

A heat acclimation protocol for team sports.

Running title: Heat acclimation and team sports

Keywords: acclimatisation, females, intermittent exercise, high-intensity

Abstract

Background: It is well documented that heat acclimation of 6 or more sessions of at least 60 min duration prolongs the time to exhaustion during endurance walking, cycling and running in the heat. **However, this type of acclimation is not specific to team sport activity and the effect of acclimation on prolonged high intensity intermittent running has not yet been investigated.**

Objective: To assess the impact of an intermittent acclimation protocol on distance run during team sport activity.

Methods: The impact of 4 short heat acclimation sessions (30 – 45 min of the Loughborough Intermittent Shuttle Test; LIST) on high-intensity intermittent running **capacity** (LIST) in the heat (30°C, 27% RH), was examined. Seventeen female well-trained games players were split into 3 groups; an acclimation group (30°C, 24% RH), a moderate training group (18°C, 41% RH), and a control group who did not complete any training between the main trials (pre- and post-acclimation). The **pre- (A) and post-acclimation (B) trials** were separated by 28 days to control for menstrual phase and verified using hormonal analysis. The 4 acclimation or moderate training sessions utilising the LIST were completed with one or two rest days interspersed between each session in a 10-day period prior to the post-acclimation trial (**B**).

Results: In the **post-acclimation trial** distance run was increased by 33% in the acclimation group (**A: 7703 ± 1401 vs B: 10215 ± 1746m**; interaction group x trial $P < 0.05$), but was unchanged in the moderate and control groups. The acclimation group had a lower rectal temperature (interaction group x trial x time $P < 0.01$) due to a lower rate of rise, and an increase in thermal comfort [**1**] after acclimation (**End A: 7 ± 2 vs 6 ± 2**; interaction group x trial $P < 0.01$). There was no difference in serum

progesterone, aldosterone or cortisol concentrations following acclimation or between groups.

Conclusion: Four **30-45 min** sessions of intermittent exercise induced acclimation, and **resulted** in an improvement in intermittent running exercise capacity **in female games players**. **A lower rectal temperature and a concomitant rise in thermal comfort may be partly responsible for the improvement in exercise capacity.**

Acclimation and acclimatisation have been shown to improve thermal tolerance and endurance capacity.[2-5] Typically the acclimatisation/acclimation protocols which induce thermoregulatory and cardiovascular adaptations involve low intensity exercise (50-60% $\dot{V}O_2$ max) of a prolonged duration (>60 min).[2,5-7] Most research acclimation protocols do not require participants to exercise at very high intensities or to exhaustion.[2,3,6] Interestingly, in studies which have exercised participants to exhaustion, improvements in capacity **have been** seen after just 1 day.[5] Also, Houmard and colleagues[8] have shown that by increasing exercise intensity **individuals** can **achieve** similar adaptations as those **attained by exercising at lower intensity for a longer duration.**

High-intensity intermittent exercise in the heat (35°C) has previously been demonstrated to provide a greater thermal strain than continuous exercise and may therefore be a more powerful stimulus for acclimation.[7,9] A rapid rise in body temperature during high-intensity intermittent running in the heat has previously been reported with a rise of >1.8°C in women in 30 min.[10,11] A high deep body temperature has been suggested to be a key determinant in adaptations to heat acclimation[7,8,12] and thus the attainment of **a high absolute** temperature in a short time period may be advantageous for heat acclimation.

To date, almost all acclimation studies have used men, yet elite sports women are performing in hot conditions. Research that has compared male and female responses to heat acclimation have used prolonged low intensity exercise and showed that the responses to acclimation were similar despite men having higher sweat rates than women.[3,4] Avellini and coworkers[3] suggested that women are more efficient

regulators of body temperature and may demonstrate a more efficient suppression of non-evaporative sweat output.

The major **tournaments** for team sports often take place in hot environmental conditions (**Football** World Cup, 2006; Beijing Olympics 2008). Clearly the need for team sport performers to acclimatise is evident, but the need to complete **technical** and **tactical-based** training means that opportunity and time is limited. The use of prolonged **low-intensity** exercise for acclimation for team sport activity is time demanding and is not specific to the requirements of the game. Furthermore, during the **final** few weeks prior to competition, players would be expected to taper rather than to be increasing the volume of their training.

Evidently it is yet to be established if short (30/45 min) bouts of high-intensity exercise, interspersed with recovery days (to allow for team tactical sessions and meetings to be completed), can induce adaptation in well-trained female games players. Such an investigation would be of physiological interest and would potentially have considerable practical application.

Therefore, the purpose of the present study was to test the hypothesis that 4 high-intensity intermittent acclimation sessions would improve the exercise capacity of well-trained female games players during games type activity in a hot environment.

METHODS

Participants

Following Institutional Ethical Committee approval 17 well-trained female games players volunteered for the study (13 had normal menstrual cycles, 4 were taking monophasic oral contraceptives [OC]). The participants were divided into 3 groups: acclimation (n = 6, 1 OC); training (n = 6, 2 OC); and control (n = 5, 1 OC). The age, height, body mass, and estimated $\dot{V}O_2$ max of the acclimation, training and control groups was (mean [SEM]) 20.1 (0.6), 20.3 (0.8), 21.3 (0.9) years; 169.4 (3.0), 165.3 (3.8), 165.2 (1.4) cm; 68.5 (3.1), 63.2 (4.4), 66.1 (4.3) kg; and 49.7 (2.2), 49.3 (1.8), 49.1 (1.8) ml·kg⁻¹·min⁻¹ respectively. All participants gave their written informed consent.

Experimental design

All participants performed an intermittent exercise protocol (the Loughborough Intermittent Shuttle Test (LIST)[13]) in hot conditions (30.5 (0.0)°C, 27 (0.1)% RH), on two occasions (trial A then B; Figure 1). Both **trials** (A then B) were performed **28 (1) days apart** in the same phase of each subject's menstrual cycle, and this was verified by analysis of progesterone concentrations. In brief, the LIST requires participants to complete repeated 15-min sets of variable speed shuttle running over a 20-m distance (Figure 2). Each set is separated by **3 min of** passive recovery. In trials A and B participants ran until volitional exhaustion, or until rectal temperature exceeded 40°C. In the 10 days before trial B the participants in the acclimation and training groups completed 4 training sessions. In the first two training sessions 2 sets of the LIST were completed, **whereas 3 sets were completed in the final two**

training sessions. Training sessions were separated by at least **one**, and by no more than **two** days rest, and all participants had **one** day of rest prior to trial B. The acclimation and training groups performed the training sessions in hot (30 (0.2)°C, 24 (1.3)% RH) or moderate (18 (1.1)°C, 41 (2.4)% RH) environmental conditions respectively. The control group did not undertake any specified training between trials A and B. **Water was drunk ad libitum in both the hot and moderate training sessions.**

Preliminary measurements

Maximal oxygen uptake was estimated,[14] and then used to calculate appropriate 'cruise' and 'jog' speeds (85% and 50% $\dot{V}O_2$ max respectively) for the LIST (see Figure 2). For familiarisation purposes, and because it was a stipulated requirement of the Ethical Committee, all participants performed 2 sets of the LIST (33 (0) minutes) in 30°C prior to trial A. This session was completed 7 days before trial A to prevent any acclimation response.[unpublished observations]

Main trials

In the 2 days prior to trial A participants recorded their diet and this was repeated prior to trial B. Participants completed trial A and B at the same time of day to control for circadian influences.

On the morning of the main trials participants reported to the laboratory 12 h after their last meal. Nude body mass was recorded and then a cannula was inserted into a forearm vein, and kept patent with an isotonic saline solution. A rectal probe (Edale Instruments Ltd., UK) was inserted to a depth of 10 cm beyond the anal sphincter.

Fifteen minutes after cannulation, during which time participants remained standing, a resting **12-ml** blood sample was collected. Participants then moved into the gymnasium and a resting rectal temperature was recorded. A standardised warm-up of 15 min was performed which consisted of jogging, stretching and faster pace running. During the warm up and throughout the exercise period participants were encouraged to drink water ad libitum to ensure adequate hydration levels. Water intake was recorded.

Heart rate was monitored continuously throughout each main trial (Polar, Finland). Rating of perceived exertion, using the Borg scale,[15] thermal comfort,[1] and perceived thirst (using a **10-point** scale from **1** 'not thirsty' to **10** 'very very thirsty'), were recorded prior to the 11th sprint in each exercise set. A 12-ml blood sample was collected from each subject between the sets of exercise and at exhaustion. Rectal temperatures were measured during the 4th and 8th cycle of each set and in the **3-min** blood sampling period between sets of the LIST. When rectal temperatures were measured participants were stationary for the equivalent time to walking 40 m of the 60 m walk in that cycle.

During the hot trials, the temperature in the gymnasium was raised to the appropriate level using four electric fan heaters and by using an externally vented gas heater (Andrews Industrial Equipment Ltd., UK). Temperature and humidity were monitored at 3 locations in the gymnasium and fan heaters adjusted to make sure the temperature was uniform. Sweat rates were estimated from pre- and post-exercise nude body mass measurements after adjusting for fluid intake.

Blood sampling and analysis

Five ml of blood was dispensed into an EDTA tube and aliquots from the venous sample were used for determination of haematocrit by microcentrifugation (Hawksley, UK) and haemoglobin concentration (by the cyanomethemoglobin method). Changes in plasma volume (%) were estimated using the method of Dill and Costill.[16] A further 1.5 ml of blood was dispensed into a collection tube (**Eppendorf, UK**) for immediate determination of blood glucose and lactate using an automated analyser (**Yellow Springs Instruments, USA**).

The remaining blood was allowed to clot for 1 h in a plain tube (Serum Z/5 ml, **Sarstedt, UK**) and the serum stored at -70°C for the determination of progesterone, aldosterone and cortisol concentrations by using commercially available radio immunoassay kits (**Diagnostic Products Corporation, USA**).

Statistical analyses

The sprint times, physiological and blood responses to the performance of the LIST were analysed using a three-way ANOVA (group x trial x time) with repeated measures on two factors (trial x time). Environmental temperatures, distance covered during the LIST, body mass and plasma volume responses during the main trials were analysed using a two-way ANOVA (group x trial) with repeated measures on one factor (trial). A Tukey *post hoc* test was used to determine differences between means when significant differences were found. Statistical significance was accepted at the $P < 0.05$ level. Data are presented as means (SEM).

RESULTS

Ambient temperatures

Dry bulb temperatures averaged 30.5°C throughout the main trials and were controlled so that there was no difference between the trials or groups (**acclimation**: A vs. B, 30.2 (0.5) vs. 30.1 (0.6)°C; **training**: A vs. B, 30.8 (0.1) vs. 30.8 (0.1)°C; **control**: A vs. B, 30.7 (0.2) vs. 30.3 (0.3)°C). Relative humidity was not different between the groups and was well maintained during the main trials (**acclimation**: A vs. B, 25.5 (2.0) vs. 24.6 (2.3)%; **training**: A vs. B, 27.2 (2.4) vs. 25.8 (1.9)%; **control**: A vs. B, 28.9 (3.5) vs. 31.2 (4.1)%). The dry bulb temperature during the training sessions was higher for the acclimation group than the moderate training group being 30.6 (0.2) and 18.1 (1.1)°C respectively ($P < 0.0001$). However, the relative humidity was higher during the moderate training sessions (hot vs. moderate, 23.9 (1.3) vs. 40.9 (2.4)%, $P < 0.0001$).

Distance run and 15-m sprint time

The distance run during trial A did not differ between the three groups (Figure 3). Following the intervention, distance run increased only for the acclimation group (Figure 3; group x trial interaction $P < 0.05$; post hoc $P < 0.05$). **Distance run during trial A and B was 7703 ± 1401 and 10215 ± 1746m, 8723 ± 1313 and 8632 ± 1131m and 7359 ± 681 and 6837 ± 800m for the acclimation, training and control group respectively.** Maximal **15-m** sprint time did not differ between the two main trials or between the groups. Decline in sprint performance was similar in all trials (main effect time $P < 0.0001$; Table 1).

Table 1: Mean sprint time (s) during the LIST.

	Set 1	Set 2	End set
Acclimation A	2.73 (0.08)	2.79 (0.08)	2.87 (0.05)
Acclimation B	2.74 (0.08)	2.81 (0.08)	2.90 (0.06)
Training A	2.73 (0.05)	2.78 (0.07)	2.85 (0.08)
Training B	2.73 (0.06)	2.80 (0.05)	2.92 (0.10)
Control A	2.77 (0.09)	2.86 (0.13)	3.00 (0.16)
Control B	2.78 (0.11)	2.95 (0.17)	3.01 (0.15)

Values are expressed as mean \pm SEM. Main effect time $P < 0.0001$.

Rectal temperature

Resting rectal temperature was similar between groups and trials. With the onset of exercise rectal temperature increased in all trials (main effect time $P < 0.0001$) but there were no differences in rectal temperatures between the groups during **trial A**. In comparison with the pre-acclimation temperatures, deep body temperature **was lower** in early exercise and increased toward the end of exercise in the acclimation group (group x trial x time interaction $P < 0.001$; Figure 4).

Heart rate and rating of perceived exertion, thirst and thermal comfort

Heart rate increased throughout the exercise period during all the trials (main effect time $P < 0.0001$). Figure 5 shows that during the first 2 sets of the LIST the heart rate was lower during trial B (main effect trial $P = 0.005$). **Both the acclimation and training groups had lower heart rates during trial B**, whereas there was a slight increase in the control group (interaction group x trial $P = 0.003$).

Rating of perceived exertion and perceived thirst increased throughout the exercise duration (main effect time $P < 0.0001$), but were not different between the two main trials (Table 2). However, participants felt cooler after acclimation in the heat, with no differences in thermal comfort found for the training or control groups (Table 3; interaction group x trial $P = 0.003$).

Table 2: Mean perceived exertion (RPE) and perceived thirst during the LIST.

	RPE			Thirst		
	Set 1	Set 2	End set	Set 1	Set 2	End set
Acclimation A	14 (1)	17 (1)	19 (1)	6 (0)	7 (1)	9 (0)
Acclimation B	13 (1)	15 (1)	18 (1)	5 (0)	6 (0)	8 (0)
Training A	13 (0)	16 (1)	19 (0)	5 (0)	7 (1)	9 (1)
Training B	12 (1)	15 (1)	17 (1)	6 (1)	7 (1)	7 (1)
Control A	13 (1)	16 (1)	19 (0)	5 (0)	7 (0)	9 (1)
Control B	14 (1)	17 (1)	19 (0)	5 (0)	7 (1)	8 (1)

Values are expressed as mean \pm SEM. Main effect time $P < 0.0001$.

Table 3: Mean perceived thermal comfort during the LIST.

	Set 1	Set 2	End set
Acclimation A	5 (0)	7 (1)	7 (2)
Acclimation B [†]	3 (1)	5 (1)	6 (2)
Training A	4 (1)	6 (1)	8 (1)
Training B	4 (1)	6 (1)	7 (1)
Control A	5 (1)	6 (0)	8 (1)
Control B	6 (1)	8 (1)	9 (1)

Values are expressed as mean \pm SEM. Main effect time $P < 0.0001$; Interaction group x trial $P = 0.003$; [†] $P < 0.05$ compared with pre-acclimation trial.

Body mass, fluid consumption and estimated sweat rate

Body mass was well maintained by the acclimation, training and control groups decreasing by less than 0.7% of basal body mass during **trials A and B** (acclimation A vs. B, -0.11 (0.26) vs -0.41 (0.26) kg; training A vs B, 0.09 (0.30) vs. -0.05 (0.20) kg; control A vs B, -0.42 (0.24) vs -0.42 (0.21) kg). Ad libitum fluid consumption was not different between the groups or between the trials (acclimation A vs. B, 18.6 (2.6) vs. 14.9 (2.4) $\text{ml}\cdot\text{kg}^{-1}\cdot\text{h}^{-1}$; training A vs. B, 17.9 (3.3) vs. 17.9 (3.7) $\text{ml}\cdot\text{kg}^{-1}\cdot\text{h}^{-1}$; control A vs. B, 12.0 (1.8) vs. 12.0 (2.3) $\text{ml}\cdot\text{kg}^{-1}\cdot\text{h}^{-1}$). Estimated sweat rate was similar in all trials, (acclimation A vs. B, **1.3 (0.2) vs. 1.1 (0.1) $\text{l}\cdot\text{h}^{-1}$** ; training A vs. B, **1.2 (0.1) vs. 1.2 (0.2) $\text{l}\cdot\text{h}^{-1}$** ; control A vs. B, **1.2 (0.1) vs. 1.2 (0.1) $\text{l}\cdot\text{h}^{-1}$**).

Metabolic Responses

Table 4 shows that blood lactate concentrations were lower following training in the moderate condition (main effect time $P < 0.0001$; interaction group x trial $P = 0.010$). There was no difference in the blood lactate response of the acclimation and control groups between trials. Blood glucose concentrations did not differ between groups or trials (Table 4).

Table 4 Blood lactate and blood glucose concentrations at rest and during the exhaustion set of the LIST.

	Acclimation		Training		Control	
	Rest	End set	Rest	End set	Rest	End set
Blood lactate concentration (mmol.l ⁻¹)						
*						
A	0.8 (0.1)	4.6 (1.1)	0.7 (0.1)	5.5 (0.9)	0.9 (0.1)	4.1 (0.6)
B	0.8 (0.1)	5.1 (1.1)	0.8 (0.1)	4.2 (0.9) [†]	0.8 (0.1)	4.2 (0.3)
Blood glucose concentration (mmol.l ⁻¹)						
*						
A	4.5 (0.1)	6.2 (0.8)	4.4 (0.1)	6.3 (0.6)	4.8 (0.2)	7.4 (1.0)
B	4.6 (0.2)	6.7 (0.9)	4.4 (0.2)	5.2 (0.5)	4.8 (0.2)	7.2 (0.6)

Values are expressed as mean \pm SEM. *Main effect time $P < 0.0001$; [†] $P = 0.013$ compared with trial A.

Hormonal responses

Resting serum progesterone concentrations were similar between groups and between trials A (**6.0 (2.3) nmol.l⁻¹**) and B respectively (**6.3 (3.1) nmol.l⁻¹**) confirming the same menstrual phase. Similarly, serum aldosterone and serum cortisol concentrations were not different between trials (Table 5).

Table 5 Serum cortisol and aldosterone concentrations at rest and during the exhaustion set of the LIST.

	Acclimation		Training		Control	
	Rest	End set	Rest	End set	Rest	End set
Serum aldosterone concentration (pmol.l ⁻¹)						
*						
A	551 (84)	1877 (221)	433 (108)	1678 (298)	443 (84)	1567 (206)
B	450 (62)	2054 (332)	495 (73)	1815 (199)	509 (35)	1554 (106)
Serum cortisol concentration (nmol.l ⁻¹)						
*						
A	538 (86)	968 (62)	702 (131) [†]	848 (106)	791 (118) [†]	798 (58)
B	561 (61)	862 (72)	811 (182) [†]	937 (190)	806 (166) [†]	819 (115)

Values are expressed as mean \pm SEM. *Main effect time $P < 0.0001$; $\dagger P < 0.05$ compared with rest value for acclimation group.

Plasma volume

There were no differences in estimated resting plasma volume between the groups or between trial A and trial B (**acclimation A vs. B, 61.9 ± 1.1 vs. 60.7 ± 1.0 ml·100 ml⁻¹; training A vs. B, 60.8 ± 0.7 vs. 62.2 ± 0.4 ml·100 ml⁻¹; control A vs. B, 61.6 ± 1.3 vs. 61.1 ± 1.1 ml·100 ml⁻¹**). The estimated change in plasma volume response was not different between trials or groups.

DISCUSSION

The main finding of the present study was that distance run during intermittent games type running was greater following heat acclimation, but did not change in a training or control group. The acclimation group had a lower rectal temperature in early exercise and a higher temperature at exhaustion in the post-acclimation trial in comparison with the training and control groups. In addition, an increase in thermal comfort was reported by the acclimation group only.

High-intensity intermittent running distance was increased by 33% following 4 short sessions of acclimation, over a **10-day** period. Thus, the games type running protocol employed for acclimation in the present study is an effective and efficient protocol for team sport acclimation. Gisolfi and Cohen[17] stated that interval or intermittent training resulted in a rapid increase in deep body temperature and thus was a powerful stimulator of thermoregulatory responses. The response and extent of capacity improvements are dependent upon the training status, exercise intensity and duration, environmental conditions and length of the acclimation protocol used. Therefore, comparisons with previous research are not straight forward. However, in the present study rectal temperatures increased to 39.3°C following the first 2 sets of the intermittent running whereas in prolonged acclimation protocols these temperatures may not be reached or are reached **after** a much longer period of time.[4] Heat acclimation occurs when a threshold stimulus for thermal inputs is attained and maintained for a certain duration,[8] and thus this threshold is reached earlier during games type intermittent running.

The acclimation group had a lower rectal temperature than the moderate training and control groups during the first 30 min of trial B. It has been suggested that the key determinant for exercising and resting rectal temperature in a hot environment is acclimation status.[18] Thus, a lower rectal temperature is often used as an indicator that acclimation has occurred. The participants also perceived that they were cooler following the heat acclimation period. The reasons for a lower rectal temperature following acclimation have been attributed to increased heat dissipation,[19] a decrease in metabolic heat production[8,20] and a lower resting deep body temperature.[7] In the current study resting rectal temperature was unchanged and there was no increase in the sweat rate and thus heat dissipation may not have been increased. It is not surprising that sweat rate was unchanged as this adaptation has been outlined to occur after 8-14 days of acclimation[12], occurs more readily in humid environments, and has shown to be unchanged in well trained individuals who have heightened sweat sensitivity.[8,17] However, sweat distribution, increased local sensitivity and evaporative heat loss may have been enhanced[21] and contribute to the decreased rectal temperature and improved thermal comfort. In previous studies metabolic rate has been shown to decrease following acclimation and may be a contributing factor to the lower deep body temperature seen in the present study.[7] Heat acclimation is a complex process, with numerous physiological adaptations and interactions occurring at different rates, which Horowitz[22] suggests widens the dynamic thermoregulatory range. The end deep body temperature following acclimation was higher (**0.2°C**), which along with the increase in thermal comfort suggests an increase in heat tolerance which may partially explain the large improvement in intermittent exercise capacity.

There is limited research using non – consecutive day acclimation protocols. Research by Gill and Sleivert[23] compared 10 acclimation sessions (30 min 70% $\dot{V}O_2$ peak; 38°C, 70% RH) on consecutive days with non-consecutive days (Mon, Weds, Fri each week). The consecutive day protocol had a greater acclimation effect than the alternate day protocol with a lower rectal temperature, skin temperature, heart rate and perceived exertion reported. For the consecutive group, a plateau in responses was reported after 6 days. The authors suggest that perhaps during the non-consecutive day protocol some of the physiological adaptations are lost between exposures and thus daily exposures might allow acclimation adaptations to summate more effectively. In contrast, an early study by Fein et al[24] found that walking for 100 min (46.5°C) every third day compared with consecutive days for 10 exposures had no effect upon the rate of acclimation. Again a plateau in responses was reported for both protocols after 6 days. The present study did not compare consecutive days with the non-consecutive day protocol employed, but had a significant effect upon distance run after only 4 sessions in 10 days. The intensity and intermittent nature of the running caused a rapid rise to a much higher rectal temperature than the study by Gill and Sleivert[23] and may therefore have had a greater stimulatory effect for acclimation. Further research would be required to see if a consecutive day protocol would be more beneficial for match performance without impacting upon the taper and tactical aspect required during team sport activity.

In the current study serum aldosterone concentrations were unaltered by the acclimation or training intervention. Previous investigations have also noted that acute acclimation and chronic acclimatisation do not alter the aldosterone response to exercise in well-trained male subjects.[4,5,7,25] These findings may

be the result of a maximised salt balance in well-trained individuals as a result of adaptation to prolonged training.[26] Acclimation also appeared to have little impact on serum cortisol concentrations, the responses of each of the groups in the present study being similar in the second hot trial. Previous research seems to confirm that acclimation does not influence cortisol concentrations.[25,27]

In recent years there has been a plethora of research completed investigating changes that occur within the brain and **in the central nervous system (CNS)** during exercise in the heat. Brain activity, decreases in central activation, a decrease in cerebral blood flow and a decrease in brain dopamine have all been reported during, or when fatigued following exercise in the heat.[28-30] **Hyperthermia has also been reported to impair CNS function reducing maximal voluntary contraction and increasing perceived exertion and thermal strain.**[31,32] To date the responses of the brain to acclimation have not been investigated and as few physiological changes are evident and thermal comfort was improved, it is possible that adaptations within the brain, **and CNS responses** may be partially responsible for the increase in distance run.

In summary the main finding of the present study was that high-intensity intermittent running capacity in the heat was improved by 33%, in well-trained female games players, following 4 short acclimation sessions. **Sprint time was unaffected by the acclimation.** The underlying mechanisms for the adaptive changes seen following acclimation are dependent upon not only the protocol employed, but also the training status of the participants. The unique protocol in the current study resulted in a lower rectal temperature following acclimation while no changes were seen in a moderate

training or control group. Thus a lowering of deep body temperature and an increase in thermal comfort may be partly responsible for the improvement in exercise capacity. The magnitude of improvement in performance in the acclimation group suggests that a short-term high-intensity intermittent protocol could improve performance for games players competing in **tournaments** in the heat.

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What is known on this topic:

Heat acclimation involving 6 or more sessions of 60 min or more duration is known to increase exercise time to exhaustion during prolonged walking, cycling and running.

High-intensity intermittent running (which mirrors games-type activity) has rarely been used as the exercise mode to induce acclimation.

What this study adds:

This study demonstrates that 4 short sessions of intermittent running, in a 10 day period, is sufficient to improve games type exercise capacity.

The changes in capacity were not associated with changes in sweat rate; but the sport specific acclimation protocol attenuated deep body temperature responses over a given time and improved thermal comfort.

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FIGURE 1 – Protocol diagram of the 28 days of the acclimation study.

FIGURE 2 – The Loughborough Intermittent Shuttle Test (LIST) protocol.

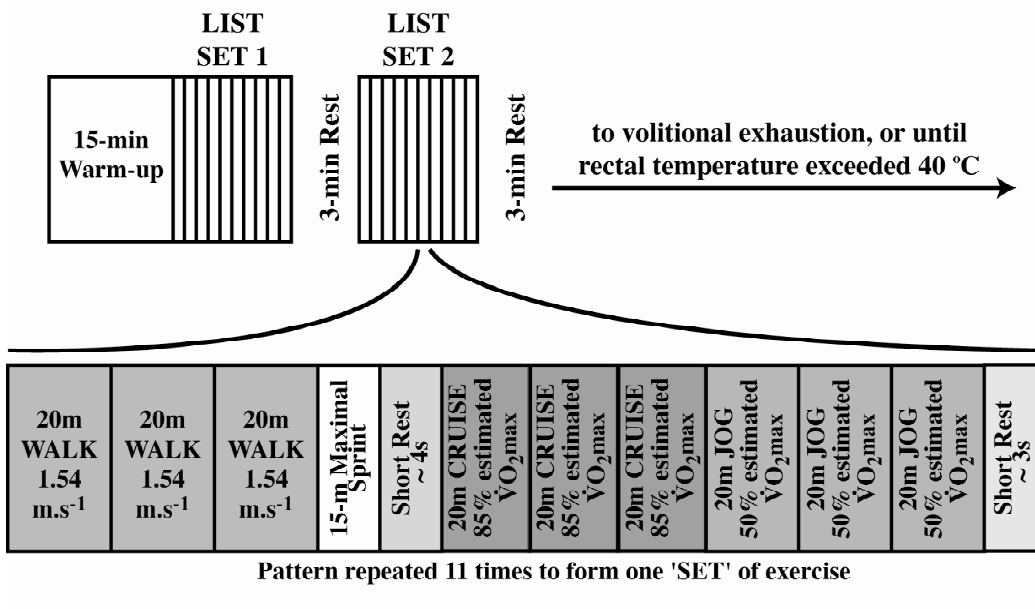
FIGURE 3 - Distance completed during the main trials by the acclimation, training and control groups. Values are expressed as mean \pm SEM; Interaction group x trial $P < 0.05$; * $P < 0.05$ compared with pre-acclimation trial.

FIGURE 4 - Rectal temperature response for the control, training and acclimation groups during trial A and B. Values are expressed as mean \pm SEM. Main effect time $P < 0.0001$; Interaction group x trial x time $P < 0.001$; * $P < 0.05$ acclimation trial B compared with acclimation trial A.

FIGURE 5 – Heart rate for the acclimation, training and control groups during trial A and B. Main effect trial $P = 0.005$; Main effect time $P < 0.0001$; Interaction group x trial $P = 0.003$.

DAY	1	2-18	19-28	29
ACCLIMATION GROUP	Trial A	Normal Activity	4 LIST Sessions in 30°C At least 1 days rest between each session and before Trial B	Trial B
TRAINING GROUP	Trial A	Normal Activity	4 LIST Sessions in 18°C At least 1 days rest between each session and before Trial B	Trial B
CONTROL GROUP	Trial A	Normal Activity	Normal Activity	Trial B

Figure 1



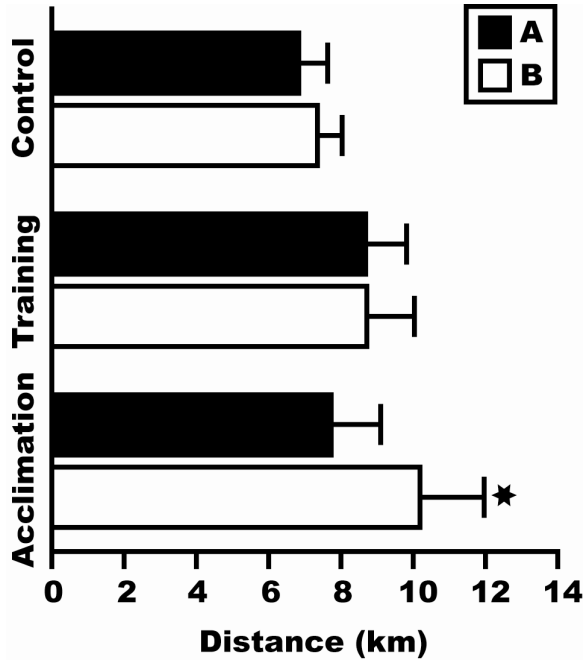


Figure 3

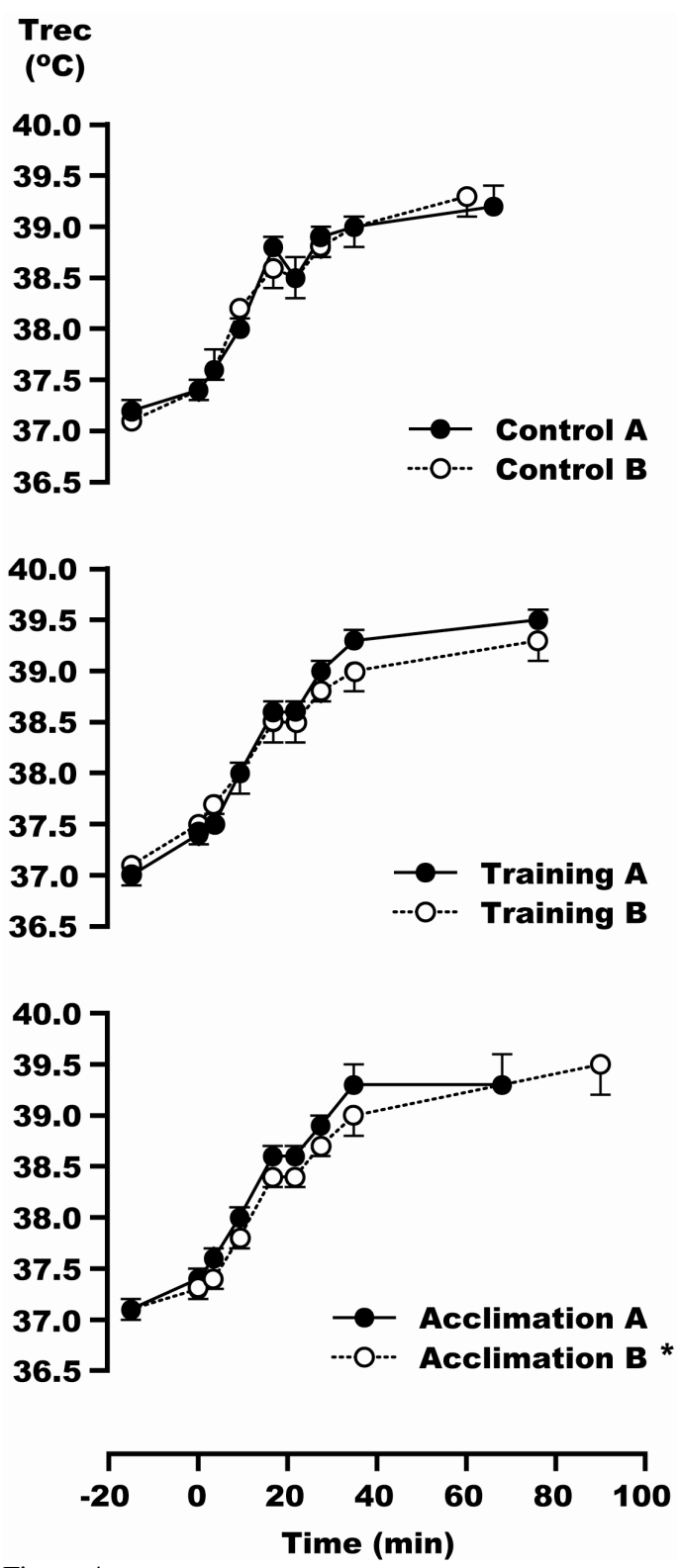


Figure 4

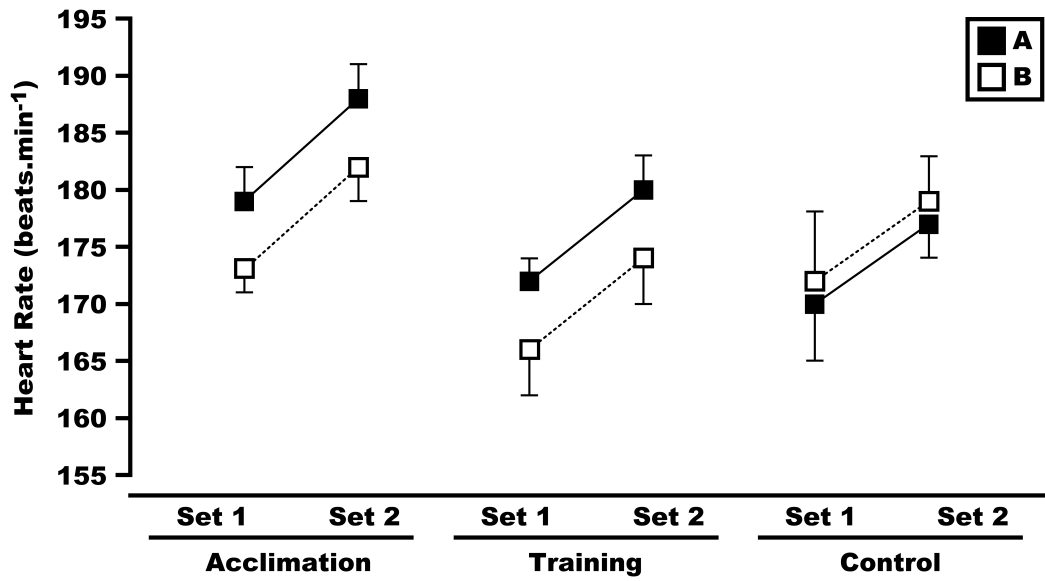


Figure 5