THE UNIVERSITY OF HULL

Effectiveness of short-term heat acclimation on intermittent performance in cold and hot environments

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by

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ABSTRACT

Introduction: It is well-established that repetition of heat stress exposure has been shown to facilitate adaptations to the heat but these protocols have tended to be of a fixed work intensity, continuous exercise, long-term in duration (>7 days) and use hydration. Secondly, there is limited information on the potential use of heat acclimation as a training method for human performance in cool/thermoneutral conditions (Corbett, Neal, Lunt, & Tipton, 2014). Therefore, the aims of this study were to investigate the effectiveness of short-term heat acclimation (STHA) for 5 days, using the controlled-hyperthermia technique with dehydration, on intermittent exercise in cool and hot environments. **Methods:** Ten, healthy, active, moderately-trained males (Mean (SD); Age 25.6 (8.9) yrs; Height 180.7 (5.6) cm; Body Mass 83.2 (10.8) kg; 45.3 (6.5) mL.kg-1.min-1 and resting cardiac output 6.3 (1.8) L.min-1), participated in a STHA programme. This consisted of 90 minutes dehydration heat acclimation (no fluid intake) for 5 consecutive days (39.5°C; 60% RH), using the controlled-hyperthermia technique (~rectal temperature [Tre] 38.5°C) (Garrett et al., 2014). The pre and post testing Exercise Stress Test (EST) consisted of 45 minutes of intermittent exercise (nine phases of 5 minutes). Including resting, walking, moderate and high intensity running) on a motorised, h/p Cosmos treadmill; and nine 6 second (s) maximal sprints on a Watt Bike, as a repeated, maximal sprint performance test. The EST was followed by a running, incremental test to exhaustion. This EST intermittent protocol was adapted from exercise intensities of professional football players (Drust, Reilly, & Cable, 2000). The EST was repeated in controlled conditions (Con; 11°C 45% RH); pre and post STHA in cool (C; 11°C 45% RH) and hot environments (H; 35°C 45% RH). Data analysis was by paired t-test. Reported as the mean differences with 95% confidence intervals (95%CI) and Cohen's d effect size for magnitude of change (ES; Where 0.2-0.6 small; 0.6-1.2 moderate; 1.2-2.0 large; 2.0-4.0 very large). **Results:** Post STHA, in the H trial at 45-min there was a decrease in Tre by -0.2°C (95%CI: -0.40 to 0.00°C; p=0.03; ES= -0.56), cardiac frequency (-3: -5 to -1 b.min-1; p=0.01; ES= -0.20) and RPE (-2: -3 to -1 units; p=0.01; ES=-0.56). Mean average power (MavP) increased in sprints 7 (111: 25 to 197 W; p=0.01; ES=0.93) and 9 (240: 9 and 489 W; p=0.04; ES=0.77). The increase in Sprint 8 (87: -8 to 182 W; p=0.06; ES=0.52) and time to exhaustion (208: -24 to 439 s; p=0.06; ES=0.63) were close to significance. In the C trial, increased MavP for sprint 9 (67: 2 to 131 W; p=0.04; ES=0.47) and time to exhaustion (43: 1 to 85 s; p=0.04; ES=0.32) were reported. There was limited change in the Con conditions across all nine sprints (p>0.05) and for time to exhaustion (-31: -72 to 11 s; p=0.12; ES=-0.18). **Discussion:** Short-term heat acclimation (5 days) with dehydration, using the controlled-hyperthermia technique, is effective for physiological adaptations during intermittent exercise in a hot environment. Furthermore, it has resulted in an increase in intermittent and endurance exercise performance in hot and cool conditions. **Conclusion:** Short-term heat acclimation is effective for intermittent exercise in the heat. It may be a useful training method for human performance in cool conditions.

PREFACE

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LIST OF ABBREVIATIONS

RH   Relative humidity [%]

T_a Ambient Temperature [$^{\circ}$C]

$\bar{T}_b$ Mean body temperature [$^{\circ}$C],

T_c Core temperature [$^{\circ}$C]

T_{re} Rectal temperature [$^{\circ}$C]

$\bar{T}_{sk}$ Mean skin temperature [$^{\circ}$C]

PV   Plasma volume [mL·kg^{-1}]

$\dot{Q}$ Cardiac output [L·min^{-1}]

V_S Stroke volume [mL]

$\dot{Q}_{sk}$ Skin blood flow [mL·min^{-1}]

f_c Cardiac frequency [b·min^{-1}]

$\dot{V}O_2$ Oxygen consumption [L·min^{-1}or mL·kg^{-1}·min^{-1}]

$\dot{V}O_{2\,max}$ Maximum oxygen uptake [L·min^{-1}or mL·kg^{-1}·min^{-1}]

STHA   Short-term heat acclimation (5 days)

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1. Introduction

Exercising in hot conditions induces thermoregulatory and physiological strain which can impair exercise endurance, exercise capacity and reduce optimal performance (Chalmers, Esterman, Eston, Bowering, & Norton, 2014; Racinais et al., 2015). The thermoregulatory responses associated with exercising in the heat include; increased thermal strain, i.e. increased exercising cardiac frequency (f_c), elevated core (T_c) and skin temperatures (T_{sk}) and a higher rate of perceived exertion (RPE), thirst and sweat loss leading to dehydration (Chalmers et al., 2014; Guy, Deakin, Edwards, Miller, & Pyne, 2015; Racinais et al., 2015). Therefore, it is important to prepare for exercising in hot conditions. It is well-established that repetition of heat stress exposure facilitates adaptations to the heat (Garrett, Goosens, Rehrer, Patterson, & Cotter, 2009), termed heat acclimation (artificial environment) or acclimatisation (natural environment). Heat acclimation can take up to 14 days for near complete cardiovascular and sudomotor adaptations (Racinais et al., 2015). However, it had been shown that 75% of physiological adaptations occur within 4-6 days, such as, decrease in exercising f_c, T_c, T_{sk}, increase in sweat rate and work capacity (Racinais et al., 2015). Many of the studies, looking at the effect of heat acclimation on performance, protocols have tended to be of a fixed work intensity, continuous exercise, long-term in duration (>7 days) and use hydration, allowing subjects to intake fluid during the heat acclimation period.

Secondly, there is limited information on the potential use of heat acclimation as a training method for enhancing human performance in cool/thermoneutral conditions (Corbett et al., 2014; Lorenzo, Halliwill, Sawka, & Minson, 2010). Therefore, the aims of this study were to investigate the effectiveness of short-term heat acclimation

(STHA) for 5 days, using the controlled-hyperthermia technique with dehydration, on intermittent exercise in cool and hot environments.

1.1 Exercising in the heat

Heat stress is a combination of heat-related factors, both internal and external, that work on the body. Heat strain is how the body responds to heat stress and can be affected by an individual's level of aerobic fitness and hydration state (Sawka et al., 1992) . During prolonged exercise in hot environments, human homeostasis is challenged, and potentially may be threatened, as one moves from a compensable state, where thermoregulation is effective and thermal steady state can be achieved, through to uncompensable heat state, where thermoregulation is overruled and thermal steady state cannot be achieved (Kraning & Gonzalez, 1991; Taylor, 2000). This transition is dependent on many factors; air temperature and its water vapour pressure, exercise intensity, clothing and its permeability, body composition, hydration status, fitness status and state of heat adaptation (Taylor, 2000). Heat stress can serve as great challenge to the cardiovascular system (González-Alonso, Crandall, & Johnson, 2008). The demand of blood flow is one of the main causes of cardiovascular strain. Active muscles rely on blood flow, primarily for oxygen, to meet the energetic demands for muscular activity, while blood flow to the skin is required for temperature regulation (González-Alonso et al., 2008). Both these demands of blood flow compete for the available cardiac output ($\dot{Q}$). A reduction in blood flow to working muscles limits the intensity and duration of exercise, while reduced skin blood flow decreases heat dissipation, elevating T_c, with adverse effects (González-Alonso et al., 2008). Studies by Rowell, O'Leary, and Kellogg (1996) and Mortensen et al. (2005) showed that $\dot{Q}$ and muscle blood flow increased linearly in small muscle exercise to exhaustion. However, in whole-body exercise (e.g. cycling, running) there was a reduction in the

rate of rise in leg muscle blood flow and oxygen delivery during exercise above 50%

$\dot{V}O_{2\,max}$, and a plateau in $\dot{Q}$ above 90% $\dot{V}O_{2\,max}$ with a levelling off in limb muscle and

systemic vascular conductance (Mortensen et al., 2005). Studies looking at skin blood

flow and vasoconstriction in active muscles (González-Alonso, Calbet, & Nielsen,

1998; Nielsen, Savard, Richter, Hargreaves, & Saltin, 1990) found no measurable effect

of extreme body heating on blood flow to active muscles. Therefore, concluding when

exercising in the heat, muscle blood flow demands are met over skin blood flow

(González-Alonso et al., 2008). However, hyperthermia, due to lack of skin blood flow,

can negatively affect muscle blood flow and performance.

Exercising in a hot environment for prolonged periods of time, without appropriate fluid

replenishment, results in significant dehydration along with progressive reductions in

$\dot{Q}$. A 4% loss of body weight, due to dehydration, during moderate exercise in the heat

can result in reductions in systemic, muscle and skin blood flow, an increase in T_c and

muscle temperature and supressed exercising muscle $\dot{V}O_2$ at exhaustion

(González-Alonso et al., 1998; González-Alonso, Calbet, & Nielsen, 1999; Sawka,

Knowlton, & Critz, 1978). A reduction of ~4 L.min^{-1} in $\dot{Q}$ results in a reduction in

active muscle blood flow, however this does not appear to be the primary factor in the

onset of fatigue in hot environments (González-Alonso et al., 2008). Muscle oxygen

delivery can be maintained for most part of prolonged moderate exercise in the heat,

with active muscle $\dot{V}O_2$ being depressed only at exhaustion (González-Alonso et al.,

1998). Instead, studies have shown a common factor of fatigue when exercising in the

heat, elevated core temperature (T_c). Studies have found fatigue to occur at T_c ~40°C,

despite initial T_c, rate of heat storage or mean skin temperature ($\bar{T}_{sk}$) (González-Alonso

et al., 2008). During exercise skin blood flow appears to reach an upper limited at T_c

~38°C, roughly 50% of maximal blood flow, as T_c increases above this threshold, skin blood flow fails to increase (González-Alonso et al., 1999).

 The first week of exercising in the heat is the most critical, as the threat of heat illness, such as heat stroke, heat exhaustion and heat cramps (Chen, Tsai, Lin, Lee, & Liang, 2013), is at its greatest and both worker and athlete performance is impaired (Taylor, 2000). Exercising in the heat has been shown to reduce $\dot{V}O_{2\,max}$ relative to the level achieved in a moderate environment (Sawka, Young, Cadarette, Levine, & Pandolf, 1985). However, over time the body will adapt to tolerate the heat by a three-phase adaptation (Candas, 1987; Taylor, 2000). According to Candas (1987) there are three distinct phases for adapting to heat; (i) acute phase, elevation of body-temperature, (ii) short-term acclimation, sweat response is enhanced, (iii) long-term acclimation, resulting in improved sweat efficiency and sudomotor habituation. Both the cardiovascular changes and sudomotor adaptations help minimise the effects of heat and exercise stress on thermal homeostasis, resulting in reduced physiological strain and a higher heat tolerance (Taylor, 2000). These changes combined allow for a greater heat flow from the core to active muscles and the skin, greater dissipation of this heat through sweating, resulting in lower T_{sk} and $T_{c,}$ for both exercise and heat stress (Taylor, 2000). Sweating is the most effective way of removing heat from the body. When the body becomes heat acclimated, the sweating response increases, cooling the body more efficiently when exercising in the heat (Taylor, 2000). This is due to an increase in steady-state sweat rate, increased sweat gland sensitivity relative to changes in body temperature and a reduced body temperature threshold for the onset of sweating (Taylor, 2000). These adaptations may also be found in endurance trained athletes, even when training in cool environments however the adaptations are of a lesser scale than training in the heat (Taylor, 2000). These sudomotor adaptations, however beneficial to the semi-clothes athlete, may not be as beneficial to workers wearing

protective but may instead elevate thermal discomfort, increase the risk of dehydration and have a negative effect on work performance.

Natural heat acclimatisation has been generally recognised as the most effective means in which to improve heat tolerance (Taylor, 2000), gradually adapting to the environment, however this is not always realistic or feasible for many occupational and sporting groups (Taylor, 2000). Therefore the use of heat acclimation (artificial means) has been widely used as a means of heat adaptation in preparation for work and exercise heat exposure. The physiological benefits of heat acclimation are of close approximation to those developed through natural acclimatisation (Taylor, 2000). With many events in World Championships, Olympic and Commonwealth games being held in hot environmental conditions (Sunderland & Nevill, 2005), it is important for athletes to train and adapt accordingly prior to competing.

1.2 Heat Acclimation

Repetitive heat exposure has been well-established in facilitating heat adaption and improving performance when exercising in the heat. Nielsen et al. (1993) investigated circulatory and thermoregulatory adaptations with heat acclimation and exercise in a hot, dry environment. The study involved eight subjects exercising until volatile exhaustion at 60% of $\dot{V}O_{2\,max}$ in hot conditions of 40°C, 10% relative humidity (RH), for 9-12 consecutive days, compared with five subjects performing the same exercise intensity for 90 min per day in a cool environment, 20°C. Nielsen et al. (1993) found an improved exercise capacity from the first to last day of heat acclimation, (48 min to 80 min) with a lower rate of rise in f_c, T_c, and increased sweating, with no changes seen in cool conditions between the first and last day. The major benefits of heat acclimation have been well defined (Garrett, Rehrer, & Patterson, 2011); these

include greater cardiovascular stability, such as a lower exercising f_c, decrease in T_c, T_{sk}, RPE and an increase in sweat rate and work capacity, when exercising in the heat. Heat acclimation can be short (<7 days), medium (8 – 14 days) or long-term (>15 days) in duration (Garrett et al., 2011). The physiological responses before and after heat acclimation are dependent on the length of exposure to heat stress with near complete cardiovascular and sudomotor adaptation occurring after 14 days of heat exposure (Racinais et al., 2015). However, long-term acclimation is not always feasible (Garrett et al., 2014), particularly for athletes competing in other countries. Therefore, short-term heat acclimation is beneficial for those looking to be acclimatised in the shortest time possible as 75% of the physiological adaptations have been shown to occur between 4 and 6 days of repetitive heat exposure (Racinais et al., 2015).

There are different methods that can be used for the heat acclimation protocol which include; constant work rate, self-regulated work-rate and the controlled-hyperthermia techniques (Taylor, 2000). Constant work rate involves subjects working at a fixed absolute rate and this is the most common technique used for military based research (Taylor, 2000). However this method is not without fault as there may be a large variability in the relative load placed on individuals and therefore physiological strain may vary widely between subjects (Taylor, 2000). Self-regulated work-rate allows subjects to exercise at their selected work rate, this is based on the individuals' physical fitness and RPE during the acclimation session (Taylor, 2000). With this method it is difficult to control the relative thermal load placed on participants, and has a greater practical use rather than research application (Taylor, 2000). The controlled-hyperthermia technique involves exercising to elevate and maintain a rectal temperature *(T_re)* of 38.5°C, this ensures equal thermal strain is placed on each participant (Taylor, 2000). The controlled-hyperthermia technique has been shown to provide a more

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complete heat adaptation than both the constant and self-regulated work-rate methods (Taylor, 2000).

The level of heat acclimation can be influenced by two factors; level of fitness and hydration status of the individual (Cheung & McLellan, 1998). Aerobically fit individuals possess similar attributes to heat acclimated individuals (Taylor, 2000). Cheung and McLellan (1998) found highly trained individuals more capable of tolerating high levels of heat stress compared to untrained individuals, with lower resting and higher end exercise T_{re} than untrained individuals. Also fit individuals are believed to adapt more rapidly to heat acclimation than those with low or moderately fitness levels, however low or moderately fit individuals may experience a greater benefit from heat acclimation (Cheung & McLellan, 1998). Shvartz et al. (1977) investigated the adaptations of heat acclimation on trained (VO_{2max} of 57-65 mL.kg^{-1}.min^{-1}), untrained (43-50 mL.kg^{-1}.min^{-1}) and unfit (29-38 mL.kg^{-1}.min^{-1}) individuals. All groups underwent a series of pre- and post-tests in a temperate environment (23°C), including a maximal test to exhaustion, separated by an 8 day heat acclimation program. The results from the study demonstrated heat acclimation produced significantly lower f_c in untrained and unfit individuals in the post trials, with no difference in f_c in trained individuals. A greater decrease in end T_{re} was also seen in untrained and unfit individuals (0.4°C and 0.4°C, respectively) compared to trained individuals (0.3°C). $\dot{V}O_{2\,max}$ was minimally changed in trained subjects, however, significantly increased in untrained and unfit subjects (13% and 23%, respectively).

Hydration is another element to be considered when implementing a heat acclimation programme. Recent studies have found that dehydration during heat acclimation can enhance adaptations, with Garrett et al. (2014) finding similar adaptive responses in physiological, psychophysical and functional effects between permissive dehydration

(no fluid consumption) and euhydration. However, there were larger adaptive responses in some aspects of fluid and cardiovascular regulation with permissive dehydration. Using short-term heat acclimation (5 days), with the controlled hyperthermia technique ($T_{re} = 38.5°C$) and permissive dehydration for 90-min at 40°C, 60% RH, Garrett et al. (2014) demonstrated a greater plasma volume (PV) expansion and lower end exercise T_{re} and f_c compared to the same participants and HA protocol in a euhydrated state. Sawka, Toner, Francesconi, and Pandolf (1983) investigated the effect of hypohydration and exercise finding post HA, hypohydration reduced f_c values in hot-dry, hot-wet and comfortable environments. Sawka et al. (1983) hypothesised the expanded plasma volume post HA to be accountable for the reduction in f_c. Therefore, for the purpose of the present study it was deemed appropriate to use permissive dehydration during the 5-day heat acclimation program to achieve the best possible results for the primary outcome measure, T_{re}.

1.2.1 Heat acclimation as a performance enhancer in cool/thermoneutral conditions

Ely, Cheuvront, Roberts, and Montain (2007) found, based on marathon runners, that as ambient temperatures (T_a) increase above ~ 10°C, aerobic exercise performance progressively deteriorates. Similarly, Galloway and Maughan (1997) found the optimal temperature for performance to be at 11°C, this was observed in eight healthy males performing prolonged cycle exercise at moderate intensity, other temperatures investigated in the study included 4°C, 21°C and 31°C.

There has been an abundance of research to the 'live high-train low' approach and the benefits it has on improving aerobic exercise performance outside the adaptation environment (Gore et al., 2001; Levine & Stray-Gundersen, 2005; Roberts et al., 2003).

However, the idea of training in a hot environment when performing in thermoneutral conditions remains undefined (Corbett et al., 2014), even though it has been shown that heat acclimation provides greater environmental specific improvements in aerobic performance than altitude acclimation (Lorenzo et al., 2010).

Sawka et al. (1985) investigated the influence of acclimation on maximal aerobic power in moderate (21°C, 30% RH) and hot (49°C, 20% RH) environments. The study included thirteen male soldiers and involved a $\dot{V}O_{2\,max}$ test, using a cycle ergometer, in both conditions before and after a HA program. The HA program consisted of 2 hrs exercise in the heat (49°C, 20% RH) for 9 consecutive days, using constant work rate with hydration. Participants were required to walk on a treadmill (1.52 m.s^{-1}) at a grade (2-6%) that elicited 40-50% of their moderate environment $\dot{V}O_{2\,max}$. M.N. Sawka et al. (1985) found an increase of 4% in $\dot{V}O_{2\,max}$ in both conditions and a decrease in maximal f_c from pre to post acclimation.

Lorenzo et al. (2010) investigated the effect of heat acclimation on exercise performance in cool conditions (13°C). Participants included ten males and two females, all highly trained endurance cyclists. Each participant underwent a $\dot{V}O_{2\,max}$ test and a 60 min time-trail test on cycle ergometers in both 38°C, 30% RH and 13°C, 30% RH. A 10 day heat acclimation protocol of temperatures 40°C, 30% RH, with constant work rate was used. A matched control group exercised at the same intensity but at 13°C, 30% RH. The findings from this study showed significant improvements in time trail performance, increasing work done in the time trail by mean of 6% in cool condition.

Neal, Corbett, Massey, and Tipton (2015) investigated the effect of short-term heat acclimation on thermoregulation and temperate exercise performance, using ten male trained cyclists. Neal et al. (2015) used a 5 day HA protocol of temperatures 40°C, 30%

for 90 min per day, using controlled-hyperthermia technique (T_{re} = 38.5°C – 38.7°C) with permissive dehydration, with pre and post-tests consisting of a heat stress test (HST), graded exercise test (GXT) and a 20 km cycling time trial (TT) all at 22°C, 60% RH and 40°C, 30% RH. The HST involved participants cycling at 35% of their pre-determined peak power output (PPO) for 60 min. The GXT required participants to cycle at 85-110 W for 20 min, thereafter, work rate increased every 3 min by 25 W until blood lactate concentration reached 4 mmol/L and then by 25 W/min until volatile exhaustion. Post testing revealed short-term HA with dehydration was effective for inducing HA, with a reduction in thermal and cardiovascular strain when exercising in the heat; resting T_{re} and mean body temperature ($\bar{T}_b$), exercise T_{re} and $\bar{T}_b$, f_c, RPE, increased sweating. There was a reduction in thermal and cardiovascular strain seen under temperate exercise conditions; exercise T_{re} (p=0.055) and $\bar{T}_b$ (p=0.038), f_c (p=0.018). However, TT performance was not significantly affected in temperate conditions.

Karlsen et al. (2015) conducted a study looking at the effect of heat acclimatisation on performance in a cool climate. Eighteen trained cyclists took part in the study. All subjects underwent pre and post testing in a cool environment, consisting of a $\dot{V}O_{2\,max}$ test and an outdoor 43.4 km TT. Half the subjects then underwent a 2 week training camp in a natural hot/dry environment, mean temperature of 34°C, 18% RH, while the other half served as a control and completed the same training in cool conditions, temperatures not exceeding 15°C. The experimental group also performed pre and post TT in the heat. Karlsen et al. (2015) found improvements in TT performance in the heat, along with increased sweat rates and resting T_{re}. However, there were no improvements in TT performance or $\dot{V}O_{2\,max}$ in cool conditions. All testing was performed in an outdoor setting and therefore was difficult to control for temperature,

with great variation in the temperature of which pre and post tests were performed in the cool environment (pre = 4.7°C, 39% RH; post = 13.2°C, 23% RH).

Chen et al. (2013) investigated short-term heat acclimation on endurance time and skin blood flow ($\dot{Q}_{sk}$) in trained athletes. The study consisted of fourteen, national all-star, table tennis and badminton players. All subjects underwent pre and post maximal cycle exercises in hot and thermoneutral conditions, with seven completing a 5 day heat acclimation program at 38°C, 52% RH (experimental group), and completing the same regime under thermoneutral conditions (24°C, 48% RH) (control group). The pre and post maximal cycle protocol involved 3 minute increment per stage, starting at 60 W and increasing by 30 W each stage, until reaching volatile fatigue or exhaustion. The 5 day HA protocol for both experimental and control groups required subjects to cycle at 10% below the individuals ventilatory threshold (VT) for 25 minutes on day 1, with an increase to 5% below VT, equal to VT, 5% above VT and 10% above VT on days 2,3,4 and 5, respectively. The duration was also increased by 5 minutes each day, reaching 45 minutes by day 5. Similar to Karlsen et al. (2015), Chen et al. (2013) showed a 6.6% increase in endurance time in the hot environment, in experimental group, but no improvements in the thermoneutral condition. There were no changes in $\dot{V}O_{2\,max}$ between pre and post HA in both hot and thermoneutral environments, mean skin temperature ($\bar{T}_{sk}$) was also unchanged. Leg $\dot{Q}_{sk}$ was found to be significantly lower in the post heat cycle trial after HA, however in the post thermoneutral trial, leg $\dot{Q}_{sk}$ was significantly higher after HA. There was no change in leg $\dot{Q}_{sk}$ in the control condition. Chen et al. (2013) hypothesized the decrease in leg $\dot{Q}_{sk}$ after HA was due to the blood flow in active muscles being maintained in the hot environment and therefore increasing time to exhaustion. A significant lower f_c was achieved in the post hot trial, in the experimental group, at 120 W, 180 W and 240 W. A lower f_c was also observed in

thermoneutral conditions in both the experimental and control groups, which potentially was caused by the training protocol producing a training effect, enhancing cardiovascular adaptations (Chen et al., 2013). There was no change in sweat loss in experimental group in either hot or thermoneutral conditions.

With the limited available literature on heat acclimation and performance in cool/thermoneutral conditions, it is not possible to conclude the effects of heat acclimation on performance in a cool/thermoneutral environment. Of the research available, the majority deemed the word 'thermoneutral' as temperatures of ~22°C. With the mean 'spring' temperature in the U.K. being ~9°C (Met office, 2014) and optimal exercise performance temperature being 11°C, the word 'cool' was used for the purpose of this study and was set at 11°C, 45% RH.

1.3 Intermittent exercise vs. steady state exercise

Intermittent exercise can be defined as short periods of moderate and/or strenuous exercise, with short intervals of recovery (Kraning & Gonzalez, 1991). Intermittent exercise and steady-rate exercise use different metabolic processes to support the activity (Drust et al., 2000). Drust et al. (2000) compared an intermittent exercise protocol with steady-rate exercise, with the same mean exercise intensity (12 km/hr) in 18°C, 54% RH. Seven male university soccer players were used as participants for the study. Both the intermittent and steady state exercise protocoled lasted 46 minutes 11 seconds. Physiological strain, mean energy expenditure, $\dot{V}O_2$, T_{re} and sweat production were all similar between the two types of exercise. However, there was a large effect size for f_c between the two modes of exercise, suggesting intermittent exercise may create a greater demand on the cardiovascular system than steady-rate exercise when performed at the same overall mean exercise intensity (Drust et al., 2000). There was a significantly greater increase in minute ventilation during

intermittent exercise than steady rate exercise, possibly due to an elevated post-exercise $\dot{V}O_2$ after high-intensity exercise or additional ventilatory responses to intermittent exercise (Drust et al., 2000). The $\dot{V}O_2$ during steady-rate exercise remained relatively stable during the duration of exercise, however there was greater fluctuation found in $\dot{V}O_2$ in the intermittent exercise protocol. The blood lactate response suggests intermittent exercise placed a greater stress on the anaerobic energy system than the steady-rate exercise. The use of the anaerobic system may also have contributed to the significantly higher RPE at the end of intermittent exercise than steady-rate exercise (Drust et al., 2000). Similar to Drust et al. (2000), Kraning and Gonzalez (1991) investigated intermittent exercise during compensable, lightly clothed, and uncompensable, heavy clothed to allow little evaporation, heat stress, comparing intermittent against continuous exercise. Intermittent exercise consisted of walking and jogging for 4 and 2 minutes, respectively, and a 4 minute seated rest. Tests were carries out in 30°C conditions. Four moderately fit males took part in the study and completed all four tests; intermittent compensable, intermittent uncompensable, continuous compensable and continuous uncompensable. Exercise intensity was depended on heat production rates and lasted 120 min. During compensable heat stress, all participants completed both the intermittent and continuous trials, however, in uncompensable heat stress, the mean continuous exercise time was 79 min, while participants only lasted a mean of 65 min in intermittent exercise (Kraning & Gonzalez, 1991). The T_{re} reached a steady state at 60 min during continuous exercise in compensable heat stress. The major change in T_{re} was also seen at the 60 min mark in intermittent exercise, however it continued to rise slightly for the remainder of the test. A steady state T_{re} was not achieved in either of the uncompensable tests and the rate of rise was 33% higher in intermittent exercise compared to continuous exercise at 30 minutes. Therefore it is possible to conclude from the study that the mode of exercise has an effect on an

individuals' response to heat stress, with individuals partaking in intermittent exercise reaching a higher level of thermal strain quicker than those partaking in continuous exercise.

1.4 Team Sports

Team sports, i.e. soccer, hockey, rugby etc., have a tendency to fluctuate between bouts of high and low exercise intensities and the performance of specific skills and sporadic patterns of movements may be included with these changes (Drust, Atkinson, & Reilly, 2007). Team sports, like soccer, are primarily aerobic sports and include frequent bouts of activity (Bangsbo, 1993). The intensity and duration of the activity vary greatly and tend to be followed by a recovery period where activity is light or no activity (Drust et al., 2007). The movements and skills involved in the team sport (tackling, maintaining possession, passing, kicking and throwing of a ball etc.) are the cause of this erratic activity profile (Carling, Williams, & Reilly, 2006).

Performing a laboratory based protocol to mimic team sports can be limiting as the movements of players are often unorthodox (Drust et al., 2007). Movements include; backward and forward movement, shuffling, and can also involve the use of objects e.g. dribbling/holding a ball, holding a hockey stick etc. Dribbling a ball whilst running, in soccer, has been shown to raise energy expenditure, f_c, lactate concentration and RPE, compared to regular running at same speed (T. Reilly, & Ball, D. , 1984). Weather conditions can also affect game play, as well as the strength of the opposition, fitness levels and player position, with midfielders tending to cover the most distance, with defensive players covering the least (Di Salvo et al., 2007; Drust et al., 2007).

Team sports are affected by environmental conditions, with a decline in performance, particularly high intensity exercise, seen in hot conditions. With dehydration and

greater glycogen utilization in the heat, a greater impairment in skill performance may be observed (Sunderland & Nevill, 2005).

Drust et al. (2000) designed a laboratory protocol, using a motorised treadmill, to simulate the activity in a soccer game, all data was based on motion-analysis by (T. Reilly & Thomas, 1976) on professional soccer players. The protocol was originally based on one half of a match (45 min), however this was later adapted to simulate a full match (90 min) (Drust et al., 2007).   The protocol includes periods of rest, walking, jogging, cruising and sprinting, all in proportion to those observed in match-play, and also incorporate a 15 min rest, to imitate the half-time period of a soccer game (Drust et al., 2007). The speeds assigned to each mode of exercise were as follows; rest – 0 km/hr, walk – 6 km/hr, jog – 12 km/hr, cruise – 15 km/hr, sprint – 21 km/hr. These speeds were based on the data of Van Gool, Van Gerven, and Boutmans (1988). Non-motorised treadmills have also been used to simulate match-play (Aldous et al., 2014) this allows individuals to reach there maximal sprint speed and also allows for more realistic acceleration and deceleration when changing speeds. However, the resistance of the treadmill belt decreases maximal velocity by ~20% compared with normal running, which needs to be taken into consideration when assigning exercise protocols (Drust et al., 2007).

Intermittent shuttle running, most commonly the Loughborough Intermittent Shuttle Run Test (LIST) (Magalhães et al., 2010; Saunders, Sale, Harris, & Sunderland, 2012), has been used to stimulate the activity pattern of soccer and can be performed in s sports hall. The LIST protocol involves 75 minutes of intermittent activity, split into 3 x 15 minute blocks separated by 3 minute rest period. Each block of exercise includes walking, low and high speed running (55% and 95% $\dot{V}O_2$, respectively), sprinting and short static recovery (4 second) (Nicholas, Nuttall, & Williams, 2000). This is then

followed by ~10 min test to exhaustion, requiring participants to run intermittently at 55% and 95% of $\dot{V}O_2$, with intensity changing every 20m (Nicholas et al., 2000). The LIST protocol has been adapted to other research, i.e. for large numbers, other team sports, females etc. (Sunderland & Nevill, 2005). According the Drust et al. (2007), laboratory based simulations are a good measure for investigating soccer-specific intermittent exercise, especially for investigations requiring high levels of experimental control with detailed/ invasive physiological assessments. However, skill is not assessed in any of these protocols. Sunderland and Nevill (2005) investigated the effect of heat on both high intensity running and skill performance in field hockey players. Previous research by Brisswalter, Collardeau, and René (2002) suggested cognitive function, under heat stress, is dependent on the task performed, level of dehydration and body temperature. Sunderland and Nevill (2005) used the LIST and field hockey skill tests (Sunderland, Cooke, Milne, Pout, & Nevill, 2003) on nine well-trained, unacclimatized female hockey players. The two tests were performed in hot (30°C, 38% RH) and moderate (19°C, 50% RH) environmental conditions. The LIST protocol was adapted to replicate the intensities seen in female field hockey players. The field hockey test involved dribbling around cones and shooting at a randomly picked target on the right or left hand side of the goal, the ball was then passed off a rebound board and participants had another shot on goal, this time to the opposite side of the target shown (Sunderland & Nevill, 2005). Errors made in the skill test resulted in 2 seconds added on to total time. A 'decision time' was also measured based on the time taken to hit the backboard, after the target was shown. Each trial consisted of three skill tests and four 15 minute blocks of the LIST. The skill tests were repeated before, after two blocks and at the end of the LIST. The results from this study showed a decrease in hockey skill performance after prolonged intermittent high-intensity running, with a greater decrease in performance in the hot environment, although there was no change

in decision making following intermittent high-intensity running in either conditions (Sunderland & Nevill, 2005). Repeated 15m sprints were found to be slower in the hot environmental conditions. According to Sunderland and Nevill (2005), the declined in skill performance did not appear to be caused from dehydration or glycogen depletion but from thermal strain, with a higher T_{re} observed in hot conditions ($T_{re} = 39.6°C$). T_{re} of $> 39°C$ was also observed at the end of the LIST in moderate conditions, which may have potentially contributed to the decrease in skill performance seen in this condition.

To prevent dehydration in team sports players, water intake should be one-half of the individuals' sweat-rate (Gisolfi & Duchman, 1992).

1.5 Aims

The aim of this study was to investigate the effectiveness of short-term heat acclimation, using controlled hyperthermia with dehydration, on intermittent exercise in (1) hot and (2) cool conditions.

2. Methods

2.1 Participants

Participants were recruited through local adverts by email and announcements in lectures. Participants had to be volunteers and had to fit the inclusion criteria. The inclusion criteria for the study included; male, age 18-49, healthy, relatively trained. Prior to volunteering, everyone was made aware of what was involved in the study prior to signing up and were informed that they may withdraw from the study at any time without reason and that all data was confidential. Before testing commenced each participant provided written informed consent and before each trail a pre-medical questionnaire was completed to ensure the participants were eligible to exercise. The

study protocol was approved by the departmental ethics committee at the University of Hull. (Appendix. I)

Twelve male participants were recruited for this study. Characteristics of participants are shown in table 1.

Table 1. Characteristics of participants (n=12), shown as mean ± SD

Age (yrs)	25.6±8.9
Height (cm)	180.7±5.6
Body mass (kg)	83.2±10.8
$\dot{V}O_2$ (mL.kg^{-1}.min^{-1})	45.3±6.5
Resting $\dot{Q}$ (L.min^{-1})	6.1±1.8

2.2 Study design and overview

The study uses a 5-day heat acclimation (HA) phase with a pre- and post-exercise stress test (EST) using a balanced cross-over design. Participants were split into two groups; heat acclimation and no heat acclimation (control). A week prior to the pre-testing, all participants underwent a $\dot{V}O_{2\,max}$ test on a treadmill, starting at 8 km/hr and increasing by 0.1 km/hr every 6 sec. Pre- and post-EST was then carried out in 11°C, for control, and 11°C and 31°C, for experimental group. The control group repeated the 11°C separated by one week of no heat exposure, while the experimental group underwent 5 consecutive days of heat exposure (39.5°C, 60% RH). After post testing was complete, there was a 3 week wash out period, to ensure all measures returned to baseline after the heat acclimation (Garrett et al., 2009). The groups then swapped over and completed the trials again (Figure 1). The thermoregulatory, cardiovascular and fluid-regulatory responses of participants were measured at rest and

throughout the EST. Fluid-regulatory measures were also recorded on day 1 and day 5 of the HA.
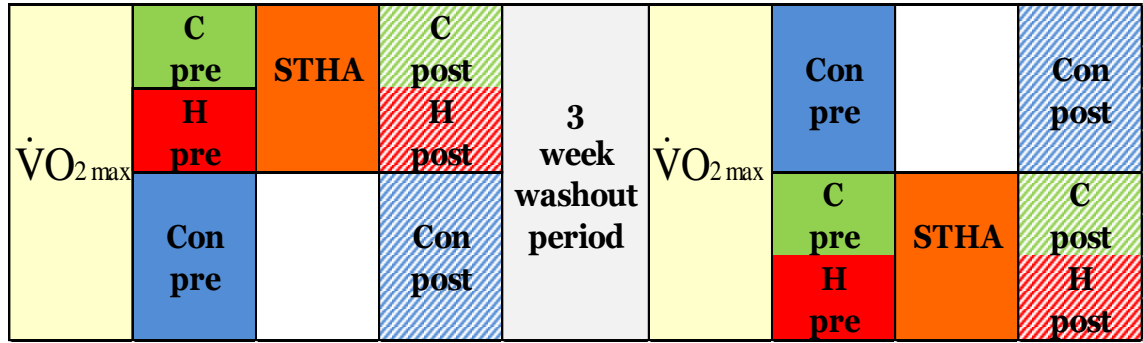
Figure 1: *Experimental design*

	Baseline $\dot{V}O_{2\,max}$
	Pre 11°C, 45% RH (experimental)
	Post 11°C, 45% RH (experimental)
	Pre 31°C, 45% RH (experimental)
	Post 31°C, 45% RH (experimental)
	Pre 11°C, 45% RH (control)
	Post 11°C, 45% RH (control)
	5-day Short-term heat acclimation (39.5°C, 60% RH)

2.3 Protocol

2.3.1 Aerobic fitness test ($\dot{V}O_{2\,max}$)

A running incremental test to exhaustion was performed by participants one week before the EST. This was to determine $\dot{V}O_{2\,max}$ at baseline for all participants. Participants ran on a motorised treadmill (HP Cosmos Pulsar Treadmill, H/P/Cosmos), starting at a speed of 8 km/hr, with a 1% incline, and increasing by 0.1 km/hr every 6 seconds until voluntary exhaustion. Breath by breath samples were taken using a metabolic system (Oxycon Pro, Jaegger, Hoechberg, Germany) and f_c and RPE were recorded every minute.

2.3.2 Exercise Stress Test (EST)

On arrival participants filled out a medical questionnaire to ensure they were fit and healthy for the trial that day. Nude body mass (BM) was then measured using digital weighing scales (SECA digital scales, SECA, Birmigham, UK), a urine sample was taken and the rectal probe was inserted, tape was placed at 10cm up the rectal probe and participants were instructed to insert up to the tape to ensure all probes were inserted correctly. The urine sample was used to measure urine colour, osmolality and urine specific gravity (USG). Urine colour was measured using a urine colour chart, osmolality was measured using an osmometer (Model 3320, Advanced Instruments Inc, Massachusetts, USA) and USG was measured using a digital refractometer (PEN SW, ATAGO, Washington, USA). Capillary blood samples were taken by finger prick method for haemoglobin and haematocrit measures. A lancet (Genie lancet 1 X 1.5, BD Vacutainer, Systems, NJ, USA) was filled with blood and placed in a haemoglobin analyser (Hemocue 201, Hemocue Ltd, Sheffield, UK) for haemoglobin levels and for haematocrit measurements, a capillary tube (Hawksley haematocrit tube, Roche Diagnostics, Sussex, UK) was filled with blood and placed in a centrifuge (Hawksley Micro Haematocrit Centrifuge, Hawksley & Sons, Lancing, UK) for 10 minutes and read off using a tube reader (Hawksley reader, Hawksley & Sons, Lancing, UK). Three samples of each were measured and the mean of the samples was used for the measurement. A heart rate (HR) monitor (Polar FS1 HRM, Polar Electro, OY, Finland) and four skin thermistors were then attached the participant outside the chamber. Skin thermistors were attached to the chest (T_{chest}), bicep (T_{bicep}), thigh (T_{thigh}) and gastrocnemius (T_{gastro}). Rectal temperature (T_{re}) and skin temperatures were recorded using a Grant squirrel data logger (Squirrel 2020 series data logger, Grant Instruments,

Cambridge, UK). Resting f_c, T_{re}, mean skin temperature ($\bar{T}_{sk}$) (Ramanathan, 1964),

mean body temperature ($\bar{T}_b$) (M. N. Sawka, Wenger, & Pandolf, 2011), ambient

temperature (T_a) and relative humidity (RH) were all recorded at rest outside the

chamber as well as thermal sensation (TS), thermal comfort (TC) and rate of perceived

exertion (RPE) (Borg scale, 1973). Participants were also required to drink a 250ml

drink, made up of a 4% CHO solution.

On entering the chamber, a resting cardiac output ($\dot{Q}$) measurement was taken using a

breath by breath cardiac output analyser (Innocor, Innovision, Odense, Denmark).

Participants then underwent a 5 min warm up on a cycle ergometer (Wattbike, Wattbike

Ltd, Nottingham, United Kingdom). Post warm up a capillary sample was taken for the

measurement of blood lactate (Bla). Blood samples were stored in a box of ice until

testing had ended, then were analysed using a lactate analyser (YSI 2300 STAT, YSI

Inc, Yellow Springs. OH). Once on the treadmill (HP Cosmos Pulsar Treadmill,

H/P/Cosmos.) participants were hooked up to a metabolic system (Oxycon Pro, Jaegger,

Hoechberg, Germany) to record respiratory function during exercise.

The pre- and post- EST consisted of 45 min intermittent exercise using both treadmill

and Wattbike followed by an incremental running test to exhaustion. The bouts of

intermittent exercise were broken into 5 min blocks (Table 2), which was repeated 9

times. Every 5 minutes f_c, T_{re}, $\bar{T}_{sk}$, $\bar{T}_b$, T_a and RH were recorded. Every 15 minutes,

RPE, TS, TC and BLa were taken, as well as the 5 minute measurements. The

participants also received a drink at the 15 minute intervals, this consisted of 150ml of

the same 4% CHO solution that was consumed before exercise. Participants were

requested to drink all of the 150ml, even if they felt it was not required, this was to

standardise the amount of fluid consumed. The $\dot{Q}$ was measured once the 45 min

intermittent exercise was complete. Participants then went on to perform a test to exhaustion on the treadmill. This was the same test completed for the baseline $\dot{V}O_{2\,max}$ test. Participants' RPE and f_c were recorded every minute. The $\dot{V}O_2$ was not recorded, as this was a performance test only.

Post EST capillary blood samples were taken to measure haemoglobin and haematocrit levels. A urine sample was produced and nude BM recorded. Urine colour, osmolality and USG were measured the same as before.

The EST was repeated in control conditions (11°C, 45% RH) and separated by a 5-day heat acclimation in both cool (11°C, 45% RH) and hot (31°C, 45% RH) conditions. All post heat acclimation EST were performed within 1 week of heat acclimation to ensure the decay of adaptations did not occur (Garrett et al., 2009).

Table 2. Speed intensities and duration

Speed (km/hr)	Duration (s)
0	30
6	60
12	180
15	30
Maximal sprint (bike)	6

2.2.3 Heat acclimation

The short term heat acclimation (STHA) consisted of 5 consecutive days of 90 minute heat exposure (39.5°C, 60% RH), using the hyperthermia controlled technique, with dehydration. Participants were required to cycle on a cycle ergometer (Monark 824E, Monark Exercise AB, Varberg, Sweden) against increasing resistance until T_{re}

reached 38.5°C. 1kg was added to the cradle every 5 minute. Once T_{re} reached 38.5°C

participants got off the bike and sat for the remainder of the 90 minutes provided T_{re} did

not drop below 38.5°C. T_{re} was measured using a rectal probe attached to a Grant

squirrel data logger (Squirrel 2020 series data logger, Grant Instruments, Cambridge,

UK). $T_{re,}$ f_c and loading was recorded every 5 minutes. Participants had to abstain from

all fluids for the 90 minutes.

On day one and five of the STHA, venous blood samples, capillary blood samples, urine

samples and nude BM were collected both pre and post the 90 minute heat exposure.

Capillary blood samples were used to test haemoglobin and haematocrit levels and urine

samples were tested for urine colour, osmolality and USG. All heat exposures occurred

at the same time of the day for each individual in order to standardise for circadian

rhythm (Shido, Sugimoto, Tanabe, & Sakurada, 1999).

2.3 Data Analysis

A retrospective power calculation was carried out using G*Power version

3.1.9.2.

Statistical analysis was carried out using IBM SPSS version 22. Two-way

repeated measures (condition by time) ANOVA was used to analysis pre and post

(condition) data at specific time points (time) in each condition (H, C and Con). Where

a statistically significant interaction was found further post hoc analysis was performed

with Bonferroni adjustment. Paired t-tests were used to analysis day 1 vs day 5 of the

heat acclimation. Where paired-t tests were performed, data is reported as the mean

difference with 95% confidence intervals (95% CI). Descriptive statistics are given as

mean ± SD.

Mean skin temperature ($\bar{T}_{sk}$) and mean body temperature ($\bar{T}_{b}$) were calculated as:

$$\bar{T}_{sk} = 0.3\ T_{chest} + 0.3\ T_{bicep} + 0.2\ T_{thigh} + 0.2\ T_{gastro}\ \text{(Ramanathan, 1964)}$$

$$\bar{T}_{b} = 0.9\ T_{re} + 0.1\ \bar{T}_{sk}\ \text{(M. N. Sawka et al., 2011)}$$

PV% change was calculated using the Dill and Costill (1978) calculation.

3. Results

The sample size required for the present study, according to the retrospective power calculation, was 20. 12 participants were recruited for the study. Participants adherence is shown in figure 2. All blood measures were obtained from all participants on day one and five of HA. All eight participants were able to complete the EST in C and Con, and seven completed all the EST in H. However, one participant terminated the pre EST in H at 40 min, therefore the end data for this participant was taken at 40 min. Three participants did not complete the incremental test to exhaustion in the pre H trial due to voluntary withdrawal or recording a Tre of 39.5°C being reached.
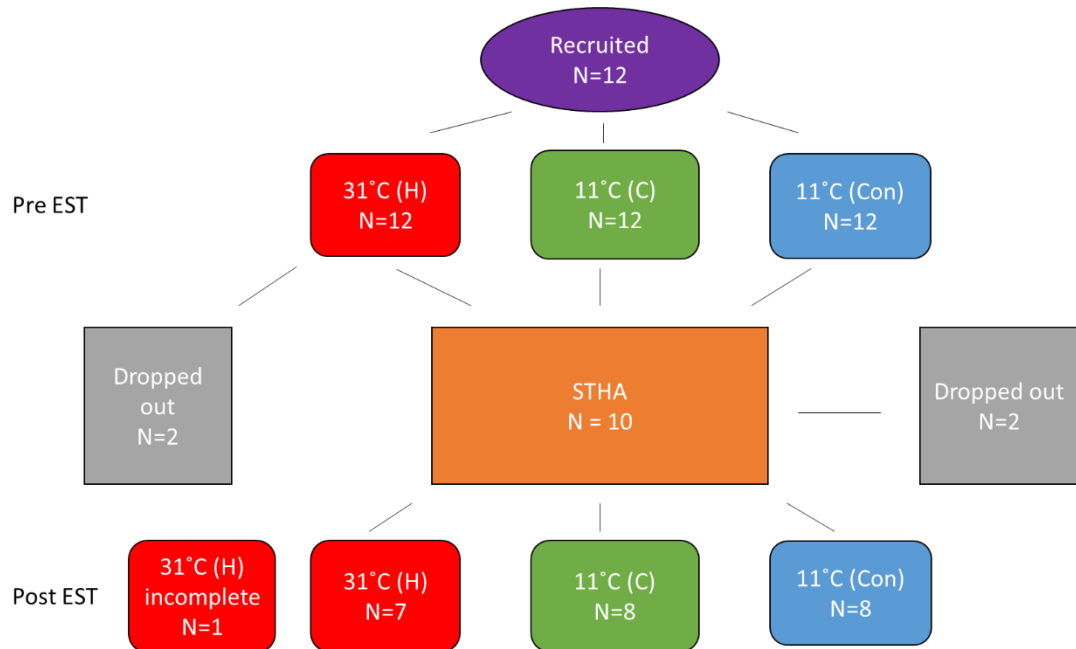

Figure 2: Flowchart of participant adherence

3.1 Acclimation

Thermal stress and strain from day 1 (D1) and day 5 (D5) of the short-term heat acclimation (STHA) regime is shown in Table 3. f_c was lower by D5 of heat exposure, despite participants taking longer to reach the target T_{re} of 38.5°C and performing more work on D5 compared to D1 (Figure 2). Participants worked a mean of 3931 J more on day 5 of HA compared to D1 (2331 to 5531; p=0.11) (Figure 2). Whole body sweat rate, seen by change in nude body mass, was significantly higher on day 5 of the HA (-0.5; -0.69 to -0.47; p=0.005). There were no significant differences found in hydration markers, urine osmolality, urine specific gravity (USG), from D1 to D5 (p=0.75; p=0.64, respectively). There was a 3.7% change in plasma volume (PV) but this was not significant (p=0.39)

Table 3. Thermal stress and strain

	Day 1	Day 5	P value
T_{am} (°C)	39.7 ± 0.2	39.7 ± 0.2	0.19
RH (%)	61 ± 1.3	62 ± 1	0.42
Mean f_c (b.min^{-1})	133 ± 19	123 ± 16	**0.06**
Mean T_{re} (°C)	38.3 ± 0.2	38.3 ± 0.2	0.46
Time to T_{re} 38.5°C (min)	31.5 ± 6.6	36.6 ± 9.3	**0.05**
Body mass change (%)	-2 ± 0.7	-2.5 ± 0.6	**0.03**
PV% change	-5.9 ± 7.5	-2.2 ± 7.98	0.39
Work (J)	24776 ± 7178	28708 ± 6652	0.11

Ambient Temperature (T_{am}), relative humidity (RH), rectal temperature (T_{re}), time to T_{re} 38.5°C, cardiac frequency (f_c), body mass change, plasma volume percentage (PV%) change, work performed on day one and five of acclimation. Data is shown as mean ± SD (n=12) and significance shown in **bold**.
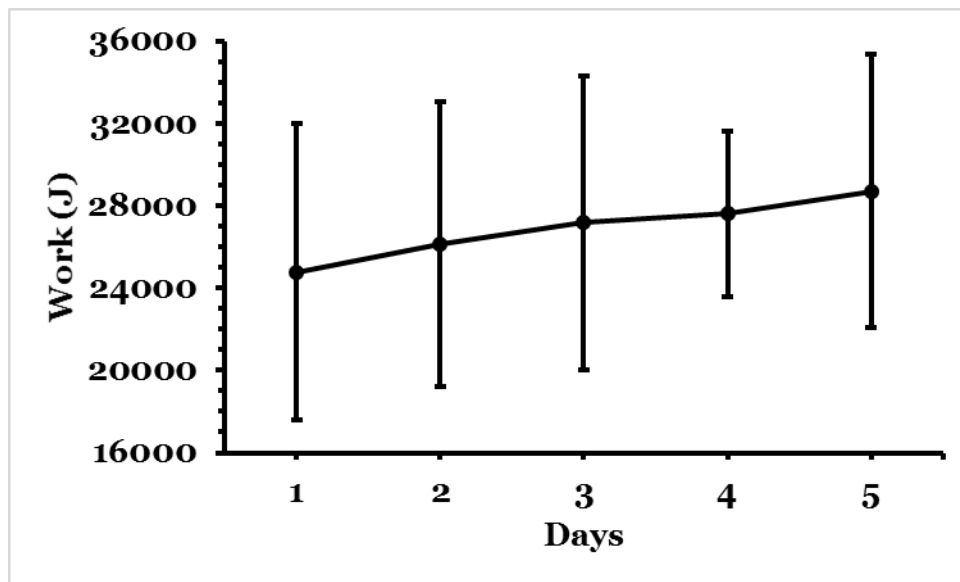

Figure 3: *Mean ± SD work (J) performed on each of the 5 days of the heat acclimation program (HA) (n=10).* *** = p≤0.05**

3.2 Exercise stress test (EST)

All data regarding EST is shown for n=8 in C and Con and n=7 in H, unless otherwise stated.

3.2.1 Oxygen consumption and cardiac frequency

Oxygen consumption ($\dot{V}O_2$) was measured throughout the 45 min intermittent exercise protocol and was recorded at the last few seconds of the cruise for all participants. There was no significant difference found in the mean cruise $\dot{V}O_2$ in H (1.94; -0.27 to 4.16; p=0.07) or Con (0.94; -0.77 to 0.65; p=0.23), however there was a significant difference in C (-1.67; -2.60 to -0.73; p=0.003).

Cardiac frequency (f_c) did not change post HA in either of the three conditions. In H, there was no significant effect for condition [$F_{(1,6)} = 0.22$; $p = 0.66$] or interaction effect [$F_{(9,54)} = 1.23$; $p = 0.30$] but there was a significant effect for time [$F_{(9,54)} = 370.16$; $p = 0.00$]. In C, there was a significant effect for condition [$F_{(1,7)} = 5.53$; p=0.05] and time [$F_{(9,63)} = 185.07$; $p = 0.00$] however there was no significant interaction effect [$F_{(9,63)} = 0.94$, $p = 0.50$]. In Con, there was no significant effect for condition [$F_{(1,7)} = 2.47$; $p = 0.16$] and interaction effect [$F_{(9,63)} = 0.55$; $p = 0.83$] but there was a significant effect for time [$F_{(9,63)} = 175.21$; $p = 0.00$].

3.2.2 Cardiac output and stroke volume

Cardiac output ($\dot{Q}$) and stroke volume (V_s) were measure before and after the 45 min intermittent exercise protocol. Pre and post exercise $\dot{Q}$ was not effected by HA in either condition, H (p=0.77; p=0.62) and C (p=0.20; p=0.10), with the same results found in Con (p=0.45; p=0.82, respectively). Similarly, the pre and post exercise V_s did

not change post HA in either the H (p=0.76; p=0.38, respectively) or C (p=0.73; p=0.48, respectively) environment.

3.2.3 Body temperatures

Rectal temperature (T_{re}), mean skin temperature ($\bar{T}_{sk}$) and mean body

temperature ($\bar{T}_{b}$) were measured at rest and at 5 min during the 45 min intermittent

exercise test.

T_{re} , in H conditions, showed no significant effect for condition [$F_{(1,6)}$ = 5.53; p

= 0.06], however there was a significant effect for time [$F_{(9,54)}$ = 105.14, p = 0.00] and a

significant interaction effect for condition x time [$F_{(9,54)}$ = 2.10, p = 0.05]. T_{re} was

significantly lower post acclimation at time points 25 min (-0.11, -0.20 to -0.03, p =

0.02), 30 min (-0.21, -0.33 to -0.09, p = 0.01), 35 min (-0.31, -0.51 to -0.10, p = 0.01),

40 min (-0.25, -0.46 to -0.04, p = 0.03), 45 min (-0.22, -0.41 to -0.03, p = 0.03) (figure

4). In C conditions there was a significant effect for condition [$F_{(1,7)}$ = 6.92, p = 0.03]

and time [$F_{(9,63)}$ = 78.16, p = 0.00]. However, there was no significant interaction effect

for condition x time [$F_{(9,63)}$ = 0.52; p = 0.85]. In Con condition, there was no

significant effect for condition [$F_{(1,7)}$ = 0.11; p = 0.76) or interaction effect for condition

x time [$F_{(9,63)}$ = 1.51; p = 0.17) but there was a significant effect for time [$F_{(9,63)}$ =

63.65, p = 0.00].

$\bar{T}_{sk}$ and $\bar{T}_{b}$ were both affected by HA in H conditions (figure 4). $\bar{T}_{sk}$ had a

significant effect for condition [$F_{(1,6)}$ = 8.89; p = 0.03], with no significant effect for

time [$F_{(1,6)}$ = 0.11; p = 0.75). However, there was a significant interaction effect for

condition x time [$F_{(1,6)}$ = 7.01; p = 0.04]. $\bar{T}_{sk}$ was significantly lower post acclimation

at time points 25 min (-0.69, -1.20 to -0.19, p = 0.02), 30 min (-0.63, -1.26 to 0.01, p =

0.05), 35 min (-0.73, -1.36 to -0.11, p = 0.03), 40min (-0.94, -1.77 to -0.12, p = 0.03) and 45 min (-0.82, -1.31 to -0.32, p = 0.01). Similarly, for $\bar{T}_b$, there was a significant effect for condition [$F_{(1,6)}$ = 13.57, p = 0.01] and time [$F_{(9,54)}$ = 96.03, p = 0.00]. There was also a significant interaction effect for condition x time [$F_{(9,54)}$ = 2.30, p = 0.03]. $\bar{T}_b$ was significantly different post acclimation at time points 25 min (-0.17, -0.27 to -0.07, p = 0.01), 30 min (-0.25, -0.39 to -0.12, p = 0.004), 35min (-0.35, -0.57 to -0.08, p = 0.01), 40 min (-0.32, -0.57 to -0.08, p = 0.02) and 45 min (-0.28, -0.48 to -0.09, p = 0.01).

There was no significant effect for condition [$F_{(1,7)}$ = 4.32; p = 0.08), time [$F_{(9,63)}$ = 1.17; p = 0.33) or interaction effect for condition x time [$F_{(9,63)}$ = 1.30; p = 0.26) for $\bar{T}_{sk}$ in C conditions. $\bar{T}_b$ had a significant effect for condition [$F_{(1,7)}$ = 10.07, p = 0.02] and time [$F_{(9,63)}$ = 60.38, p = 0.00] but no significant interaction effect for condition x time was found [$F_{(9,63)}$ = 0.91; p = 0.52) in C conditions (figure 5).

In Con conditions, there was no significant effect for $\bar{T}_{sk}$ between condition [$F_{(1,7)}$ = 0.001; p = 0.98] or interaction effect [$F_{(9,63)}$ = 0.95; p = 0.49] but there was a significant effect for time [$F_{(7,9)}$ = 2.47; p = 0.05].

Figure 4: *Mean+SD rectal temperature (Tre) (upper plate), mean skin temperature (MST) (mid plate) and mean body temperature (MBT) (lower plate), pre and post EST in H (31°C 45% rh; n=7). * = p≤0.05*

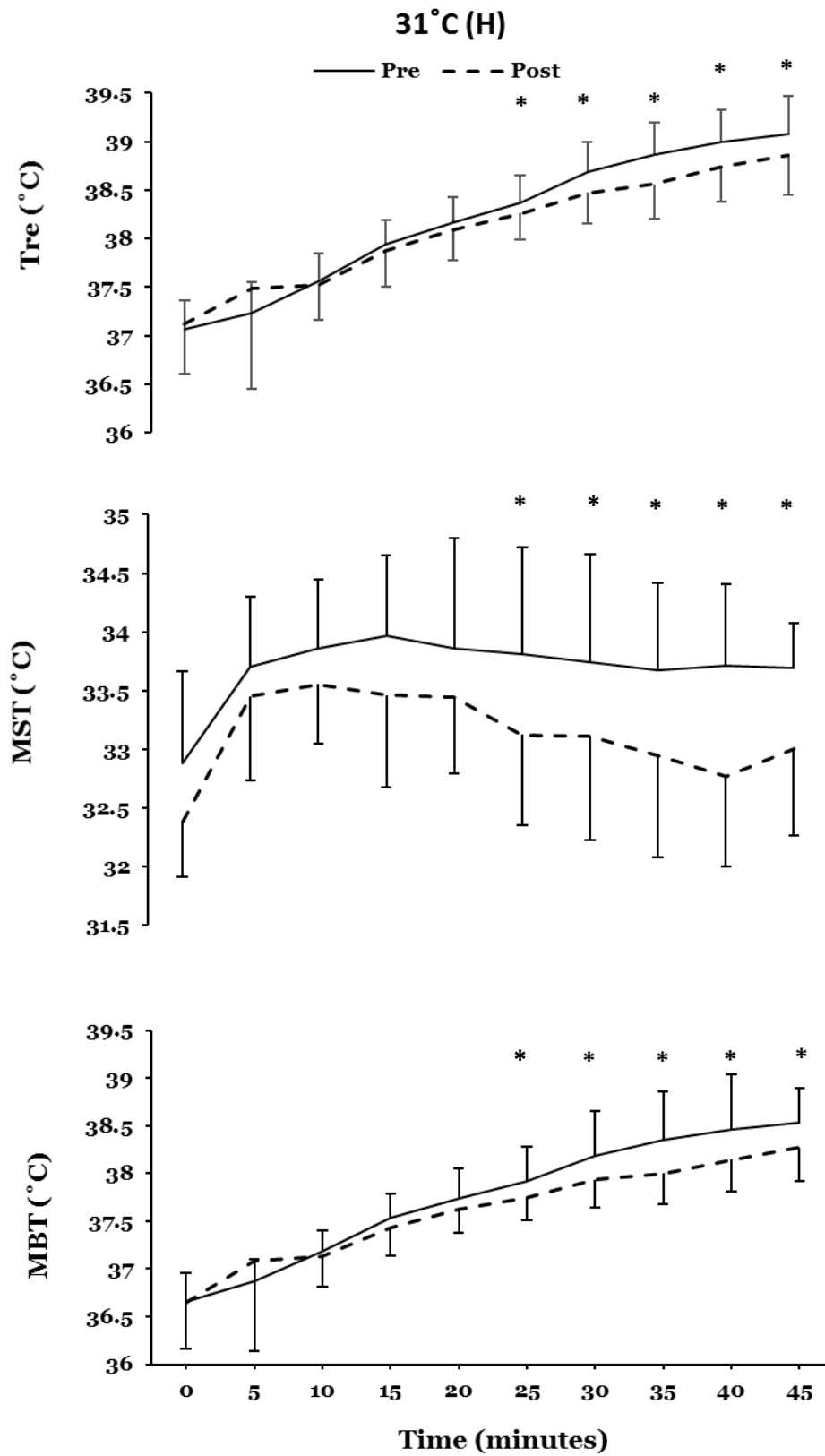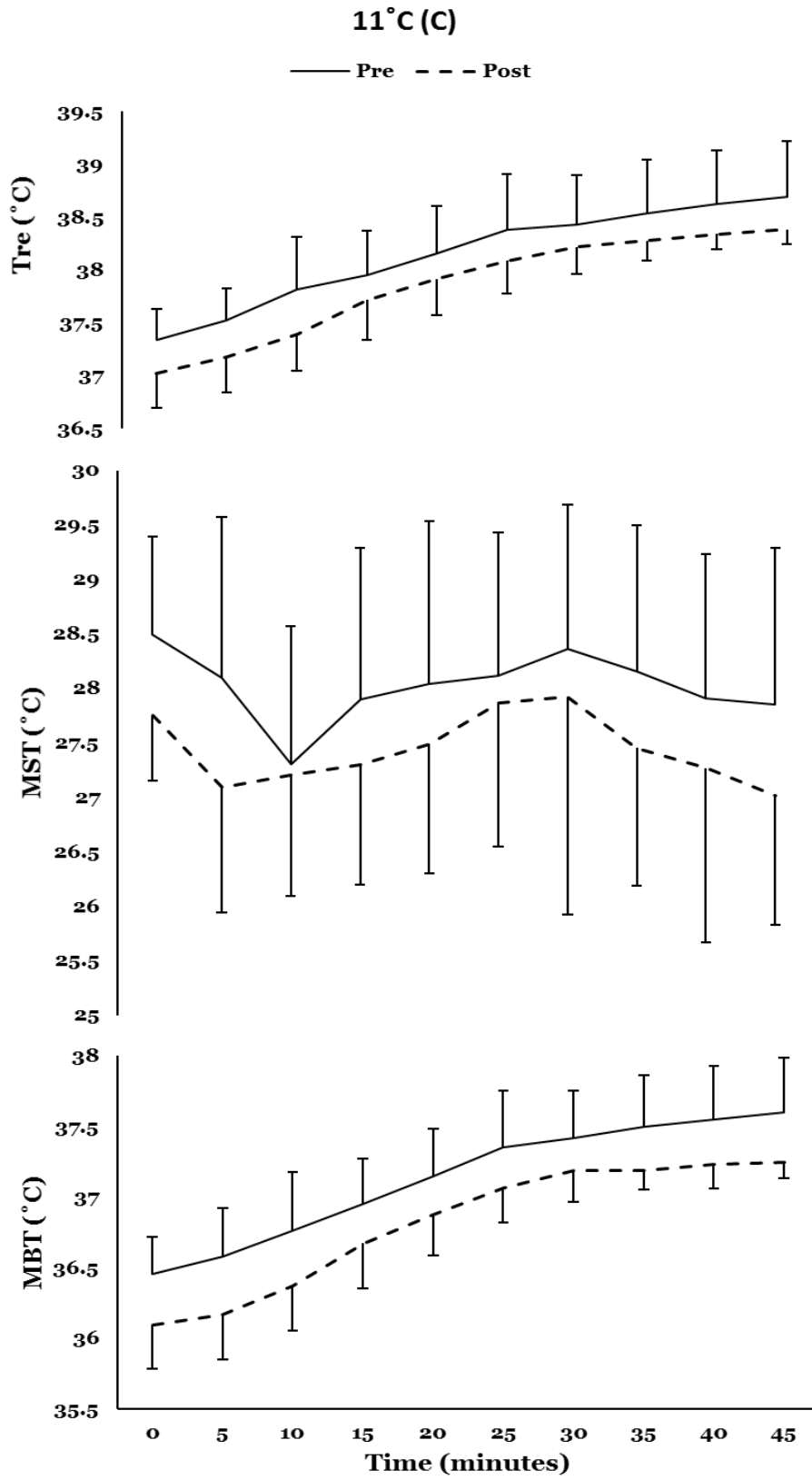**Figure 5:** *Mean+SD rectal temperature (Tre) (upper plate), mean skin temperature (MST) (mid plate) and mean body temperature (MBT) (lower plate), pre and post EST in C (11°C 45% rh; n=8).*

3.2.4 Sudomotor responses

Whole-body sweat rate, measured by difference in nude body mass pre and post EST, was not altered in any of the conditions post HA; H (-0.32; -0.97 to 0.33 %; p=0.27), C (-0.10; -0.43 to 0.22 %; p=0.48) and Con (0.13; -0.33 to 0.60 %; p=0.51).

3.2.5 Plasma Volume

Plasma volume percentage change (PV%) was calculated using pre and post exercise haemoglobin (Hb) and haematocrit (Hct) measures. There was no significant change in %PV change post HA in either H, C or Con conditions; H (-4.72; 13.20 to 3.75; p=0.22), C (1.23; -5.21to 7.68; p=0.66) and Con (-4.56; -11.08 to 1.95; p=0.14).

3.2.6 Sprint Performance and Time to Exhaustion

In the H trials there was no effect for condition [$F_{(1,6)}$ = 1.03; p = 0.35] however there was a significant effect for time [$F_{(8,48)}$ = 2.61; p = 0.02] and a significant interaction effect for condition x time [$F_{(18,48)}$ = 3.34, p =0.04]. The sprints which were significantly different post acclimation include sprint 7 (111.00, 24.88 to 197.11, p = 0.002) and sprint 9 (156.86, 82.18 to 231.53, p = 0.002) (Figure 6). In C trials, there was no significant effect for condition [$F_{(1,7)}$ = 0.11; p = 0.75] or interaction effect for condition x time [$F_{(8,56)}$ = 0.94; p = 0.50]. There was a significant effect for time [$F_{(8,56)}$ = 2.09, p = 0.05] (figure 7). Similar results were seen in Con trials with no significant effect for condition [$F_{(1,7)}$ = 0.17; p = 0.70], time [$F_{(8,56)}$ = 0.97; p = 0.47] or interaction effect for condition x time [$F_{(8,56)}$ = 0.69; p = 0.70] (figure 8).

Three participants were unable to begin the time to exhaustion test, after reaching T_{re} of 39.5°C at the end of the 45 min intermittent exercise, in pre H EST. Post

HA, all participants completed the EST, with mean increase of 208 s in time to exhaustion (-24 to 439 s; p=0.06; ES=0.63). There was a significant increase in time to exhaustion in C (43; 1 to 85 s; p=0.04; ES=0.32), with no increase seen in Con (31; -72 to 11 s; p=0.12; ES=-0.18) (figure 19).
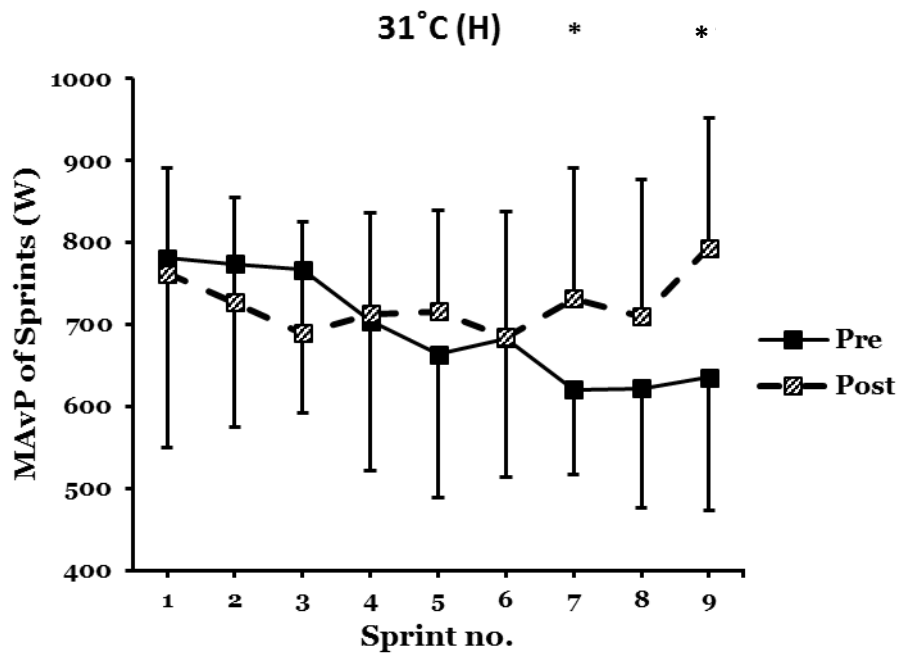

Figure 6: *Mean average power (MAvP) of all 9 sprints in pre and post EST in H (31°C 45% rh; n=7). * = p≤0.05*
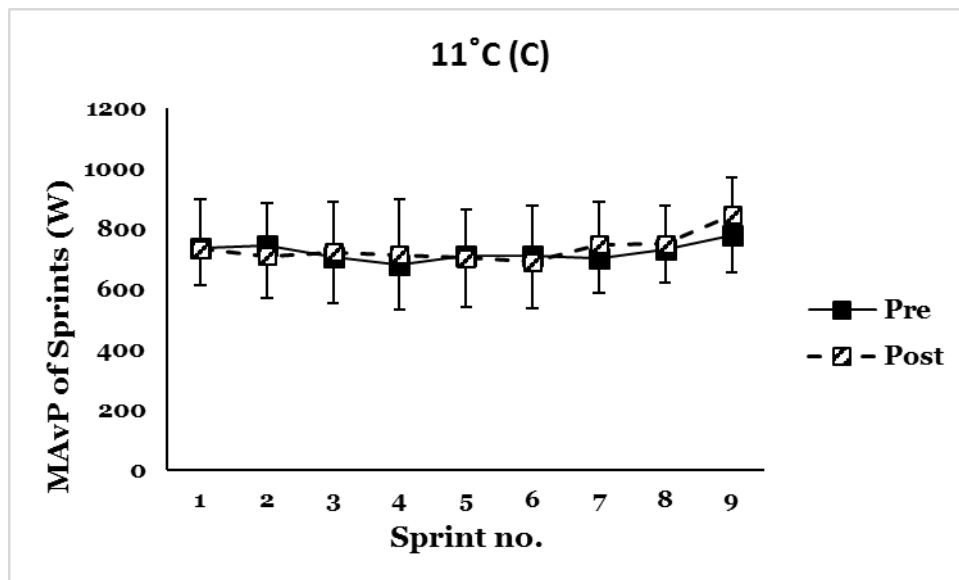
Figure 7: *Mean average power (MAvP) of all 9 sprints in pre and post EST in C (11°C 45% rh; n=8). * = p≤0.05*
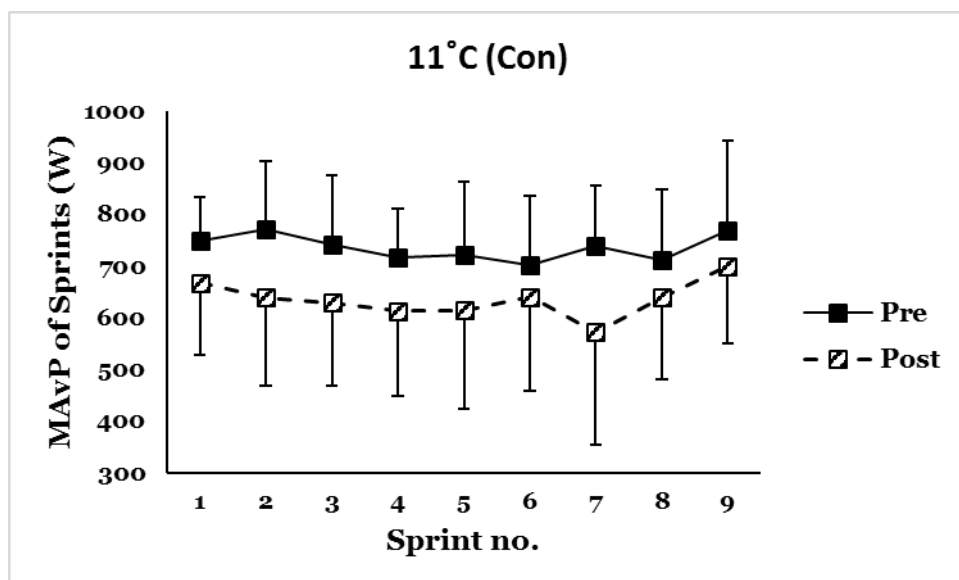

Figure 8: *Mean average power (MAvP) of all 9 sprints in pre and post EST in Con*

*(11°C 45% rh; n=8). * = p≤0.05*
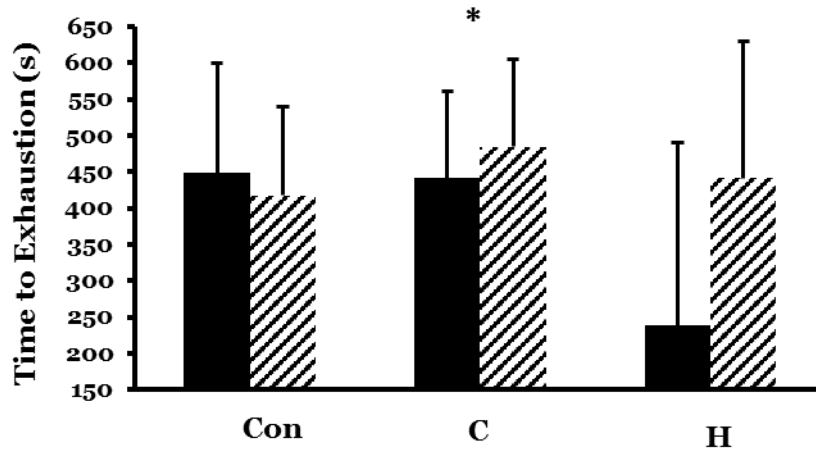
Figure 9: Time to exhaustion across control (Con; 11°C 45% rh; n=8); cool (C; 11 °C 45% rh; n=8) and hot (H; 31°C 45% rh; n=7). * = p≤0.05

4. Discussion

The current study was designed to determine whether short-term heat acclimation could be used to improve intermittent exercise performance in (1) hot (31°C, 45% RH) and (2) cool (11°C, 45% RH) conditions. The short-term heat acclimation consisted of 5 consecutive days of heat exposure (90 min/day, 39.5°C, 60% RH), using controlled hyperthermia (T_{re} = 38.5°C), with dehydration. As much of the research on heat acclimation uses continuous or fixed intensity protocols, an intermittent protocol, adapted from Drust et al. (2000), was designed for the purpose of this study. The exercise stress test consisted of 45 min intermittent activity, including 9, 6 sec, sprints on a Watt bike and an incremental running test to exhaustion as the performance measure. Physiological adaptations, including reduction in f_c, T_{re}, $\overline{T}_{sk}$, were more prominently seen in hot conditions. However, performance was seen to improve in both hot and cool conditions.

4.1 Effectiveness of short-term heat acclimation

The adaptations from short-term (5 days) heat acclimation, using controlled hyperthermia and dehydration as seen in Table 3, coincide with previous research (Garrett et al., 2014; Nielsen et al., 1993). These adaptations include; lower exercise T_{re} and f_c and increased exercise capacity (Garrett et al., 2014). Mean f_c was significantly reduced on day 5 of the acclimation compared to day 1. Although the time to reach T_{re} 38.5°C took slightly longer on day 5 than day 1, more work was performed and a lower f_c was maintained. Whole body sweat rate also improved by day 5 of heat acclimation as reported by Nielsen et al. (1993) and Neal et al. (2015).

4.1.1 Cardiovascular and Thermoregulatory responses

Mean $\dot{V}O_2$ remained unchanged throughout all pre and post trials. Other studies have had mixed reports of the effect of heat acclimation on $\dot{V}O_2$ (Chen et al., 2013; Neal et al., 2015; Sawka et al., 1985; Shvartz et al., 1977). Shvartz et al. (1977) found a significant increase in $\dot{V}O_{2\,max}$ in untrained and unfit individuals post acclimation, with no change in $\dot{V}O_{2\,max}$ in trained subjects. The trained subjects had a $\dot{V}O_{2\,max}$, post acclimation, of 57-65 mL.kg^{-1}.min^{-1}. The mean $\dot{V}O_{2\,max}$ of the subjects in the present study was 45.3$\pm$6.5 mL.kg^{-1}.min^{-1}, ranging from 33.5 to 56.4 mL.kg^{-1}.min^{-1}. The wide range in $\dot{V}O_{2\,max}$ values, ranging from 'trained' to 'unfit', according to Shvartz et al. (1977), may be accountable for the limited change seen in mean $\dot{V}O_{2\,max}$ throughout the 45 min intermittent exercise trial in both conditions. Neal et al. (2015) and Chen et al. (2013), similarly, did not find any improvements in $\dot{V}O_{2\,max}$ following short-term heat acclimation in hot and thermoneutral conditions.

A key feature of heat acclimation is cardiovascular stability, typically seen by a lowering exercising f_c (Garrett et al., 2009). In the present study, f_c was not found to be significantly reduced in hot conditions. Garrett et al. (2011) showed a 7.5% decrease in end-exercise value, compared to the present study, f_c decreased by -3; -5 to -1 b·min^{-1}. The small sample size (n=7) and the variety in fitness levels may have affected these results. Exercise f_c was not found to be significantly different in the cool trial. This contradicts that of Neal et al. (2015), who found a reduction in cardiovascular strain when exercising under temperate conditions. Neal et al. (2015) conducted the HST in 22°C, 60% RH, these temperate conditions have more of a thermal load than the conditions utilised in the present study (11°C, 45% RH). As Galloway and Maughan (1997) found the optimal temperature for performance is ~11°C and Ely et al. (2007) showing that aerobic performance declines as temperature increases above ~10°C. Therefore, the reasoning for the non-significant decrease in f_c at end exercise in cool conditions may be due to the lack of thermal strain placed on individuals during the cool exercise stress test in the present study.

It has been reported by González-Alonso et al. (1999) that during exercise where dehydration and hyperthermia are induced, $\dot{Q}$ is reduced due to the decrease in V_s and the increase in f_c. The $\dot{Q}$ and V_s were not affected by acclimation in the present study. However the end exercise values were taken within 2 mins of end exercise, so therefore participants may have recovered slightly prior to measurements. Secondly, heat-acclimation-induced PV expansion has been shown to alter V_s (M. N. Sawka et al., 2011), however in the present study there was no significant change in PV post heat acclimation

One of the primary indexes of heat acclimation is the reduction in T_{re} (Garrett et al., 2014; Garrett et al., 2011; Neal et al., 2015; Nielsen et al., 1993). In the present study

end T_{re} was significantly reduced in hot conditions but end exercise T_{re} was not significantly different post heat acclimation in cool conditions, this finding contradicts that of Neal et al. (2015) who found a reduction in end exercise T_{re} post acclimation in thermoneutral conditions. However, the present study was under powered, with only 8 participants completing all cool trials compared to 10 in Neal et al (2015) study and 20 to the recommended amount of participants needed in the present study. Figure 5 appears to show a trend for lower T_{re} throughout all of the EST, however the number of participants may have affected the statistical outcome. A lower resting T_{re} is also an adaptation to the heat (Garrett et al., 2014; Garrett et al., 2011; Neal et al., 2015; Nielsen et al., 1993), however it was not evident in the present study. We were unable to control for the manner in which subjects arrived to the lab for the EST, albeit requesting to arrive in a rested state. For logistical reasons it was not possible to perform all trials the same time of day as the heat acclimation which took place in the mornings, and therefore may be accountable for the nonsignificant decrease in resting T_{re} in the hot condition.

The decrease in $\bar{T}_{sk}$ and $\bar{T}_{b}$ at 45 min in hot conditions is similar to that reported in other studies (Racinais et al., 2015; Taylor, 2000). $\bar{T}_{sk}$ was not found to be significantly lower post heat acclimation in cool conditions. This is similar to the results found by Chen et al. (2013), who reported no change in $\bar{T}_{sk}$ after a 5-day heat acclimation program. However this was a cycling study, with pre- and post-testing involving a $\dot{V}O_{2\,max}$ to exhaustion on a cycle ergometer. Also the heat acclimation regime used constant work rate compared to the controlled hyperthermia utilised in the present study. Neal et al. (2015) reported a significant decrease in $\bar{T}_{b}$ but not $\bar{T}_{sk}$.

4.1.2 Performance in the heat

There is abundance of research supporting the positive effect of heat acclimation on performance in hot conditions (Garrett et al., 2014; Nielsen et al., 1993). However, this research tends to use endurance based protocols. The present study investigated the effect of short-term heat acclimation on intermittent exercise performance. The performance measures were based on 9 x 6 sec maximal sprints on a Watt bike and a maximal running testing to exhaustion post 45 min, running based, intermittent exercise. It is evident from the results of these performance tests (Figure 6 & 9) that short-term heat acclimation improves intermittent exercise performance in hot conditions. The mean AvP of Sprint 7 and 9 was significantly improved post acclimation. Time to exhaustion also increased by a mean of 208 s post acclimation. Prior to acclimation, three participants ceased testing before completing the maximal test to exhaustion, either by voluntary withdrawal or had to be stopped due to T_{re} reaching 39.5°C. With all participants completing and improving in the maximal test to exhaustion post acclimation, proves short-term heat acclimation is effective for exercise performance in hot environments. The significant increase in sprint output indicates short-term heat acclimation is effective in improving intermittent exercise performance in hot conditions.

4.1.3 Performance in cool conditions

The limited literature available on heat acclimation and performance in cool/thermoneutral conditions has had varied results. Lorenzo et al. (2010) found a 6% improvement in work done during a time trial on a cycle ergometer, while Neal et al. (2015) found no improvement in time trial performance. The current study found significant improvements in time to exhaustion. Time to exhaustion increased by a mean of 43 s post acclimation. Therefore, it is evident short-term heat acclimation,

using controlled hyperthermia technique with dehydration, can improve intermittent exercise performance in cool conditions.

5. Conclusion

There were significant physiological adaptations and increase in work capacity after short-term heat acclimation, using hyperthermia technique with dehydration. These physiological adaptations were evident during exercise in the heat, resulting in lower end exercise T_{re}, $\overline{T}_{sk}$ and $\overline{T}_{b}$. Exercise performance increased post acclimation in both intermittent and incremental maximal exercise performance. Although there were limited physiological changes found during exercise in cool conditions, endurance exercise performance improved. Therefore it is possible to include short-term heat acclimation is effective for improving intermittent exercise performance in the heat and may be a beneficial training method for performance in cool conditions.

The results from this study may be beneficial to sports involving intermittent activity, particularly team sports. When competing in hot conditions, it is evident, a period of short-term heat acclimation/acclimatization, can significantly improve sprint performance and endurance activity in the heat. With many World Championship events being held in hot environments, teams from a cooler climate, e.g. UK, would greatly benefit from a period of heat exposure prior to competing in hotter climates. It is not possible to suggest a period of heat acclimation prior competition in the UK, however the results from the present study indicate an improvement in endurance exercise performance post 5-days heat acclimation, however sprint performance was not affected.

Limitations to the study include the small sample size and a varied level of fitness within the small sample size. With a greater population sample, more positive effects of short-term heat acclimation on intermittent exercise performance may have

been found in both the hot and cool environments. Also the 45 min exercise protocol was of a fixed intensity, with some subjects finding the intensity relatively easy and others finding it more difficult. Therefore further research could look at making the intermittent exercise relative to individuals for more accurate results. Also this study and the majority of heat acclimation research uses a male population sample, with limited research available on females, The current study may be carried out using a female population, adapting the treadmill running speeds, to add to the limited existing literature.

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APPENDICES

APPENDIX A: Ethics Application, EC1A & EC1B

APPENDIX B: Abstract accepted for presentation at the 16th International Conference on Environmental Ergonomics

EFFECTIVENESS OF SHORT-TERM HEAT ACCLIMATION ON INTERMITTENT EXERCISE IN THERMONEUTRAL AND HOT ENVIRONMENTS

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Introduction: It is well-established that repetition of heat stress exposure has been shown to facilitate adaptations to the heat but these protocols have tended to be of a fixed work intensity, continuous exercise, long-term in duration (>7 days) and use hydration. Secondly, there is limited information on the potential use of heat acclimation as a training method for human performance in thermoneutral conditions [1]. Therefore, the aims of this study were to investigate the effectiveness of short-term heat acclimation (STHA) for 5 days, using the controlled-hyperthermia technique with dehydration, on intermittent exercise in thermoneutral and hot environments.

Methods: Ten, healthy, active, moderately-trained males (Mean (SD); Age 25.6 (8.9) yrs; Height 180.7 (5.6) cm; Body Mass 83.2 (10.8) kg; 45.3 (6.5) mL.kg-1.min-1 and resting cardiac output 6.3 (1.8) L.min-1), participated in a STHA programme. This consisted of 90 minutes dehydration heat acclimation (no fluid intake) for 5 consecutive days (39.5 oC; 60% rh), using the controlled-hyperthermia technique (~rectal temperature [Tre] 38.5 oC) [2]. The pre and post testing Exercise Stress Test (EST) consisted of 45 minutes of intermittent exercise (nine phases of 5 minutes). Including resting, walking, moderate and high intensity running) on a motorised, h/p Cosmos treadmill; and nine 6 second (s) maximal sprints on a Watt Bike, as a repeated, maximal sprint performance test. The EST was followed by a running, incremental test to exhaustion. This EST intermittent protocol was adapted from exercise intensities of professional football players [3]. The EST was repeated in controlled conditions (C; 11 oC 45% rh); pre and post STHA in thermoneutral (TN; 11 oC 45% rh) and hot environments (H; 35 oC 45% rh). Data analysis was by paired t-test. Reported as the mean differences with 95% confidence intervals (95%CI) and Cohen's d effect size for magnitude of change (ES; Where 0.2-0.6 small; 0.6-1.2 moderate; 1.2-2.0 large; 2.0-4.0 very large).

Results: Post STHA, in the H trial at 45-min there was a decrease in Tre by -0.2 oC (95%CI: -0.40 to 0.00 oC; p=0.03; ES= -0.56), cardiac frequency (-3: -5 to -1 b.min-1; p=0.01; ES= -0.20) and RPE (-2: -3 to -1 units; p=0.01; ES=-0.56). Mean average power (MavP) increased in sprints 7 (111: 25 to 197 W; p=0.01; ES=0.93) and 9 (240: 9 and 489 W; p=0.04; ES=0.77). The increase in Sprint 8 (87: -8 to 182 W; p=0.06; ES=0.52) and time to exhaustion (208: -24 to 439 s; p=0.06; ES=0.63) were close to significance. In the TN trial, increased MavP for sprint 9 (67: 2 to 131 W; p=0.04; ES=0.47) and time to exhaustion (43: 1 to 85 s; p=0.04; ES=0.32) were reported. There was limited change in the C conditions across all nine sprints (p>0.05) and for time to exhaustion (-31: -72 to 11 s; p=0.12; ES=-0.18).

Discussion: Short-term heat acclimation (5 days) with dehydration, using the controlled-hyperthermia technique, is effective for physiological adaptations during intermittent exercise in a hot environment. Furthermore, it has resulted in an increase in intermittent and endurance exercise performance in hot and thermoneutral conditions.

Conclusion: Short-term heat acclimation is effective for intermittent exercise in the heat. It may be a useful training method for human performance in thermoneutral conditions.

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3. Drust, B., Atkinson, G. & Reilly, T. (2007). Future perspectives in the evaluation of the physiological demands of soccer. Sports Medicine, 37 (9), 783-803.

APPENDIX C: Publication in Extreme Physiology & Medicine, 2015

Department of Sport, Health & Exercise Science

UNIVERSITY OF **Hull**
Faculty of Science

RISK CHECKLIST AND STAGE 1 - RESEARCH ETHICS APPROVAL FORM

All research carried out by students and staff in the Department of Sport, Health & Exercise Science must receive ethical approval before the project or study begins.

Forms
- All applicants MUST complete this Risk Checklist and Stage 1 - Research Ethics Approval Form.
- Applicants whose research studies are classified as Risk Category 2 or 3 must also complete the separate Stage 2 - Research Ethics Approval Form.

Notes for completion

- *University Research Ethics Policy and Research Ethics Procedures*
  The University Research Ethics Policy and Research Ethics Procedures should be read prior to the completion of this application. Consideration of the application will be undertaken in accordance with the University's Research Ethics Policy and Procedures.
- *Professional, Statutory or Regulatory Bodies*
  Applicants should consider any additional requirements by any relevant Professional, Statutory or Regulatory body; and any other bodies (for example, learned societies) which may be relevant to the subject area in question. Where the project comes under the jurisdiction of the National Research Ethics Service, a copy of the approval from an NHS Research Ethics Committee should be included in the submission.

Submission
Students: please email the typed form/s to your Research Supervisor / Director of Studies.
Staff: please email the completed form/s to Alicia Milson, Departmental Administrator who will log your application and then forward to an appropriate Local Research Ethics Co-ordinator (LREC) for consideration. Please make sure the DISCIPLINE box is completed which will ensure that the appropriate LREC receives the application.

How to complete the form
You can navigate through the form by using the tab keys.

Signatures
Electronic/typed signatures are acceptable for emailed forms.

Outcome
Applicants will be advised of the outcome of the application by:
- The Research Supervisor or Director of Studies for Risk Category 1 student projects;
- The Local Research Ethics Co-ordinator or the Faculty Research Ethics Committee for Risk Category 2 and 3 projects.

You may only begin your research when you receive notification that the project has ethical approval.

If the circumstances of your research study change after approval it is your responsibility to revisit the Risk Checklist and complete a further application.

Advice
Complete the Risk Checklist and Stage 1 - Research Ethics Approval Form first. If you are uncertain about the answer to any question:
- Seek guidance from your Research Supervisor or Director of Studies (students only);
- Contact your Local Research Ethics Co-ordinator (staff only).

CONFIRMATION STATEMENTS	
The results of research should benefit society directly or by generally improving knowledge and understanding. Please tick this box to confirm that your research study has a potential benefit. *If you cannot identify a benefit you must discuss your project with your Research Supervisor to help identify one or adapt your proposal so the study will have an identifiable benefit.*	☒
Please tick this box to confirm you have read the Research Ethics Procedures and will adhere to these in the conduct of this project.	☒

RISK CHECKLIST - Please answer ALL the questions in each of the sections below

WILL YOUR RESEARCH STUDY……..?

	RISK CATEGORY 1	YES	NO
1	Involve direct and/or indirect contact with human participants?	☒	☐
2	Involve analysis of pre-existing data which contains sensitive or personal information?	☐	☒
3	Require permission or consent to conduct?	☒	☐
4	Require permission or consent to publish?	☐	☒
5	Have a risk of compromising confidentiality?	☐	☒
6	Have a risk of compromising anonymity?	☐	☒
7	Contain sensitive data?	☐	☒
8	Involve risks to any party, including the researcher?	☐	☒
9	Contain elements which you OR your supervisor are NOT trained to conduct?	☐	☒
10	Use any information OTHER than that which is freely available in the public domain?	☐	☒
	RISK CATEGORY 2		
11	Require permission or informed consent OTHER than that which is straightforward to obtain in order to conduct the research?	☐	☒
12	Require permission or informed consent OTHER than that which is straightforward to obtain in order to publish the research?	☐	☒
13	Require information to be collected and/or provided OTHER than that which is straightforward to obtain?	☐	☒
	RISK CATEGORY 3		
14	Involve participants who are particularly vulnerable or at risk? (e.g. young people, prisoners, sports disability groups)	☐	☒
15	Involve participants who are unable to give informed consent?	☐	☒
16	Involve data collection taking place BEFORE informed consent is given?	☐	☒
17	Involve any deliberate deception or covert data collection?	☐	☒
18	Involve a risk to the researcher or participants beyond that experienced in everyday life?	☐	☒
19	Cause (or could cause) physical or psychological harm or negative consequences?	☐	☒
20	Use intrusive or invasive procedures?	☒	☐
21	Involve a clinical trial?	☐	☒
22	Include a financial incentive to participate in the research?	☐	☒
23	Involve the possibility of incidental findings related to health status?	☐	☒
24	Involve your own students or staff (this question is for STAFF MEMBERS ONLY)	☐	☐

CLASSIFICATION - Please answer the following questions in order to classify the risk level of your study

C1 – Did you answer 'YES' to any of the questions (1 to 24) in the Risk Checklist above?

Yes	☒	Please go to question C2
No	☐	If you answered **NO** to all the above questions, your study is classified as **Risk Category 1** (literature reviews will be Risk Category 1)

C2 – Did you answer 'YES' to any of the questions in Rick Category 3 (14 to 24) of the Checklist above?

Yes	☒	If you answered **YES** to any question in Risk Category 3, your study is classified as **Risk Category 3** (unlikely to be appropriate for undergraduate students – with the exception of working with young people)
No	☐	If you answered **NO** to all the questions in Risk Category 3 (but you answered yes to questions in Risk Categories 1 and/or 2), your study is classified as **Risk Category 2**

APPROVAL PROCESS

Category	Student applicants	Staff applicants
Risk Category 1	If your study has been classified as Risk Category 1, your Supervisor or Director of Studies can give approval for the project. You must complete the remainder of this form and submit it to your Research Supervisor for consideration. A copy of the signed form must be given to Alicia Milson, Departmental Administrator.	If your study has been classified as Risk Category 1, you do not need ethical approval for the project. You must complete the remainder of this form so that your research project is registered with the University. Please submit this form to Alicia Milson.
Risk Category 2	If your study has been classified as Risk Category 2, your Supervisor or Director of Studies can recommend approval for your study by the Local Research Ethics Coordinator. You must complete the remainder of this application form and also the separate Stage 2 - Research Ethics Approval form. Once you have completed the forms please submit both forms to your Supervisor for consideration. Your Supervisor may disagree with your assessment and ask you to make revisions or reject your application. The Local Research Ethics Coordinator will review your project and then decide to approve it, ask for revisions, reject it or pass it on for review via the Chair to the Faculty Research Ethics Committee.	If your study has been classified as Risk Category 2, your project will be considered for ethical approval by the Local Research Ethics Coordinator. You must complete the remainder of this application form and also the separate Stage 2 - Research Ethics Approval form. Please submit both forms to your Local Research Ethics Coordinator for consideration. The Local Research Ethics Coordinator will review your project and then decide to approve it, ask for revisions or pass it on for review via the Chair to the Faculty Research Ethics Committee.
Risk Category 3	Postgraduate Research Students If your study has been classified as Risk Category 3, you should consult with your Director of Studies as you will normally need to submit to the appropriate Faculty Research Ethics Committee for approval. You must complete the remainder of this application form and also the separate Stage 2 - Research Ethics Approval form and submit both forms to your Director of Studies. Undergraduate and Taught Postgraduate Students If your study has been classified as Risk Category 3, you should consult with your Supervisor without delay as it is highly unlikely you will be able to proceed with your study and you should negotiate a project that is of lower risk. The exception may be working with young people.	If your study has been classified as Risk Category 3, your project will be considered for ethical approval by an appropriate Local Research Ethics Coordinator. You must complete the remainder of this application form and also the separate Stage 2 - Research Ethics Approval form and submit both forms to your Local Research Ethics Coordinator. In some instances, Risk Category 3 projects will need to be considered by the appropriate Faculty Research Ethics Committee.

APPLICATION DETAILS

APPLICANT DETAILS:	
DISCIPLINE	Environmental Physiology PSYCH,BIOMECH) (PLEASE INSERT DISCIPLINE AREA I.E. COACHING, REHAB, PHYS,
Your name (if a group project, include all names here)	Fiona Nation and Matthew Birkett
Department	Sport, Health & Exercise Science
Faculty	Science
Status	
• Undergraduate student	☐
• Taught Postgraduate student	☐
• Research Postgraduate student	☒
• Staff member	☐
• Other (give details)	
If student project	
• Student ID	201005676 and
• Course title with award	MSc Sports Science
• Student email	F.Nation@2013.hull.ac.uk and M.Birkett@2013.hull.ac.uk
• Research Supervisor's name Or Director of Studies' name	Dr Andrew Garrett
THE PROJECT/STUDY:	
Project /study title	
Start date of project	30/9/2013
Expected completion date of project	31/8/2015
Is the project externally funded	No

Project Summary - Please give a brief summary of your study (maximum 100 words):

The purpose of the study is to investigate the affects of short-term heat acclimation on intermittent activity performance in both hot (31 degrees/45% RH) and temperate (11 degrees/45% RH) conditions. The project will consist of 5 days heat acclimation aswell as an intermittent pre and post performance test in both hot and temperate conditions.

NEXT STEP:

IF YOUR PROJECT HAS BEEN CLASSIFIED AS **RISK CATEGORY 1,** PLEASE COMPLETE THE DECLARATION BELOW AND:

• Students: please submit this form to your Research Supervisor or Director of Studies in the first instance for signature. A copy must then be submitted to Alicia Milson for information.

• Staff: please submit this form to Alicia Milson.

IF YOUR PROJECT HAS BEEN CLASSIFIED AS **RISK CATEGORY 2 OR 3** PLEASE DO NOT COMPLETE THE DECLARATION BELOW. Instead you MUST now also complete the Stage 2 - Research Ethics Approval form and submit both forms together with any supporting documentation.

RISK CATEGORY 1: DECLARATION AND SIGNATURE/S

I confirm that I will undertake this project as detailed above. I understand that I must abide by the terms of this approval and that I may not make any substantial amendments to the project without further approval.

Signed		Date	

FOR STUDENT PROJECTS:

Agreement from the Research Supervisor or Director of Studies for student projects:
I have discussed the ethical issues arising from the project with the student. I approve this project.

Name		Signed		Date	

Local Research Ethics Co-ordinator (LREC) name		Date form sent to LREC	

- **PLEASE MAKE SURE THAT BOTH STUDENT AND SUPERVISOR SIGN THE EC1A FORM IF YOU ARE CONDUCTING A LOW RISK PROJECT.**
- **IF YOU ARE CONDUCTING A HIGHER RISK PROJECT WHICH REQUIRES COMPLETION OF THE EC1B – PLEASE MAKE SURE THAT THIS FORM IS SIGNED BY BOTH STUDENT AND SUPERVISOR.**
- **PLEASE FORWARD ALL SUPPORTING DOCUMENTATION IN A ZIPPED FILE TO THE EMAIL DROP-BOX BELOW FOR PROCESSING:**

Email: ethics-shes@hull.ac.uk

This form will be retained for the purposes of quality assurance of compliance and audit for FIVE years

Department of Sport, Health & Exercise Science	UNIVERSITY OF **Hull** Faculty of Science

STAGE 2 - RESEARCH ETHICS APPROVAL FORM

All research carried out by students and staff in the Department of Sport, Health & Exercise Science must receive ethical approval before the research or data collection commences.

Forms

- All applicants MUST complete the Risk Checklist and Stage 1 - Research Ethics Approval Form prior to completing this Stage 2 - Research Ethics Approval Form.
- Following completion of the Risk Checklist and Stage 1 - Research Ethics Approval Form, if your research study was classified as Risk Category 2 or 3, you need to complete this form.

Please ensure you include specific details in the appropriate section below especially where a question in the Risk Checklist was answered YES. If a section is not relevant to your project, put 'Not Applicable' or 'N/A'. Please make sure the DISCIPLINE box is completed which will ensure that the appropriate LREC receives the application.

TO BE COMPLETED FOR PROJECTS IN RISK CATEGORY 2 AND 3	
DISCIPLINE	Physiology (PLEASE INSERT DISCIPLINE AREA I.E. COACHING, REHAB, PHYS, PSYCH,BIOMECH)
Your name	Fiona Nation and Matthew Birkett

THE PROJECT	
1	**Project title**
The effect of short-term heat acclimation on intermittent activity performance in hot and temperature environments	
2	**Purpose and Aims**
What are the purpose and aims of this research?	
The purpose of the study is to investigate the effect of 5-day heat acclimation on performance, using an intermittent activity based protocol, in both hot (31 degrees/45% RH) and temperate (11 degrees/45% RH) conditions.	

3	**Project Description**
Describe the project, identifying clearly any human participants and/or secondary datasets involved (this should be a summary description. Details of methodology are required later). What is the intended project duration?	
The collection data for this project has been propsed to commence in February 2014 and expected to run until June 2014. 10 participants will be recruited for this project. Healthy, trained male participants will be recruited from the University of Hull using multiple advertising methods.	

4	**Risk: participants**
Provide a statement of risk consideration and evaluation in respect of the participants including how any elements of risk will be addressed.	
The project will use standard testing procedures which should minimise any risk to the participants involved. There are small risks of injury and cardiovascular events happening during any form of exercise, however each participant will be screened prior to any exercise. Participants will be excluded from the study if they have been advised not to exercise by a medical profession or if during screening exhibit any risk factors.	
The pre and post test, consisting of a 90 minute intermittent activity protocol, will include a standardised warm-up and cool down to minimise the risk of injury to participants.	
Blood samples will be collected during the 5-day heat acclimation by both venepuncture and finger prick method. There is a risk of bruising from these methods aswell as some physical discomfort, however this should be minimal. There	

is also a small risk of infection when sampling blood, however standard infection control procedures will be in place to prevent infection; use of alcohol wipes to prepare the puncture site, use of sterile needles and equipment. Blood samples will be taken by those who have been trained at Castle Hill Hospital under NHS supervision.

During all testing there will be a first aider immediately available in case of a medical emergency. An automated external defibrillator (AED) will be available. Emergency medical services will be summoned if necessary by contacting Security on ext. 5555.

5	Risk: researchers / other parties

Provide a statement of risk consideration and evaluation in respect of the researchers and any other parties (eg, the University), including how any elements of risk will be addressed.

There should be minimal risk to other parties involved in the study. Parties most at risk will be those directly involved in data collection. Risks expected are trips/falls, injury from lifting/moving equipment.

There is a risk of infection from the collection and handling of bodily fluids. Those handling bodily fluids will be trained in proper technique to reduce risk of cross-infection and the use of personal protective equipment (PPE) will further reduce risk associated with this activity.

6	Health and Safety
6a	In addition to any factors considered under 'risk' above, are there any other health and safety issues either for participants or researchers? (eg, in relation to premises, equipment, etc)
N/A	
6b	Has advice been taken on how these might be addressed, from whom, and when?
N/A	

METHODOLOGY	
7	Human Participants
7a	Describe the size and nature of group and the rationale for selection. Describe how potential participants will be identified, approached and recruited. Please include inclusion/exclusion criteria.

The project will aim to recruit 10 healthy, trained males from the University of Hull. Participants will have to be trained and free from any medical condition preventing them from exercise due to the nature of the protocol; 90 minute intermittant activity. The participants will be recruited using a number of methods including email circulation and poster advertising.

Inclusion criteria:
Healthy, trained males
Free from injury and medical conditions preventing exercise

Exlusion criteria:

7b	What information is being given to participants? The proposed Information Sheet must be included.

The participants will be provided with information on the experimental protocol, what they should expect and what they are required to do during the study.

7c	How is consent being obtained? The proposed consent form must be included.

Written consent will be taken on the first week of the project

7d	What steps are being taken to ensure that participation is voluntary?

The participants will have to contact the research team to enquire about the project. They will be made fully aware that they do not have to participate in the study and that they are obliged to drop out at anytime during the study. This information will be communicated in written form as well as verbally.

7e	What provisions for participants' withdrawal from the project are in place?

Participants can withdraw from the study at anytime by contacting a member of the research team.	
7f	Is it intended to pay participants? If yes, include the rationale for this, with payment rates and source of funding.
No	
7g	Children and Adults at risk: How is informed consent being obtained? The proposed Consent (and Assent Form where appropriate) must be included. If it is anticipated that consent is not in written form, full justification for this approach must be included.
N/A	

8	**Confidentiality and Anonymity**
8a	How will anonymity of participants be secured?
Each participant will be assigned a unique identification number. This number will be used on all documentation. After the data collection phase of the project concludes, all identification of the participants will be removed or destroyed and all analysis will be done annoymously.	
8b	How will confidentiality of personal information and/or information provided by participants be secured?
Only members of the research team will have access to confidential information. Hard copies of documents and forms will be stored securely in the Department of Sport, Health and Exercise Science, or in a safe and secure location off site. Any electronic data will be saved on an encrypted USB drive or University networked computing accounts, which only members of the research team will be able to access.	
8c	Are there circumstances in which the requirements of professional practice might impact on confidentiality and anonymity provisions?
N/A	
8d	Are there any issues relating to information provided by public bodies, corporations, contractors etc?
N/A	
8e	If the identity of a person, company, etc, is likely to be disclosed or inferred or discoverable, how will this be discussed with the potential participant(s), and what impact might the outcomes of this have on the proposed project?
N/A	
8f	How will any participants or subjects be clearly informed about any limits to confidentiality, their rationale and the possible outcomes?
N/A	

9	**Project Design**
9a	Has statistical or methodological advice been sought on the size and/or design of the project? If so, from whom?
9b	If a questionnaire is to be used, it is recognised that this may be subject to change during the life of the project. The remit of the questionnaire and an advanced draft of this must be included, with, where possible, an outline indication of the expected development of the enquiry.
N/A	
9c	If interviews (structured or semi-structured) are to be used, it is recognised that these may be subject to change during the life of the project. The remit of the interviews and an advanced draft of their format must be included, with, where possible, an outline indication of the expected development of the enquiry.
N/A	
9d	If procedure(s) are to be carried out on the participants, what are these?
VO2 peak	

90 minute intermitant exercise protocol followed by maximal test to exhaustion

Finger prick blood sampling

Venepuncture blood sampling

9e	Is the researcher and/or Research Supervisor qualified to carry out these procedures?
Yes	

10	**Covert Research**: if the project involves covert research, give details here
Explain the rationale for the use of this approach and explain why it is necessary to use this particular methodology successfully to undertake the research and achieve its purpose and aims.	
N/A	

11	**Secondary datasets**: if the project involves secondary data, give details here
11a	Describe the size and nature of the group and the rationale for selection. Who holds the documents and data?
N/A	
11b	Are there any limits or restrictions placed on access to and/or use of these documents or data?
N/A	
11c	Statement of permission for use from all document/data holders, including any restrictions, **must** be included here.
N/A	

12	**Dissemination of Results**
12a	What is the planned method of dissemination? (eg, undergraduate dissertation, doctoral thesis, research report, intended publication in…)
12b	Will any restrictions be placed on the dissemination/publication of results?
None expected	

13	**Data Security and Disposal**
13a	Is the researcher aware of the requirements of the Data Protection Act? (eg: has the processing of the data been considered; have the operations necessary been identified; and has the issue of the sensitivity of the data been considered in relation both to data protection and general lawfulness?)
13b	What provisions have been considered for the secure retention of sensitive or personal data?
13c	What provisions are in place for the secure destruction of this data, and when is it anticipated that this should take place?
13d	Where results are collected individually, but the outcomes are anonymised, what data protection procedures are

	in place to ensure the protection of personal details and at what point and how will these be destroyed?

14	**Intellectual Property**
14a	Is the researcher aware of the wide variety of reproduction methods which are restricted in respect of protected data; and the possible implications of any copyright infringements?
14b	Have any relevant permissions in respect of this been obtained (eg, the use of unpublished material)?
14c	If online material is being used, are there any international laws which impact on this?
14d	Is there knowledge of how to use licences and assignment of rights when creating or using material protected as intellectual property?

15	**Independence**
15a	Is the project externally funded? If so by whom? Does this entail any actual or potential conflict of interest?
15b	Has the funding body placed any restrictions on the conduct or publication of the research?
15c	Is it intended that application will be made to an external funding body subsequent to receipt of faculty approval? If so, to whom? Is it fully understood that if any subsequent application is made to an external funding body, and that body seeks to impose any restrictions or conditions on the project, that this must be reported to the faculty and approval granted for these restrictions or conditions?

16	**Overseas Research**: if the project is based overseas (outside of the UK), give details here
16a	In which country or countries is it proposed that the investigation take place?
16b	Is the proposal in accordance with the laws of the country or countries in which it is proposed that the investigation take place, and how has this been ascertained?
16c	Does the proposal comply with local laws on Data Protection and Intellectual Property? If yes, how has this been ascertained?

17	**Collaborative projects**: if the project is a collaboration, give details here
17a	With which institutions is the project being conducted and who is the project director?
17b	Has ethical approval been given by all other institutions involved? (Confirmatory documentation **must** be included). If ethical approval is in process, when is this expected to be completed?

17c	What processes have been put in place, or will be put in place, to ensure ethical compliance across all elements of the project?

FOR PROJECTS INVOLVING RISK CATEGORY 2 AND 3: DECLARATION AND SIGNATURE/S

STUDENT/RESEARCHER/APPLICANT

I confirm that I will undertake this project as detailed in stage one and stage two of the application. I understand that I must abide by the terms of this approval and that I may not make any amendments to the project without further approval. I understand that research with human participants must not commence without ethical approval.

Signed		*Date*	

RESEARCH SUPERVISOR/DIRECTOR OF STUDIES RECOMMENDATION FOR STUDENT PROJECTS

I confirm that I have read stage one and stage two of the application. The project is viable and the student has appropriate skills to undertake the project. The Participant Information Sheet and recruitment procedures for obtaining informed consent are appropriate and the ethical issues arising from the project have been addressed in the application. I understand that research with human participants must not commence without ethical approval. I recommend this project for approval.

The student has completed a risk assessment form:		Yes ☐ N/A ☐	
The student has read an appropriate professional or learned society code of ethical practice:		Yes ☐ N/A ☐	
Where applicable, give the name of the professional or learned society:			
Name		*Signed*	*Date*

For projects approved by the Research Ethics Co-ordinator
LOCAL RESEARCH ETHICS CO-ORDINATOR APPROVAL

I confirm ethical approval for this project

Name		*Signed*		*Date*	

For projects that require Faculty level approval
LOCAL RESEARCH ETHICS CO-ORDINATOR'S RECOMMENDATION FOR FACULTY APPROVAL

I recommend this project for consideration at faculty level. It cannot be approved at local level due to the following reason(s)

Name		*Signed*		*Date*	

PROJECTS APPROVED BY THE FACULTY RESEARCH ETHICS COMMITTEE

I confirm that this project was considered by the Faculty Research Ethics Committee and has received ethical approval

Chair		*Signed*		*Date*	

This form will be retained for the purposes of quality assurance of compliance and audit for FIVE years

INFORMATION TO SUBMIT WITH THE APPLICATION

INFORMATION SHEET AND CONSENT FORM: You must submit the information sheet/s for participants and assent/consent form/s (where appropriate) with the application. You must submit every communication letter and measurement tool e.g. questionnaire that a participant will see or receive. Failure to do so will result in delays to the application.

SUBMISSION CHECKLIST	Tick box (where relevant)
EC1A RISK CHECKLIST AND STAGE 1 – RESEARCH ETHICS APPROVAL FORM	☐
EC1B STAGE 2/3 – RESEARCH ETHICS APPROVAL FORM	☐
Research proposal/protocol (no more than 3 pages of A4)	☐
Participant Information Sheet/s	☐
EC2 Informed Consent Form/s	☐
EC2-U18 Assent Form (for children)	☐
Recruitment documents (eg, posters, flyers, email invitations, advertisements)	☐
Measures to be used (eg, questionnaires, surveys, interview schedules, psychological tests)	☐
Letters/communications to and from gatekeepers	☐
Evidence of any other approvals or permissions (eg, NHS research ethics approval)	☐
EC3 Risk assessment form	☐
For projects involving ionising radiation, approval documentation	☐
Confirmation of insurance cover (required for certain projects – check if in doubt)	☐
Other: give details here: Evidence of (enhanced) CRB certificate (if appropriate)	☐
EC4 Pre-exercise medical history questionnaire	☐
Letters/communications with head teachers	☐

SUBMISSION DETAILS

Students: please email the completed forms (stage one and stage two) and other relevant documentation (see Submission Checklist above) to your Research Supervisor / Director of Studies.

- **PLEASE MAKE SURE THAT BOTH STUDENT AND SUPERVISOR SIGN THE EC1A FORM IF YOU ARE CONDUCTING A LOW RISK PROJECT.**
- **IF YOU ARE CONDUCTING A HIGHER RISK PROJECT WHICH REQUIRES COMPLETION OF THE EC1B – PLEASE MAKE SURE THAT THIS FORM IS SIGNED BY BOTH STUDENT AND SUPERVISOR.**
- **PLEASE FORWARD ALL SUPPORTING DOCUMENTATION IN A ZIPPED FILE TO THE EMAIL DROP-BOX BELOW FOR PROCESSING:**

Email: ethics-shes@hull.ac.uk

Extreme Physiology & Medicine

MEETING ABSTRACT

Open Access

Effectiveness of short-term heat acclimation on intermittent exercise in thermoneutral and hot environments

Fiona Nation, Matt Birkett, Damien Gleadall-Siddall, Rachel Burke, Christopher Towlson, James Bray, Grant Abt, Andrew Garrett[*]

Introduction

It is well-established that repetition of heat stress exposure has been shown to facilitate adaptations to the heat but these protocols have tended to be of a fixed work intensity, continuous exercise, long-term in duration (>7 days) and use hydration. Secondly, there is limited information on the potential use of heat acclimation as a training method for human performance in thermoneutral conditions [1]. Therefore, the aims of this study were to investigate the effectiveness of short-term heat acclimation (STHA) for 5 days, using the controlled-hyperthermia technique with dehydration, on intermittent exercise in thermoneutral and hot environments.

Methods

Ten, healthy, active, moderately-trained males (Mean (SD); Age 25.6 (8.9) yrs; Height 180.7 (5.6) cm; Body Mass 83.2 (10.8) kg; $\dot{V}O_{2\,max}$ 45.3 (6.5) mL.kg^{-1}.min^{-1} and resting cardiac output 6.3 (1.8) L.min^{-1}), participated in a STHA programme. This consisted of 90 minutes dehydration heat acclimation (no fluid intake) for 5 consecutive days (39.5 °C; 60% rh), using the controlled-hyperthermia technique (~rectal temperature [T_{re}] 38.5 °C) [2]. The pre and post testing Exercise Stress Test (EST) consisted of 45 minutes of intermittent exercise (nine phases of 5 minutes). Including resting, walking, moderate and high intensity running) on a motorised, h/p Cosmos treadmill; and nine 6 second (s) maximal sprints on a Watt Bike, as a repeated, maximal sprint performance test. The EST was followed by a running, incremental test to exhaustion. This EST intermittent protocol was adapted from exercise intensities of professional football players [3]. The EST was repeated in controlled conditions (C; 11 °C 45% rh); pre and post STHA in thermoneutral (TN; 11 °C 45% rh) and hot environments (H; 35 °C 45% rh). Data analysis was by paired t-test and reported as the mean differences with 95% confidence intervals (95%CI).

Results

Post STHA, in the H trial at 45-min there was a decrease in T_{re} by -0.2 °C (95%CI: -0.40 to 0.00 °C; p = 0.03), cardiac frequency (-3: -5 to -1 b.min^{-1}; p = 0.01) and RPE (-2: -3 to -1 units; p = 0.01). Mean average power (MavP) increased in sprints 7 (111: 25 to 197 W; p = 0.01) and 9 (240: 9 and 489 W; p = 0.04). The increase in Sprint 8 (87: -8 to 182 W; p = 0.06) and time to exhaustion (208: -24 to 439 s; p = 0.06) were close to significance. In the TN trial, increased MavP for sprint 9 (67: 2 to 131 W; p = 0.04) and time to exhaustion (43: 1 to 85 s; p = 0.04) were reported. There was limited change in the C conditions across all nine sprints (p > 0.05) and for time to exhaustion (-31: -72 to 11 s; p = 0.12).

Discussion

Short-term heat acclimation (5 days) with dehydration, using the controlled-hyperthermia technique, is effective for physiological adaptations during intermittent exercise in a hot environment. Furthermore, it has resulted in an increase in intermittent and endurance exercise performance in hot and thermoneutral conditions.

Conclusion

Short-term heat acclimation is effective for intermittent exercise in the heat. It may be a useful training method for human performance in thermoneutral conditions.

* Correspondence: a.garrett@hull.ac.uk
Department of Sport, Health and Exercise Science, Exercise Health and Human Performance Research Group, University of Hull, UK

References

1. Corbett J, Neal RA, Lunt HC, Tipton MJ: Heat acclimation and exercise performance under cooler conditions: a new hot topic. *Sports Medicine* 2014, **44**:1323-1331.
2. Garrett AT, Goosens NG, Rehrer NJ, Patterson MJ, Harrison J, Sammut I, Cotter JD: Short-term heat acclimation is effective and is not impaired by dehydration during acclimation. *American Journal Human Biology* 2014, **26**:311-320.
3. Drust B, Atkinson G, Reilly T: Future perspectives in the evaluation of the physiological demands of soccer. *Sports Medicine* 2007, **37**(9):783-803.