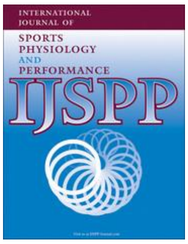

In press

Title: Does short-duration heat exposure at a matched cardiovascular intensity improve intermittent running performance in a cool environment?

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1. ABSTRACT

Purpose: To investigate whether a five-day cycling training block in the heat (35°C) in Australian rules footballers was superior to exercising at the same relative intensity in cool conditions (15°C) for improving intermittent running performance in a cool environment (<18°C).

Methods: Using a parallel-group design, 12 semi-professional football players performed five days of cycling exercise [70% heart rate reserve (HRR) for 45 min (5 x 50 min sessions in total)] in a hot (HEAT, 35±1°C, 56±9% RH) or cool environment (COOL, 15±3°C, 81±10% RH). A 30-15 Intermittent Fitness Test to assess intermittent running performance (V_{IFT}) was conducted in a cool environment (17±2°C, 58±5% RH) prior to, one and three days after the intervention.

Results: There was a likely small increase in V_{IFT} within each group [HEAT: 0.5±0.3 $km.h^{-1}$, 1.5±0.8 x smallest worthwhile change (SWC); COOL 0.4±0.4 $km.h^{-1}$, 1.6±1.2 x SWC] three days post the intervention, with no difference in change between the groups (0.5±1.9%, 0.4±1.4 x SWC). Cycle power output during the intervention was almost certainly lower in the HEAT group (HEAT 1.8±0.2 $W{\cdot}kg^{-1}$ vs. COOL 2.5±0.3 $W{\cdot}kg^{-1}$, -21.7±3.2 x SWC, 100/0/0).

Conclusions: This study indicates that when cardiovascular exercise intensity is matched (i.e. 70% HRR) between environmental conditions, there is no additional performance benefit from short-duration moderate-intensity heat exposure (5 x 50 min) for semi-professional footballers exercising in cool conditions. However, the similar positive adaptations may occur in the HEAT with 30% lower mechanical load, which may be of interest for load management during intense training or rehabilitation phases.

Key Words: heat acclimation; football; plasma volume; relative-intensity exercise, V_{IFT}

2. INTRODUCTION

With the increasing competiveness and time demands associated with elite sport, scientists, coaches and athletes are always searching for time-efficient methods to improve physical performance. Recently, supplementing traditional training with training in hot environments has gained increasing interest as a time efficient means of enhancing exercise performance. Heat acclimation has been shown to induce physiological adaptations such as plasma volume (PV) expansion,[1, 2] reduced oxygen uptake at a given power output[3] and a reduced cardiac frequency at a given work rate[2] that may improve exercise performance in cool conditions (<18°C). [1-3]

Physiological benefits and improvements in intermittent running performance in hot ambient conditions in highly trained female hockey athletes have been shown following as few as four heat exposures[4] and intermittent running performance was improved by 44% (*d*=2.0) in temperate conditions in elite Australian rules football (ARF) players following a 14-day training camp in the heat.[5] Given improvements in intermittent running may relate to improvements in on-field performance in team sports,[6] heat exposure may prove a substantial ergogenic aid for team sport athletes.

Improvements in intermittent running performance are observed with heat exposure, although the degree of improvement varies greatly (7-44%) (*d*=0.5-2.0).[4, 5, 7] Racinais[5] reported a 44%

improvement in elite ARF player's intermittent running performance although this was conducted early pre-season, when the greatest gains in fitness could be expected. A 7-day heat acclimation training camp with footballers in season has led to a smaller, 7% increase in intermittent running.[7] While improvements have been reported,[5, 7] these studies determining the effect of heat exposure on intermittent running performance have lacked a control group. Therefore, the true effect of heat exposure on performance in team sport athletes exercising in cool environments is still unknown. While traditional heat exposure protocols entail exposure periods of seven or more consecutive exercise sessions of 90 min,[1-3] physiological adaptations and performance benefits have been observed in hot conditions after as little as four to five exposures of ≤60 min.[4] To date, only two studies[9, 10] have investigated the effect of short-duration heat exposure (≤5 x 60 min sessions) on running performance in cool-temperate conditions. Of these studies, neither investigated intermittent aerobic running performance in team sport athletes. In a team sport setting, a short-duration heat exposure protocol may be more practical than traditional acclimation procedures due to the nature of weekly competition and limits on training load, where additional running volume must be added with caution. Consequently, the investigation of a time-efficient heat exposure protocol with a control group is of interest.

Traditional heat acclimation studies have prescribed exercise at a set work rate and then compared this with a control group performing exercise at the same work rate in a cooler environment.[2, 11] The use of a set work rate based on speed or power output increases the physiological strain experienced in the heat compared to a cooler environment. Maw and colleagues[12] found that cycling for 30 min at the same work rate in a hot (40°C) versus a cool (8°C) environment resulted in significantly higher end heart rate (164 vs. 135bpm) and skin temperature (38 vs. 28°C). While the additional physiological strain associated with exercising in the heat is well documented,[13, 14] very little literature[9, 15] has employed heat exposure protocols where exercise is prescribed using a relative intensity based on heart rate (HR) or rate of perceived exertion (RPE). Periard and colleagues[16] have recently proposed a HR clamp protocol whereby exercise intensity is prescribed by a set HR determined from cool condition testing (eg. HR corresponding to %VO_{2max}). This method could potentially be quite efficient for the practitioner whilst also addressing the current debate around the effect of higher relative intensity on adaptations observed with heat acclimation and exposure. With this in mind, the investigation of an easily administered HR clamp based protocol is warranted.

The aim of this study was to compare intermittent running performance (V_{IFT}) in cool conditions (<18°C) following five days of training in the heat (35°C) or cool (15°C), at a comparable cardiovascular intensity. The cycle heat exposure protocol was deliberately designed with a short exposure time using relative intensity in order to address the practical relevance of minimising 'non-specific' aerobic training time and intensity faced by many elite team sports.

3. METHODS

Subjects

Twelve Tasmanian State League (TSL) ARF players were recruited (age 23±4 years, height 186.0±7.6 cm, body mass 83.4±10.2 kg) from three separate TSL teams. Participants provided written informed consent and the study was approved by the institutional research ethics committee, which conformed to the recommendations of the Declaration of Helsinki.

Design

Using a parallel-group study design, participants were allocated to either a hot (HEAT, n=6: age 22±4 years, height 190.8±7.6 cm, body mass 85.0±9.6 kg) or a cool group (COOL, n=6: age 23±4 years, height 181.3±3.6 cm, body mass 81.8±11.4 kg) where they cycled for 50 min at 70% HRR. A graded aerobic intermittent running test (30-15_{IFT}) was conducted one day prior, then one (Post 1) and three (Post 2) days after the final cycle training intervention to determine peak velocity (V_{IFT}). All of the 30-15_{IFT} testing sessions were conducted in an indoor basketball stadium where average temperature was 17±2°C, 58±5% RH. Groups were matched for running performance (heat: V_{IFT} 19.33±1.4 km.h^{-1}; cool: V_{IFT} 19.50±1.1 km.h^{-1}) and team (except one pair matched only by running performance). Players completed at least one familiarisation session of the 30-15_{IFT} in the week prior to baseline testing. Blood was collected one day prior (except for one pair whose blood samples were collected 8-days prior) and one day post the cycle-training. Participants were in the final weeks of an 18-week preseason period (average maximum daily environmental temperature during study period was 22°C) and required to continue normal football training sessions and practice matches but avoid any additional training.

Training intervention

Participants completed five consecutive days of cycle training for 50 min in addition to their normal training. All cycle sessions were conducted early morning (06:00-09:00), a similar time to the time of 30-15_{IFT} testing. The 50 min sessions involved a 5 min warm-up (2.5 min at 50% HRR, followed by 2.5 min building up to 70% HRR) followed by 45 min at 70% HRR. Cycle training on Wattbike ergometers (Wattbike pro, Nottingham, UK) occurred in either hot (35±1°C, 56±9% RH) or cool (15±3°C, 81±10% RH) environments with no additional airflow provided. Cycling power output was adjusted manually via the participants adjusting cadence as required. Average power output was recorded for each cycle training session. For each cycle-training session thermal sensation (using a 13-point scale from -3 “unbearably cold” to 3 “unbearably hot”)[19] and RPE[20] were collected every 10 min during and immediately post each cycle-training session. Participants were given water (2.5ml.kg^{-1}) that was to be consumed completely prior to the end of the training session. After each cycle-training session, participants were encouraged to consume 1.5x the fluid lost during the session and were provided access to a commercial sports drink solution. RPE was also collected during normal football training sessions to determine entire training workload.

Measurements

The 30-15_{IFT}[21] was performed pre and twice post (1 and 3 days) the 5-day cycle-training intervention. A standardized warm-up protocol utilising a 5 min submaximal shuttle run over 20m at a speed 9 km.h^{-1} then a 5 min dynamic warm-up component was completed prior to each 30-15_{IFT}.

Resting HR was collected upon wakening on the mornings of each testing session. Participants were instructed to remain still for two minutes before recording the measurement of HR over a 60s period. Maximal heart rate was determined as the maximal heart rate achieved during either the familiarisation or baseline 30-15IFT testing sessions. 70% HRR was then calculated by the following equation: [0.7(maximal HR – resting HR) + resting HR].

A finger prick blood sample (100µL) was collected on baseline and Post 1 testing days prior to the 30-15_{IFT}. Participants were seated for approximately 10 min prior and then during collection, with all samples analysed within 15 min of collection. Haemoglobin (Hb) concentrations were determined in duplicate using a HemoCue® Hb 20. Haematocrit (Hct) was determined via the capillary centrifuge method, spinning at 12,000rpm for 5 min. Haemoglobin and Hct measures were performed by two experienced operators with inter-tester reliability determined as 3.3% for Hb and 0.9% for Hct. Changes in Hb and Hct enabled calculation of relative change in plasma volume[22].

Urine samples were collected before cycle-training sessions to enable determination of urine specific gravity (USG) (PAL 10-S, Atago Co, Ltd, Tokyo, Japan). Body mass (participants wearing only their underwear) was measured before each testing session, and before and after cycle training to determine fluid loss.

Prior to each exercise session, tympanic temperature was recorded (Thermoscan, Braun GmbH, Kronberg, Germany) and water (2.5 $ml \cdot kg^{-1}$ of body mass) provided to each participant. Participants were instructed to consume all fluid during the 50 min cycling training. Tympanic temperature and HR (Team 2 system, Polar, Oulu, Finland) were recorded at 5 min intervals during each session. The tympanic temperature recording device was stored at room temperature and was only exposed to the exercise climate conditions for brief periods for recording.

Training load was calculated using the session RPE x time method using the Borg RPE scale of 6-20.[20]

Statistical Analysis

Data are presented as mean ± standard deviation (SD). Comparisons of group averages for variables across the entire intervention period,[23] between-group differences and within-group comparisons[24] were calculated with 90% confidence limits (90% CL) using specifically-designed Excel spreadsheets. The smallest worthwhile change (SWC) was variable-dependent and determined via one of the following three methods: 0.2 x between-subjects SD for V_{IFT} and cycle session relative power output, the change that corresponds to a worthwhile change (0.2 x between-subjects SD) in high-intensity running performance for submaximal HR (3%) and within-individual day-to-day variations (present lab setting) for the remaining variables (plasma volume: 4%, haemoglobin: 2%, haematocrit: 4%, training load: 5%, thermal sensation: 5%, body mass and fluid loss: 0.5%, tympanic temperature: 1% and urine-specific gravity: 0.7%). All changes and differences in the variables were expressed as a factor of the SWC. Quantitative chances of clear changes (within-group analysis), or greater or smaller changes in performance or physiological variables in HEAT vs. COOL, were assessed qualitatively as follows: >25–75%, possibly; >75–95%, likely; >95–99%, very likely; >99%, almost certainly, with percentages presented as increase/trivial/decrease.

4. RESULTS

Training Load

During the study the HEAT group had a possibly small higher session-RPE load during football training sessions (cycle sessions not included) (HEAT 3960±444 vs. COOL 3608±735, 2.3±4.1 x SWC, 70/20/10). Average cycle-training session-RPE load was likely similar (HEAT 3432±115 vs. COOL 3335±107, 0.6±0.7 x SWC, 16/84/0). When both football training load and cycle training intervention load were combined to calculate total training load the HEAT group had a possibly small higher training load than the COOL (HEAT 7392±362 vs. COOL 6942±798, 1.4±2.3 x SWC, 63/33/4). When total training load was compared for the participants matched by teams (n=10), total training loads were similar between HEAT and COOL groups (HEAT 7421±396 vs. COOL 7250±288, 0.5±1.1 x SWC, 20/78/2).

Cycle intervention

Relative cycle power output was almost certainly lower in the HEAT group (HEAT 1.8±0.2 $W \cdot kg^{-1}$ vs. COOL 2.5±0.3 $W \cdot kg^{-1}$, -21.7±3.2 x SWC, 100/0/0), while average tympanic temperature was very likely higher in the HEAT group (HEAT 37.6±0.3°C vs. COOL 36.9±0.3°C, 2.4±0.8 x SWC, 99/1/0), and maximum tympanic temperature was almost certainly higher (HEAT 38.3±0.4°C vs. COOL 37.3±0.2°C, 2.7±0.6 x SWC, 100/0/0). Thermal sensation and fluid loss were almost certainly higher in the HEAT group (thermal sensation: HEAT 2.1±0.1 vs. COOL 1.2±0.3, 15.3±8.0 x SWC, 100/0/0; fluid loss: HEAT 1.10±0.04 L vs. COOL 0.75±0.11 L, 98.4±45.7 x SWC, 100/0/0) while USG and RPE were likely similar (USG: HEAT 1.023±0.001 vs. COOL 1.018±0.002, 0.7±0.4 x SWC, 0/91/9; RPE: HEAT 14±0 vs. COOL 13±0, 0.6±0.7 x SWC, 16/84/0).

High-Intensity intermittent running performance

There appeared to be no worthwhile between group difference on V_{IFT}, with a possibly trivial difference in change between groups from Pre to Post 1 and a likely trivial difference from Pre to Post 2 (Table 1). Despite no worthwhile difference between the two groups in the change from Pre to either Post 1 or Post 2, both groups showed a likely small increase in V_{IFT} at Post 2 (Figure 1) but a likely trivial change in V_{IFT} at Post 1 (Figure 1).

Physiological Adaptations

Submaximal HR, Hct, and Hb data from between-group analyses are presented in Table 1. There was a likely trivial difference in between-group change for Hct and an unclear difference in Hb concentration change from Pre to Post 1. Despite no difference in change between the two groups, within-group comparisons revealed that at Post 1, the HEAT group had a likely trivial decrease in Hct (-2.5±3.2%, -0.6±0.8 x SWC, 1/78/21) and a likely large decrease in Hb concentration (-7.0±5.7%, -3.5±2.8 x SWC, 1/6/93) whilst the COOL group showed a possibly large decrease in Hct (-4.6±2.4%, -1.1±0.6 x SWC, 0/29/71) and a likely large decrease in Hb concentration (-3.8±4.9%, -1.9±2.5 x SWC, 3/21/76).

When submaximal HR was compared between the groups, there was a possibly trivial difference in change from Pre to Post 1 and a possibly greater decrease in submaximal HR in the HEAT group at Post 2 (Table 1). When analysed within-group, the HEAT group showed a likely large decrease at Post 1 and a possibly large decrease at Post 2 whilst the COOL group showed a possibly small decrease at both Post 1 and Post 2 (Figure 2). When changes in PV were compared between-groups, the HEAT group displayed a possibly small greater increase from Pre to Post 1 (1.9±9.0%, 0.5±2.3 x SWC, 34/53/13) (Table 1). When analysed within-group both the HEAT and COOL groups showed likely large increases in PV from Pre to Post 1 respectively (Table 1).

5. DISCUSSION

The findings of this study suggest that an improvement in V_{IFT} in cool conditions (<18°C) can be achieved from 5 x 50 min cycle sessions in the heat, however the benefits are likely similar when compared to training at the same relative intensity in a cool environment. Whilst no additional running performance benefits were achieved by cycling in the HEAT compared to the COOL at equal relative intensity (70% HRR), it is worth noting that the HEAT group achieved similar performance benefits to the COOL group despite performing approximately 30% less mechanical training load during the cycle training.

There is currently conflicting evidence to whether heat exposure can lead to physiological adaptations that improve exercise performance in cool conditions. Lorenzo et al[2] and Scoon et al[25] found that significant performance benefits from the use of heat acclimation can be realised in cool conditions . However, recently Karlsen et al[26] and Keiser et al[27] found no performance increase in cool conditions in either intervention or control groups after a 14-day and 10-day heat acclimation protocol, respectively. Given the conflicting evidence, the recent cross-talk debate from Minson and Cotter[28] regarding the adaptations from heat exposure, and the issue of relative versus absolute exercise intensity prescription effects on performance in cool environments, our study adds to the scarce amount of literature investigating the effect of short-duration heat exposure (≤5 x 60 min sessions) on performance in cool environments. Our findings contrast previous longer-duration heat exposure literature as we found an increase in performance in both groups. Plausible reasons for this difference may have been our relatively short exposure duration, use of relative training intensity under both conditions, and the additional load to participants' current training.

Traditionally, heat acclimation protocols have utilised exposure durations of ≥7 x 90 min sessions.[1, 2, 11] Due to the competing time demands of elite sport, the efficacy of shorter, less disruptive heat exposure protocols have been investigated. Recently, Chalmers et al[9] found a possibly small increase in lactate threshold in the heat exposure group (1.9%, d=0.42) and a likely large increase in the control group (2.3%, d=1.04) after a 5-day RPE-prescribed, mixed intensity treadmill heat exposure protocol (accumulated exposure time 240 min). Despite this improvement in the heat group, the possible worthwhile improvement was considered trivial (d<0.2) when compared to the change in the cool group. These results are similar to those found in our study. We found intermittent running improvements in both the HEAT (2.6%) and the COOL (2.2%) groups after a 250 min moderate intensity (70% HRR) cycle heat exposure protocol, with trivial differences in improvement when compared between the groups. Whilst the similar increases between the heat and cool groups in both Chalmers[9] and our study may potentially be due to a lack of physiological adaptations consistent with more lengthy heat exposure protocols, the fact that these two studies utilised relative intensity protocols should be highlighted, as the majority of previous heat exposure research has been based on exercise prescribed as an absolute intensity.

Setting training intensity based on relative intensities such as % maximal heart rate or RPE is not common in heat exposure studies. Previous studies that have shown significant performance and physiological adaptations after heat exposure have prescribed exercise as an absolute intensity.[2, 11, 17] In the study by Lorenzo[2] a heat exposure protocol of 10 x 90 min cycling prescribed with an absolute workload of 50% of peak power output at VO_{2max} resulted in a 6.5% increase in PV and a 5% increase in 60 min time trial performance in cool conditions when compared to the control group in highly-trained cyclists. Lorenzo et al[2] showed that the group that exercised in the heat consistently worked at a higher cardiac frequency. End session HR was 35bpm higher on day 1 in the heat group, and still 27bpm higher on day 10, suggesting a greater relative intensity throughout the intervention. A study by Morrison and colleagues,[15] where exercise prescription was matched by relative intensity (RPE) during a 7 x 90 min heat exposure cycle protocol found no difference in PV expansion between the heat and the cool group, and no benefit of heat exposure on 40 km time trial performance in cool conditions. Similarly, recent findings from Keiser et al[27] found no significant improvements in cool-condition VO_{2max} or 60 min time trial performance with well-trained participants after 10 x 90 min HR prescribed heat acclimation sessions. Keiser[27] did however find an increase in both VO_{2max} and time trial performance in the heat after the 10 x 90 min heat acclimation protocol. The findings from Keiser et al[27] suggest that heat exposure may benefit performance in hot but not cool conditions. Interestingly, whilst no significant increase in cool-condition exercise performance was seen in the Keiser[27] study, Lorenzo[29] proposed that the statistical approach used for analysis may have underpowered the statistical significance of the ~3-4% increase in cool-condition VO_{2max}. Uniquely, in our study, using a HR clamp protocol similar to that proposed by Periard and colleagues,[16] similar performance improvements were achieved in both groups despite the HEAT group performing 30% less mechanical work during the cycle intervention. The similar increase in running performance despite the reduced mechanical workload in the heat may be attributed to similar cardiovascular strain in both groups. While heat alone may significantly contribute to improvement in performance the exercise intensity and volume are also integral to aerobic performance improvement.

The increased training load from the participants' baseline in this study could potentially account for the increases in PV and intermittent running performance by both groups. However, as stated previously, this study showed similar improvements in performance between the two groups despite the HEAT group performing 30% less mechanical load. This is potentially of great interest for practitioners looking to condition injured or rehabilitating athletes, or those wanting to increase running performance without additional running volume. Whilst it has recently been suggested by Chalmers et al[8] that a protocol of ≥5 x 60 min of high intensity exercise in the heat may be necessary to elicit physiological and performance benefits, the increase in training load of 5 x 50 min moderate intensity sessions was sufficient to dampen any increase in in V_{IFT} immediately following the intervention. It was not until three days post intervention (Post 2) that improvements in V_{IFT} were observed for either group. This suggests that residual fatigue may have occurred as a result of the increased training load. Consequently, adding five days of cycle exercise in either a hot or cool environment to a team sport athlete's weekly training may elicit residual fatigue, and as such performance benefits may not be realised one day post intervention. As a result, a heat exposure protocol consisting of ≥5 x 60 min high intensity sessions may not be viable for team sport athletes that compete on a weekly basis.

Limitations of this study include the use of a short-duration heat exposure period and the limited ability to accurately measure key physiological adaptations consistent with substantial heat exposure such as core temperature. Adaptations that are associated with heat acclimation such as PV expansion,[2] lower HR at a given intensity[2] and resting tympanic temperature[30] showed conflicting results, with a lower resting tympanic temperature, a similar decrease in 30-15$_{IFT}$ submaximal HR and a possibly small increase in PV at Post 1 in the HEAT group when compared to the COOL. Whilst it is acknowledged that a longer heat exposure period may have resulted in greater physiological adaptations, this was not the intent of the study. Our intent was to determine the effectiveness of a short-duration protocol that could be utilised in a team sport setting, not one that was known to elicit significant heat acclimation. It must also be acknowledged that given the training status of the participants (Tasmanian State League footballers) and the exposure to a novel, additional training stimulus, that the possibility of a training effect cannot be excluded when assessing the participants' responses to the cycling exercise intervention. Despite the potential of a training effect in this study it is of interest to note that similar running performance improvements were seen between the two groups despite the HEAT group performing 30% less mechanical cycling load during the intervention. The small sample size (n=12) used for this study is also a limitation from a statistical power perspective.

Future studies investigating the use of high-intensity protocols to determine if more conclusive heat acclimation adaptations can be achieved in a short-time period (≤45 min) would be of significant value to practitioners looking to improve intermittent running performance with the lowest amount of additional workload possible. Furthermore, studies investigating a longer heat exposure protocol (eg. ≥10 x 90 min sessions) utilising relative intensity exercise prescription, such as percentage of VO_2max, would be of significant value to determine if the effects of 'traditional' heat acclimation protocols based on matched absolute intensity are due to the heat exposure or the increased relative exercise intensity.

6. PRACTICAL APPLICATIONS

- Supplementing usual training with five days of cycling at 70% HRR in either hot or cool environment can lead to small intermittent running performance improvements in semi-professional ARF players
- Implementing heat exposure sessions may be a useful strategy to condition injured or rehabilitating athletes, or those wanting to increase running performance without additional running volume.
- If implementing a 5-day cycling program to a team sport program ensure the intervention ends at least two days prior to the desired match or event to avoid residual fatigue.

7. CONCLUSIONS

The addition of 5 days of cycling in either HEAT or COOL at the same relative intensity can lead to likely small increases in high-intensity running performance in a cool environment. Whilst no additional running performance benefits were produced by heat training, the HEAT group performed approximately 30% less mechanical training load during the cycle training. The addition of a 5-day cycle training intervention into the training regime of semi-professional ARF players could elicit residual fatigue requiring three days before performance improvements are realised.

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Table 1. Comparison of change in performance and physiological variables from two days prior (Pre) to 1 (Post 1) and 3 days (Post 2) post a 5-day cycle intervention in either the HEAT (35 ± 1°C, 56 ± 9 % RH) or COOL (15 ± 3°C, 81 ± 10% RH) in semi-professional Australian Rules Football (ARF) players.

	HEAT			COOL			Differences in change observed for HEAT compared with COOL	
							Pre – Post 1	Pre – Post 2
	Pre	Post 1	Post 2	Pre	Post 1	Post 2	Standardised differences as a factor of the SWC ± 90% CL (% chances of higher/similar/lower)	Standardised differences as a factor of the SWC ± 90% CL (% chances of higher/similar/lower)
V_{IFT} (km/h)	19.3 ± 1.4	19.6 ± 1.4	19.8 ± 1.3	19.5 ± 1.1	19.7 ± 1.1	19.9 ± 1.2	0.3 ± 2.4 (27/57/16)	0.4 ± 1.4 (20/76/5)
Submax HR (bpm)	133 ± 3	128 ± 2	128 ± 6	130 ± 9	125 ± 10	125 ± 5	0.2 ± 2.7 (23/60/17)	0.4 ± 1.8 (27/65/8)
Hct (%)	44 ± 2	43 ± 2		45 ± 1	43 ± 2		0.6 ± 0.7 (13/87/0)	
Hb (g/dl)	15.9 ± 0.9	14.8 ± 0.8		15.7 ± 0.6	15.1 ± 0.7		-1.0 ± 3.1 (13/36/51)	
PV (%)		*Δ from pre* *9.7±8.6*			*Δ from pre* *7.7±6.2*		*0.5 ± 2.3* *(34/53/13)*	

Note: mean values (±SD) for maximal intermittent running velocity (V_{IFT}) during the 30-15IFT, submaximal HR (Submax HR) during the 30-15IFT, haematocrit (Hct) and haemoglobin (Hb). PV: plasma volume. SWC: smallest worthwhile change.