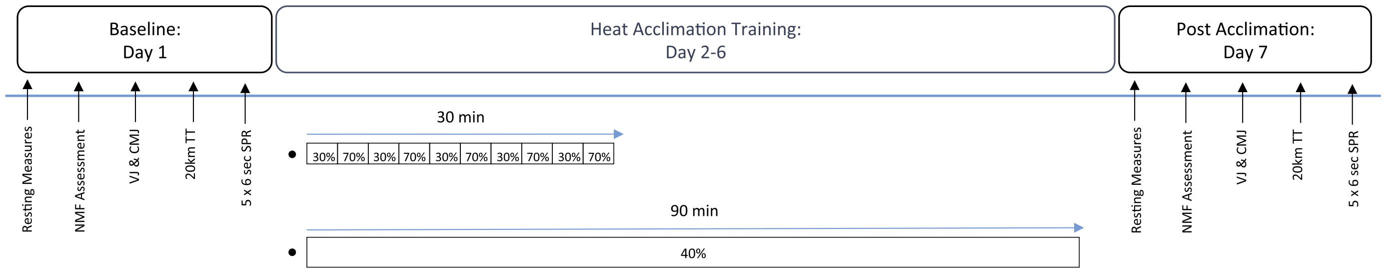

Fig. 1. Schematic overview of study design for baseline, heat acclimation training and post-acclimation.

understanding how short term, high-intensity HA stimuli may impact neuromuscular properties associated with improved pacing strategy remains to be elucidated.

Increased rates of heat storage in high environmental temperatures demonstrate a dose-response relationship with neuromuscular performance (Racinais and Oksa, 2010). Importantly, the exercise duration, and associated changes in local muscle and core body temperature (T_{core}), highlight contrasting direct (i.e., improved brief, powerful action) and inverse trends (i.e., reduced prolonged exercise performance) (Maughan and Shirreffs, 2004; Racinais and Oksa, 2010). Although increased short-term muscle contractility, force and power output (PO) are reported in warm conditions (Edwards et al., 1972), continual rise in T_{core} during extended exercise in the heat inhibits neural drive to the muscle and reduces voluntary activation (VA) (Nybo and Nielsen, 2001; Périard et al., 2011). This suboptimal neuromuscular recruitment under heat stress may reduce metabolic heat gain to protect health status (Kay et al., 2001), and downregulate exercise intensity as a result (Tucker et al., 2004). Enhanced thermoregulatory efficiency achieved via HA may protect self-paced exercise performance in the heat, but how such strategies can influence neuromuscular mechanisms, including central and peripheral contributions to performance outcomes remain unknown. This is notable considering the specificity of neuromuscular adaptations to exercise prescription (Häkkinen et al., 2003) and the relationships between maximal voluntary contraction (MVC) and training status (Lattier et al., 2003).

Accordingly, the primary aim of the present study was to compare low-intensity, long duration (90 min; 90LI) to intermittent high-intensity, short duration (30 min; 30HI) cycling during HA on cycling performance. A further aim of the present study was to compare neuromuscular responses between two HA training types. This is pertinent as this study is the first to compare neuromuscular changes between exercise duration and intensity to explain improvements in exercise performance following HA. We hypothesised that 30HI would produce greater power output during maximal sprints post-acclimation, while 90LI is hypothesised to produce better endurance performance post-acclimation. Further, we hypothesised that any performance gains may be caused by increases in maximal voluntary torque (MVT) and VA specific to the respective training stimuli.

2. Methods

2.1. Participants

Participants were 20 recreationally active, male team-sport players who reported undertaking physical training and/or competition 2–3 times per week. All participants were required to be non-acclimated (mean climatic temperature during the intervention: 17.3 °C), non-smokers, with no current illness or injury. Mean ± standard deviation (mean ± SD) age, body mass, height and peak oxygen uptake (VO_{2peak}) characteristics of the participants for the respective cohorts were; 30HI (24.3 ± 4.2 y, 80.5 ± 6.3 kg, 180.2 ± 5.3 cm, and 41.9 ± 3.7 ml kg^{-1} min^{-1}, respectively); and 90LI (23.5 ± 5.0 y, 72.7 ± 6.3 kg, 175.4 ± 4.9 cm, and 44.3 ± 6.0 ml kg^{-1} min^{-1}, respectively). Ethical approval was gained from the Institution Human Research Ethics Committee prior to any data collection. All participants were informed of the demands and risks involved in the research, and provided verbal and written consent prior to testing.

2.2. Overview

Participants completed a singular familiarisation session to become accustomed to all testing equipment and procedures 5–7 days prior to experimental trials. Familiarisation also included assessment of VO_{2peak} using a ramp protocol (Barstow et al., 2000) and a cycle ergometer to pair match participants for the respective cohorts based on peak oxygen uptake and power output at VO_{2peak} (Lode B.V., Excalibur Sport, Groningen, The Netherlands). The VO_{2peak} test commenced at 35 W with increments of 35 W every 60 s with cadence maintained at 80 rpm for the duration of test. At exhaustion, peak power (P_{max}) was recorded to calculate load for the subsequent HA training cycling protocols. Participants were advised to abstain from food and caffeine 2 h prior to all exercise protocols, and strenuous physical activity 24 h prior to all exercise training. See Fig. 1 for schematic overview of study design.

2.2.1. Baseline and post-acclimation experimental trials (Day 1 and 7)

Baseline and post-acclimation experimental trials occurred within 24–48 h before and after HA, respectively. Urine specific gravity (USG), nude body mass, resting heart rate (HR), core temperature (T_{core}), skin temperature (T_{skin}), capillary blood sample for lactate (La^-), thermal sensation (TS) and rate of perceived exertion (RPE) were recorded on arrival following ~10 min seated in a rested state. This was immediately followed by neuromuscular assessment of the right knee extensors including MVC, and vertical jump (VJ) and countermovement jumps (CMJ). Participants then completed cycling trials in an environmental chamber (33.1 ± 0.8 °C and 60 ± 3% relative humidity (RH)), including a 20 km time trial (TT) (Tucker et al., 2004) and 5 × 6 s maximal cycling sprints (SPR) on an air-braked stationary cycle ergometer (Velotron, RacerMate Inc., Seattle, USA). Previous literature demonstrates the maximal sprint protocol has a high test-retest reliability ICC = 0.96–0.98 (Koninckx et al., 2010). During the 5 min seated recovery between TT and SPR participants were allocated with maximal 600 ml water (475 ± 128 ml ingested). Each SPR was separated by 24 s active recovery (work:rest ratio of 1:5) during which participants continued to cycle slowly. Participants were required to remain seated for duration of all cycling protocols. Immediately following cycling protocols, participants completed physiological measures including nude mass, HR, T_{core}, T_{skin} and capillary blood sample was obtained.

2.2.2. Heat acclimation training (Day 2–6)

Following baseline testing, participants underwent five