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Research article

Short Duration Heat Acclimation in Australian Football Players

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Abstract
This study examined if five sessions of short duration (27 min), high intensity, interval training (HIIT) in the heat over a nine day period would induce heat acclimation in Australian football (AF) players. Fourteen professional AF players were matched for VO_2peak ($mL \cdot kg^{-1} \cdot min^{-1}$) and randomly allocated into either a heat acclimation (Acc) (n = 7) or Control (Con) group (n = 7). The Acc completed five cycle ergometer HIIT sessions within a nine day period on a cycle ergometer in the heat (38.7 ± 0.5 °C; 34.4 ± 1.3 % RH), whereas Con trained in thermo-neutral conditions (22.3 ± 0.2 °C; 35.8 ± 0. % RH). Four days prior and two days post HIIT participants undertook a 30 min constant load cycling test at 60% $\dot{V}O_2$peak in the heat (37.9 ± 0.1 °C; 28.5 ± 0.7 % RH) during which VO_2, blood lactate concentration ([Lac^-]), heart rate (HR), rating of perceived exertion (RPE), thermal comfort, core and skin temperatures were measured. Heat acclimation resulted in reduced RPE, thermal comfort and [Lac^-] (all $p < 0.05$) during the submaximal exercise test in the heat. Heart rate was lower ($p = 0.007$) after HIIT, in both groups. Heat acclimation did not influence any other measured variables. In conclusion, five short duration HIIT sessions in hot dry conditions induced limited heat acclimation responses in AF players during the in-season competition phase. In practice, the heat acclimation protocol can be implemented in a professional team environment; however the physiological adaptations resulting from such a protocol were limited.

Key words: Core temperature; thermoregulation; high intensity interval training; adaptation; metabolism.

Introduction

Professional Australian Football League (AFL) players are occasionally required to travel during winter from their regular place of residence and training in southern Australia (12-18 °C) to tropical northern Australia to compete in a warm to hot climate (30-35 °C). This sudden switch in climatic conditions imposes a thermoregulatory stress on these athletes and is known to negatively impact in-game movement patterns (Aughey et al., 2014). In order to attenuate heat-induced stressors and better maintain in-game running performance, field sport athletes are recommended to complete a period of heat acclimation prior to competition in the heat (Grantham et al., 2010). In support of this concept running performance in both hot and temperate environments has been improved in professional AFL players after a 2 week pre-season training camp in hot ambient conditions that stimulated heat acclimatization (Racinais et al., 2014).

In a professional field sport setting, implementing a time efficient heat acclimation program during the competitive season that is effective is particularly challenging (Chalmers et al., 2014). In general, any heat acclimation protocol implemented in-season will typically compromise between the time required to acclimate and other considerable demands on the player's time, including weekly competition. As such, the extent of heat acclimation maybe affected, given that complete adaptation to heat stress typically requires ~14 consecutive days of exposure (Armstrong and Maresh, 1991), although 75% of the adaptation can occur after ~4 to 6 consecutive days (Pandolf, 1998).

Garrett and colleagues (2009; 2012; 2014) have conducted several short-term (five consecutive days) heat acclimation studies in recent years and demonstrated beneficial performance and physiological heat adaptations. Although only five heat exposures were undertaken in these studies, each exposure involved 90 min of continuous low intensity exercise to induce controlled hyperthermia (core temperature of 38.5 ºC). This is a large time commitment over consecutive days employing an exercise task which is not very specific to field sport athletes. In contrast, three studies have investigated the effectiveness of short duration heat acclimation protocols relevant to field sport athletes (Brade et al., 2013; Petersen et al., 2010; Sunderland et al., 2008). The protocols involved high intensity interval exercise (running or cycling) during four to five heat exposure sessions (30-35 °C; 27-60% relative humidity (RH)) either on consecutive or non-consecutive days for a total heat exposure time ranging from 150 to 200 min. It has been reported that acclimation of well-trained female hockey players resulted in lower rectal temperature and an improved perception of thermal comfort during high intensity intermittent running in the heat (Sunderland et al., 2008). Similarly, it was also reported that moderately trained team sport players exposed to a short duration heat acclimation protocol displayed partial acclimation - as evidenced by lower heart rate (HR), core and skin temperatures, in addition to greater sweat loss and sweat sensitivity during intermittent cycling exercise in the heat (Brade et al., 2013). Finally, Petersen and colleagues (Petersen et al., 2010) reported that heat acclimation, involving very high intensity, interval cycling in male club cricketers, induced a moderate decrease in HR and caused a moderate to large decrease in sweat electrolyte concentration during a constant speed submaximal treadmill running test in the heat. In contrast to the other two studies, heat acclimation did not result in

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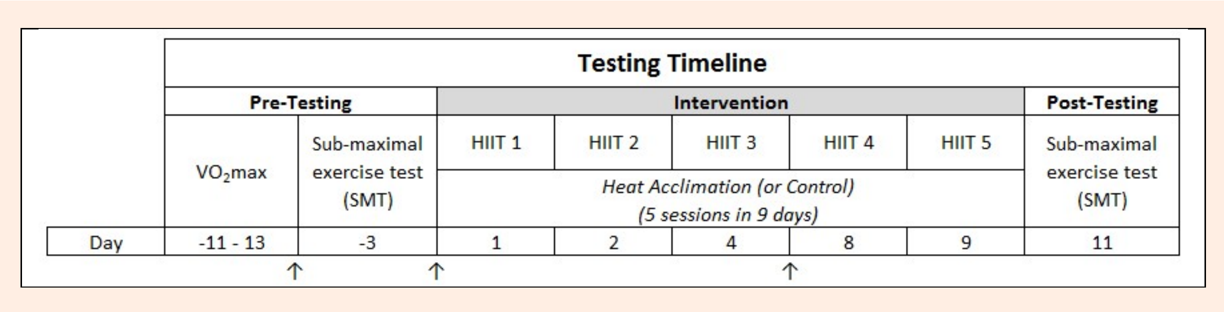

Figure 1. Experimental protocol and testing timeline related to a short duration high intensity interval training program (five 27 min sessions in 9 days) in the heat (temperature = 38.7 ± 0.5 °C, relative humidity = 34.4 ± 1.3 %) or at room temperature (22.3 ± 0.2 °C; 35.8 ± 0.6 %). ↑ denotes competition on the weekend.

a decrease in core temperature and the perceptions of thermal comfort were improved to a similar extent in both the acclimation and control groups.

Based on results obtained from non-elite field sport athletes (Brade et al., 2013, Petersen et al., 2010, Sunderland et al., 2008), and the known time and training constraints which impose on professional AF players, the present study aimed to determine if five sessions of very short duration (27 min each; total exposure time 135 min), high intensity, interval training (HIIT) in the heat (~39 °C; 34% RH) over a nine day period would induce heat acclimation in professional male AF players during an actual competitive season. The research rationale was to assess the efficacy of a time-efficient training protocol to pre-acclimatize to heat without travelling to the competition venue in advance.

Methods

This study employed a mixed (between and within group) three factor experimental design. In brief, a group of professional footballers were recruited and subsequently matched for relative aerobic fitness then randomly allocated to either a heat acclimation (Acc) or control (Con) group (between group factor – condition). Both groups performed five sessions of HIIT in a nine day period during the football season with the Acc group training in hot conditions, whilst the Con group trained at room temperature (within participants factor – training). Prior to, and after HIIT, all participants performed a standard 30 min submaximal continuous exercise test in the heat in order to compare changes in the thermoregulatory and perceptual responses at various time points throughout the test within and between the groups (within participants factor – time). Similarly, comparisons between session 1 and session 5 of HIIT were also made between and within the groups. Figure 1 provides an overview of the experimental design.

Participants

Fourteen male, professional AFL or Victorian Football League (VFL) players participated in this study. Inclusion criteria required that all participants played competitive football during the study period. Eight of the participants played a minimum of two AFL matches during the study period. All participants had a professional training history of at least two years. The participant characteristics of each group are reported in Table 1. Experiments were conducted from May to August in southern Australia (temperature and relative humidity averages of 16ºC and 76%, respectively; Australian Bureau of Meteorology) during the competitive season. The research was approved by Deakin University Human Research Ethics Committee (Project Number 2013-060) and all participants provided their informed consent.

Procedures

Initially, participants performed an incremental cycling test to volitional exhaustion to determine VO_2peak at room temperature using a metabolic system (Cortex Metamax, Germany). This test was performed after a scheduled rest day and was used to match participants for relative VO_2peak ($mL·kg^{-1}·min^{-1}$) and to calculate target work rates for subsequent submaximal exercise testing and HIIT. Participants were then randomly allocated to either heat acclimation (Acc) or control training (Con) groups.

Submaximal exercise test

All participants cycled for 30 min at approximately 60% VO_2peak on an electronically braked cycle ergometer

Table 1. Participant characteristics of the Control (Con) and Acclimation (Acc) groups. Values are mean (± SD) (95% CI).

	Con Group (n = 7)	Acc Group (n = 7)	P-value	ES
Age (years)	21.7 (2.8) (19.2-24.3)	20.6 (2.2) (18.6-22.6)	.40	.44
$\dot{V}O_2$peak ($mL·kg^{-1}·min^{-1}$)	48.7 (6.9) (42.3-55.0)	48.1 (5.5) (43.0-53.2)	.86	.10
Body mass (kg)	90.1 (6.6) (84.0-96.2)	89.4 (5.0) (84.8-94.0)	.82	.12
Height (m)	1.89 (.07) (1.83-1.95)	1.90 (.04) (1.86-1.94)	.68	.23

Con: Control, Acc: Acclimation. ES: effect size.

(Lode Cycle Ergometer, Lode, Netherlands) in hot, dry conditions (mean ± SD, [95% confidence interval]; 37.9 ± 0.7 [37.8-38.1] °C; 28.5 ± 7.0 [27.3-29.8] % RH). This submaximal test (SMT) was undertaken 1 week following the initial VO_2peak test, and 2 days after the final HIIT session. There were no differences in environmental temperature ($p = 0.95$) or %RH ($p = 0.85$) between the Acc and Con groups, nor were there differences in the conditions (temperature, $p = 0.70$; %RH, $p = 0.20$) during the SMT pre and post HIIT. Participants cycled in shorts and wore a chest harness, required to secure the core temperature receiver (Equivital, Cambridge, UK) and HR monitor (Polar, Finland).

In the heat room, four 1800 W bar radiators (Gasmate Electric Heater EH420, Australia) were positioned 1.8 m from the cycle ergometers. Four portable humidifiers (Vaporaire Steam Vaporizer, BOC, Australia) were located on the floor near the wall where the radiators were mounted. The room also had a split-system heater (Fujitsu Plasma Air Conditioner Inverter, Japan) mounted on the opposite wall. Environmental conditions were measured periodically using a portable weather monitor (HT30, Extech, USA) positioned in the centre of the room at cycle seat height.

Twenty four hours prior to each submaximal cycling test, participants followed a similar diet, abstained from alcohol and caffeine consumption and completed team training as prescribed (similar within and between groups on any given day). Two hours prior to the submaximal test, participants ingested a core temperature pill (VitalSense, MiniMitter Co, Oregon, USA) with a small meal. During submaximal cycling, core temperature, HR, skin temperatures at four different sites (chest, forearm, thigh and calf; iButton, Thermodata, QLD), rating of perceived exertion (RPE) on a scale of 1-10 (Borg and Kaijser, 2006) and thermal comfort on a scale of 0-8 (Young et al., 1987) were measured at 5 min intervals. Mean body temperature was calculated using the formula from Schmidt and Bruck (Schmidt and Bruck, 1981). Mean skin temperature was calculated as described by Ramanathan (Ramanathan, 1964). Capillary blood was taken from a fingertip prick every 10 min during exercise and immediately analysed for blood [Lac-] (Lactate Pro, Arkray, Japan). Oxygen consumption and respiratory exchange ratio (RER) were measured during the submaximal test at 6-8 min and 16-18 min using a metabolic system (Cortex Metamax, Germany) and the data averaged over this time period. Immediately before and after the SMT, body mass was measured in kg to the nearest 5 g (PW 200, Evocare, Australia), with change in mass used to calculate sweat loss. No fluid was consumed during the test.

About 30 min prior to each submaximal test, 4 ml of blood was extracted from an antecubital forearm vein after sitting for 10 min, via a 21 gauge needle. Blood was collected into a Vacutainer (B2 K2EDTA Vacutainer, Becton Dickinson), gently rolled, and transported on ice to a commercial pathology laboratory (Pathcare Pty Ltd) for analysis of haemoglobin (Hb) concentration and haematocrit (Hct) in order to calculate changes in plasma volume (Dill and Costill, 1974). Each participant provided a mid-stream urine sample upon waking on the morning prior to each submaximal test in order to determine urine specific gravity (USG) (Atago Pocket Refractometer, Japan). Regardless of body height or mass, participants were also instructed to drink 1-1.5 L of water periodically over ~2 h prior to each submaximal exercise test.

High intensity interval training

Three days following the first submaximal exercise test, participants began HIIT on an air-braked cycle ergometer (Wattbike, Nottingham, UK) either in the heat (Acc) or in thermo-neutral conditions (Con). The HIIT involved five sessions in a nine day period (i.e., two sessions on consecutive days, one day off, one session, three days off and finally two sessions on consecutive days). This training occurred in addition to the prescribed football training sessions and official AFL and VFL matches which occurred in the middle of the 9 day protocol during the 3 days off. Participants in the Acc group completed training in hot, dry conditions (38.7 ± 0.5 [38.5-39.1] °C; 34.4 ± 1.3 [31.9-36.9] % RH) within the heat room. The control group performed identical training in cooler conditions (22.3 ± 0.2 [22.0-22.7] °C; 35.8 ± 0.6 [34.6-37.0] % RH) (HT30, Extech, USA). Environmental conditions were measured periodically during each HIIT session.

The HIIT protocol began with a 3 min warm up at 60% VO_2 work rate peak on a cycle ergometer (Wattbike, Nottingham, UK). This was followed by 3 x 5 min work periods with alternating intervals of 30 s at 90% and 30% VO_2 work rate peak. Between each 5 min period of work a 3 min active recovery was completed at 50% VO_2 work rate peak. The actual work rate achieved during each HIIT session was recorded and downloaded from each Wattbike and averaged per minute. The total time of each HIIT session was 27 min. Participants were not allowed to consume fluid during any of the HIIT sessions.

On the first and fifth HIIT sessions (days one and nine respectively), core temperature, skin temperatures at three sites (chest, forearm, and thigh), HR, thermal comfort and RPE were measured as previously described at 8, 16 and 24 min in the Acc and Con. Mean skin temperature could not be calculated for the HIIT sessions as insufficient skin temperature sites were measured. In the 24 h prior to these sessions, participants were instructed to abstain from alcohol and caffeine consumption, and completed similar team training as prescribed.

Statistical analyses

Descriptive data for each group were expressed as mean ± standard deviation (SD) and analysed using two sample t-tests. The remaining data were expressed as mean ± SD, 95% confidence intervals (95% CI) and effect size when comparing two means (ES, Cohen's d - ≥0.2 small, ≥0.5 moderate, ≥0.8 large effect; (Cohen, 1988)) or partial eta^2 (effect size, 0.01 small, 0.06 medium, 0.14 large) generated from the ANOVA analysis involving multiple mean comparisons. A priori power analysis revealed the need for a sample size of 10 per group during the SMT to detect an effect size of 0.25 for the condition by training interaction at a power of 0.8 with a correlation of 0.5 between repeated measures (Faul et al., 2007). High

Table 2. **Core temperature (°C) during 30 min of continuous submaximal cycling exercise (SMT) in the heat and during session 1 and session 5 of high intensity, interval training (HIIT) in room temperature (Con) or hot (Acc) conditions. Values are (mean ± SD) (95% CI).**

	Con Group		Acc Group	
	Resting	**End Exercise**	**Resting**	**End Exercise**
SMT Pre HIIT[a]	37.0 (.2) (36.6-37.4)	38.3 (.2) (38.0-38.7)	36.9 (.3) (36.7-37.1)	38.3 (.3) (38.1-38.5)
SMT Post HIIT	36.7 (.4) (36.2-37.3)	38.1 (.4) (37.6-38.6)	37.0 (.3) (36.8-37.2)	38.2 (.3) (38.0-38.4)
HIIT 1[b]	36.9 (.3) (36.6-37.3)	37.8 (..5) (37.4-38.1)	36.8 (.8) (36.1-37.4)	38.0 (.5) (37.5-38.4)
HIIT 5	37.1 (.3) (36.7-37.4)	37.9 (.5) (37.4-38.3)	37.0 (.3) (36.7-37.3)	38.0 (.3) (37.7-38.4)

n = 7 per group (HIIT), n = 7 Acc and n = 5 Con (SMT). Acc: acclimation, Con: Control. [a] significant main effect for time (p = 0.000; partial eta^2 = 0.97). [b] significant main effect for time (p = 0.000; partial eta^2 = 0.92).

intensity interval training and submaximal exercise data were analysed using a three factor mixed ANOVA (group x pre/post-test x time) (Field, 2009). When ANOVA identified a significant difference, simple main effects post-hoc analyses were used to identify where the differences occurred. Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 21.0 (SPSS, Inc., Champaign, IL) and statistical significance was set at $p \leq 0.05$.

Results

There was a group x time interaction (p = 0.04, partial eta^2 = 0.30) for core temperature during HIIT (Table 2), however post-hoc analysis did not reveal any significant differences. Acc displayed higher (group x time interaction; p = 0.003, partial eta^2 = 0.50) chest skin temperatures compared with Con at all times during the HIIT sessions, irrespective of training day. Both forearm and thigh skin temperatures were also higher during the HIIT sessions in Acc compared with Con (main effect for group for both forearm and thigh skin temperatures; both p < 0.001, partial eta^2 = 0.73 for forearm and 0.91 for thigh skin temperatures).

Heart rates during HIIT were higher from 16 min (p = 0.012) on both session one and five within Acc compared to Con (Figure 2A; group x training x time interaction; p = 0.05, partial eta^2 = 0.23). After 26 min, HIIT session five heart rate in Acc remained higher (p = 0.007) than both days in Con, but was also higher than Acc session one response (Figure 2A). Rating of perceived exertion was reduced with HIIT in the heat (group x training interaction; p = 0.044, partial eta^2 = 0.30). Mean RPE in Acc was lower on session five when compared to session one of HIIT, whilst mean Con RPE was not different between days of training (Figure 2B). Thermal comfort (group x training x time; p = 0.05; partial eta^2 = 0.25) was also lower during the initial stages of HIIT in Acc on session five compared with session one (Figure 2C). Towards the end of the HIIT sessions, rating of thermal comfort was higher (p = 0.002) in Acc on both days compared to Con (Figure 2C).

Mean relative exercise intensities throughout SMT were similar across Acc and Con (Acc: 61.2 ± 6.1 [60.0-63.9] %VO_2peak vs Con: 65.5 ± 4.9 [63.6-67.1] %VO_2peak; p = 0.18, partial eta^2 = 0.14). There were no significant interaction effects ($p \geq 0.08$, partial eta^2 $\leq$ 0.26) for mean skin, body or core temperatures during

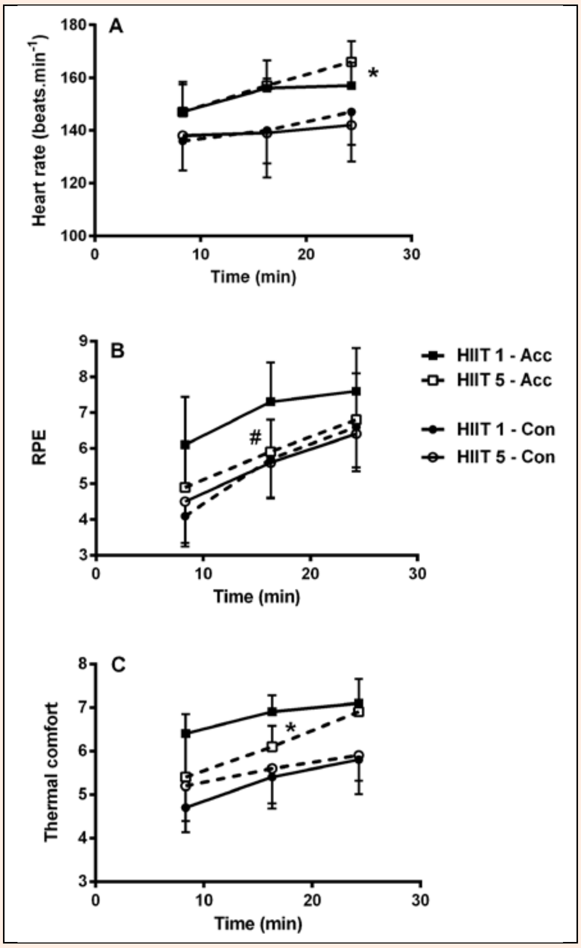

Figure 2. **Heart rate (A), rating of perceived exertion (B) and rating of thermal comfort (C) during session 1 and session 5 of high intensity interval training (HIIT 1 and HIIT 5) in the Acc group who performed exercise in the heat (temperature = 38.7 ± 0.5 °C, relative humidity = 34.4 ± 1.3 %) and Con who exercised at room temperature (22.3 ± 0.2 °C; 35.8 ± 0.6 %).** Values are mean ± SD, n = 7 per group. Difference between HIIT 1 and HIIT 5 at the corresponding time point within the Acc group, * p < 0.05. Mean rating of perceived exertion (RPE) during HIIT 1 in Acc is different from HIIT 5 in Acc, # p < 0.05. Acc: acclimation, Con:control.

SMT in the heat. Furthermore there were no main effects for group or training ($p \geq 0.36$, partial eta^2 ≤ 0.10) for any of these temperature variables, except for a group main effect for mean skin temperature. Mean skin temperature was higher in Con (35.0 ± 0.2 [34.8-35.2] °C) compared with Acc (34.3 ± 0.3 [34.1-34.5] °C; $p = 0.02$, partial eta^2 = 0.50). There was a group x training interaction ($p = 0.03$, partial eta^2 = 0.43) for the increase in mean skin temperature (30 min – 5 min values) during the submaximal cycle test. Mean skin temperature tended to be lower after training in the heat (pre Δ 1.9 ± 1.1 [0.8-3.0] vs post Δ 0.6 ± 1.6 [-0.8-2.1] °C; P=0.06), but not after training in thermo-neutral conditions (pre Δ 0.8 ± 0.2 [0.4-1.2] vs post Δ 1.5 ± 0.4 [0.8-2.1] °C; $p = 0.23$). There were no differences observed in sweat rate (Acc: pre 1.4 ± 0.5 [0.9-1.8] vs post 1.2 ± 0.4 [0.8-1.6] L.min^{-1}; Con: pre 1.5 ± 0.6 [0.9-2.1] vs post 1.4 ± 0.3 [1.0-1.7] L.min^{-1}) between groups (Acc vs Con, $p = 0.54$, partial eta^2 = 0.04) or training (pre vs post, $p = 0.27$, partial eta^2 = 0.11).

High intensity interval training resulted in a decrease in HR during the submaximal cycling tests in the heat, irrespective of whether HIIT was conducted in hot or thermo-neutral conditions (main effect for training ($p = 0.007$, partial eta^2 = 0.50 and time $p < 0.001$, partial eta^2=0.94) (Figure 3A and 3B). Rating of perceived exertion was decreased throughout submaximal exercise in the heat after acclimation, but remained unchanged in Con (group x training x time; $p = 0.02$, partial eta^2 = 0.25 (Figure 3C and 3D). Mean thermal comfort was lower (group x training interaction; $p = 0.03$, partial eta^2 = 0.35) after heat acclimation, but was higher in Con after HIIT (Figure 3E and 3F). High intensity interval training decreased RER during submaximal cycling tests in the heat, irrespective of the environmental conditions in which HIIT was conducted (Acc: pre- 0.99 ± 0.05 [0.95-1.03], post- 0.97 ± 0.05 [0.92-1.01]; Con pre- 0.99 ± 0.04 [0.96-1.03], post- 0.96 ± 0.04 [0.92-1.00]) (main effect for training, $p = 0.04$, partial eta^2 = 0.32). In contrast, after 30 min of submaximal exercise blood [Lac-] was reduced (group x training interaction; $p = 0.03$, partial eta^2 = 0.34) only after HIIT in the heat (4.3 ± 1.1 [3.4-5.1] pre-Acc vs 2.8 ± 0.5 [2.4-3.2] mM post-Acc; $p < 0.000$; 3.5 ± 0.7

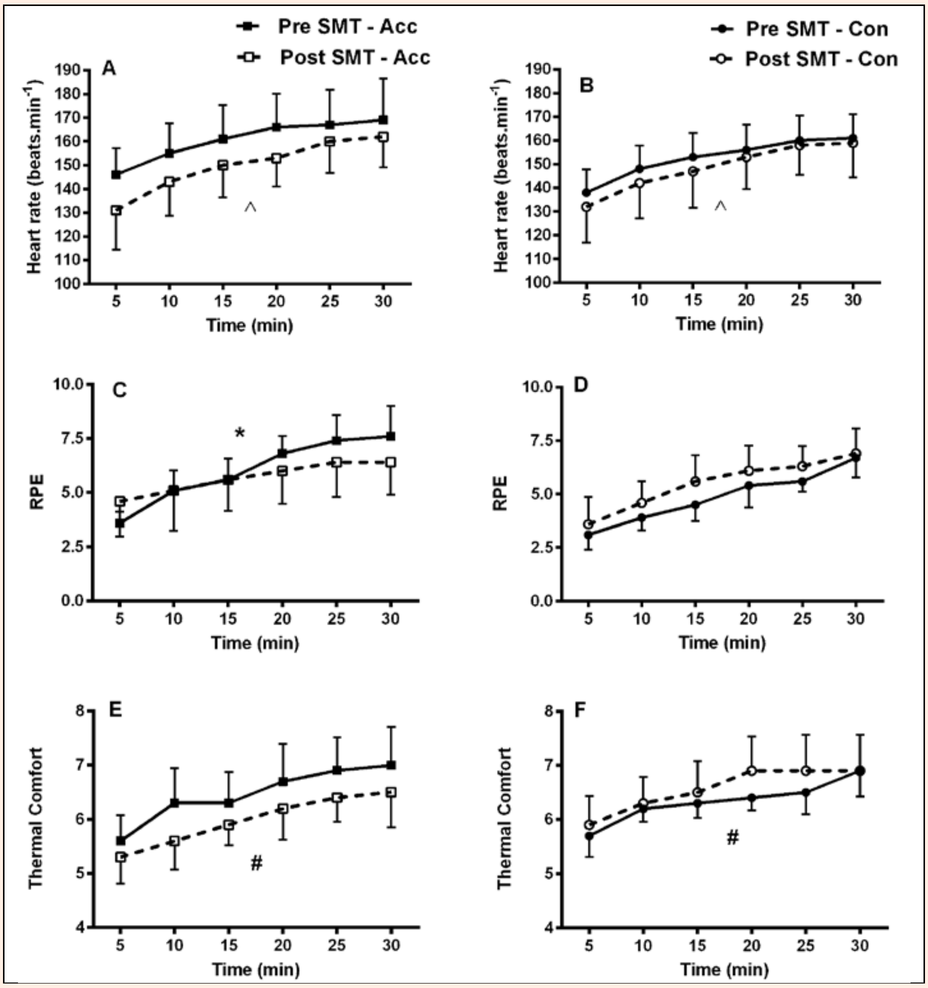

Figure 3. Heart rate (A,B), rating of perceived exertion (C,D) and thermal comfort (E,F) during 30 min of continuous submaximal cycling exercise (SMT) at approximately 60% VO_2peak in hot conditions before (pre) and after (post) 5 sessions of high intensity interval training (HIIT) in the heat (Acc; temperature = 38.7 ± 0.5 °C, relative humidity = 34.4 ± 1.3 % or Con: 22.3 ± 0.2 °C; 35.8 ± 0.6 %). Values are mean ± SD, n = 7 per group except for heart rate where n = 6 for Con. Main effect for training, ^ $p < 0.05$. Difference between pre and post training at all corresponding time points within the Acc group, * $p < 0.05$. Mean rating of thermal comfort during pre is different from post training within both Acc and Con groups, # P <0.05. Acc: acclimation, Con: control, HIIT denotes high intensity interval training.

[3.0-4.0] pre-Con vs 4.0 ± 0.7 [3.3-4.6] mM post-Con; $p = 0.17$). Finally, there were no differences ($p = 0.75$, ES = 0.17) in the percentage change in plasma volume between the Acc (3.1± 7.1% [-3.6-9.9]) and Con (1.8 ± 7.1% [-6.1-9.6]) groups following HIIT, nor were there any differences observed for USG measured prior to each of the submaximal exercise tests (group x time interaction $p = 0.57$, partial $eta^2 = 0.03$, data not shown).

Discussion

A short duration (27 min) intense interval heat training protocol elicited significant decreases in RPE and thermal comfort during HIIT and submaximal cycling exercise in the heat. Additionally, blood [Lac-] was reduced and the rate of rise of mean skin temperature in the Acc group tended to be reduced during submaximal continuous cycling exercise in the heat. Therefore this study demonstrates that short duration HIIT in the heat induces some signs of heat acclimation in professional AF players. Training in the heat however did not induce changes in core or mean skin temperatures during either the SMT or HIIT. A HR training response was identified during submaximal exercise after HIIT, irrespective of environmental conditions.

Results detailed within the current research are mostly consistent with that reported by Petersen et al. (2010) who utilised a four consecutive day, intensive cycling acclimation protocol in male club cricketers. They found moderate reductions in HR, improved sensations of thermal comfort and small reductions in blood lactate during 30 min of submaximal treadmill running in the heat, without a decrease in core temperature in either the intervention or control groups. Similarly Sunderland et al. (Sunderland et al., 2008), who utilised a non-consecutive ten day HIIT regime, reported reductions in thermal comfort for the intervention group after training in the heat.

In contrast to the current research, a reduction in core temperature was identified in team sport athletes when performing high intensity intermittent exercise after completing short-duration high intensity, interval acclimation training sessions (Brade et al., 2013; Sunderland et al., 2008). It is not clear why core temperature did not decrease in the present study during either the HIIT sessions or submaximal exercise. A possible reason for the conflicting finding is that core temperature was elevated >1ºC above basal, as recommended by Taylor (Taylor, 2000) in order to optimally drive the heat acclimation process, for only approximately 15 min in total across the five HIIT sessions in the heat. This may have been an insufficient time period to induce the necessary thermoregulatory adaptations required to decrease core temperature. Similarly, fluid restriction has been demonstrated to enhance heat acclimation (Garrett et al., 2014), however it is unlikely that the 27 min HIIT session was long enough to induce sufficient dehydration for this to occur. It should also be noted that the end-exercise core temperature in the training sessions was only ≤0.2°C different between the groups (Table 2). This small difference in core temperature suggests that the stimulus for heat adaptation was not markedly different between the groups and may also explain why no decrease in core temperature was observed in the Acc group after HIIT. Finally, it is possible that we failed to detect a decrease in core temperature following heat acclimation due to the small sample size.

The reduction in blood lactate concentration during submaximal exercise after short-duration intense heat acclimation has been previously observed (Petersen et al., 2010) and suggests a reduction in glycolytic contribution from the contracting muscle, which is also known to occur with more traditional heat acclimation protocols (Febbraio et al., 1994). Additionally, the reduction in RER irrespective of group, suggests that HIIT in both hot and thermo-neutral conditions is successful at reducing aerobic muscle glycogen utilisation and a shift towards a greater rate of lipid oxidation during submaximal exercise (Lorenzo et al., 2010). Although the precise mechanisms causing the reduction in blood lactate concentration and RER is /are unclear, previous research suggests that the change is at least in part due to a decrease in sympatho-adrenal activation and circulating catecholamines levels (Febbraio, 2001), an adaptation known to occur with only three consecutive days of heat exposure (Febbraio et al., 1994; Hodge et al., 2013). The interpretation of findings is made difficult as many of the adaptive responses associated with high intensity interval training are also observed during heat acclimation. In terms of energy metabolism, these include both oxidative and non-oxidative changes. For example, the change in RER in both groups illustrates the influence of training on oxidative substrate utilisation, while intramuscular lactate production seems only to have been influenced by repeated heat exposure (Febbraio, 2001).

Although speculative, the reductions in RPE and perceptions of thermal stress observed with partial heat acclimation may be expected to enhance subsequent exercise performance in the heat given these perceptual indicators are typically used by an athlete as cues to select and/or modify exercise intensity and/or duration to avoid impending fatigue (Noakes, 2012; Chalmers et al., 2014). In AF, players are known to reduce low intensity activity and overall running volume during matches played in hot conditions, likely a result of changes in the perception of thermal load and an anticipatory pacing strategy to maintain high intensity activity (Aughey et al., 2014). In support of the concept that partial acclimation may provide some benefits for subsequent exercise in the heat, Nielson et al. (Nielsen et al., 1993) reported improvements in endurance exercise performance in the heat in most participants during the first few days of heat acclimation. Furthermore, the four day HIIT heat acclimation protocol used by Sunderland et al. (Sunderland et al., 2008) resulted in an improvement in intermittent running exercise capacity in hot environmental conditions. Clearly, further research is required to ascertain whether partial heat acclimation, as induced in the current study, could lead to exercise performance benefits for elite field team sport athletes.

Conclusion

In conclusion, short duration HIIT in the heat can induce only partial heat acclimation in professional male AF players. The five 27 min non-consecutive intense interval sessions in the heat, designed specifically to be incorporated into an in-season competition phase program, resulted in reductions in RPE, thermal comfort and blood lactate during the continuous submaximal exercise test. Failure to see any change in core temperature was likely dependent on the inability to rapidly elevate and maintain a high enough core temperature for a sufficient period of time during the acclimation sessions. While the heat acclimation protocol employed in this study was able to be implemented in a professional team sport environment during an actual competitive season, modifications to the protocol such as longer or more heat training sessions or some form of pre-heating prior to exercise in the heat (González-Alonso et al., 1999) may be required to achieve effective acclimation in preparation for competition in a hot environment.

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Key points

- Some minor heat acclimation adaptations can be induced in professional AF players with five 27 min non-consecutive, short duration HIIT sessions in the heat.
- The heat acclimation protocol employed in this study was able to be implemented in a professional team sport environment during an actual competitive season.
- Elevating and maintaining a high core temperature sufficient for heat acclimation likely requires a longer heat training session or some pre-heating prior to exercise.

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