Title: Heat acclimation attenuates the increased sensations of fatigue reported during acute exercise-heat stress.

Running Title: Sensations of fatigue and heat acclimation

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Figure 1. Mean ± SD pre and post session *General Fatigue*, *Physical Fatigue* and *Vigor* scores during ODHA and TDHA for sessions 1, 5 and 10 (* indicates a significant difference [*P*<0.05] between pre and post session scores, † indicates a significant difference [*P*<0.05] in the change of fatigue scores from pre to post between ODHA and TDHA).

Abstract

Athletes exercising in heat stress experience increased perceived fatigue acutely, however it is unknown whether heat acclimation (HA) reduces the magnitude of this perceptual response and whether different HA protocols influence the response. This study investigated sensations of fatigue following; acute exercise-heat stress; short- (5-sessions) and medium-term (10-sessions) HA; and between once- (ODHA) and twice-daily HA (TDHA) protocols. Twenty male participants (peak oxygen uptake: 3.75±0.47 $L \cdot min^{-1}$) completed 10 sessions (60-min cycling at ~2 $W \cdot kg^{-1}$, 45°C/20% relative humidity) of ODHA (n=10) or non-consecutive TDHA (n=10). Sensations of fatigue (*General*, *Physical*, *Emotional*, *Mental*, *Vigor* and *Total Fatigue*) were assessed using the multi-dimensional fatigue scale inventory-short form pre and post session 1, 5 and 10. Heat adaptation was induced following ODHA and TDHA, with reductions in resting rectal temperature and heart rate, and increased plasma volume and sweat rate ($P<0.05$). *General*, *Physical* and *Total Fatigue* increased from pre-to-post for session 1 within both groups ($P<0.05$). Increases in *General*, *Physical* and *Total Fatigue* were attenuated in session 5 and 10 *vs.* session 1 of ODHA ($P<0.05$). This change only occurred at session 10 of TDHA ($P<0.05$). Whilst comparative heat adaptations followed ODHA and TDHA, perceived fatigue is prolonged within TDHA.

Key words

Heat stress; internal load; fatigue; heat acclimation; heat adaptation

1. Introduction

Exercise-heat stress, such as that forecasted for the Tokyo 2020 Olympic and Paralympic Games (Gerrett et al., 2019), induces physiological (e.g. hyperthermia, dehydration and cardiovascular load) and perceptual strain (e.g. elevated thermal sensation [TS], decreased thermal comfort [TC] and increased rating of perceived exertion [RPE]). These disruptions are associated with an increased risk of heat related illness (Howe and Boden, 2007) and/or compromised athletic performance (Guy et al., 2015), in comparison to equivalent exercise in temperate conditions. Sensations of fatigue are a complex emotion and can be self-assessed by single- (e.g. ratings of subjective or perceived fatigue [Borg, 1998]) or multi-dimensional Likert scales (e.g. via *General, Physical, Emotional, Mental, Vigor* and *Total Fatigue* scores [Stein et al., 2004]), to indicate an individual's sense of tiredness and/or exhaustion before and after exercise (Donovan et al., 2015). These sensations of fatigue are typically experienced alongside changes in physiological responses (e.g. increased rectal temperature [T_{re}], heart rate [HR] and/or inflammatory/stress markers), which can further augment the magnitude of perceptual strain experienced (McMorris et al., 2006; Tamm et al., 2014). For example, greater perceived fatigue has been found during exercise-heat stress (running at 60% of peak oxygen uptake [$\dot{V}O_{2peak}$] in 42°C, 18% relative humidity [RH]) compared to temperate conditions (22°C, 35% RH) (Tamm et al., 2014, 2015). Similarly, increased *General* and *Physical Fatigue* scores were reported whilst cycling at 2 $W \cdot kg^{-1}$ during the first of four sessions of exercise-heat stress (45°C, 30% RH), with reported symptoms of augmented lethargy and tiredness (Willmott et al., 2017), which were correlated with an increased T_{re} (~39.0°C). These contributing factors and symptoms accompanying increased perceived fatigue, may manifest into unplanned cumulative fatigue, illness and/or potentially over-reaching if not monitored adequately during repeated and/or intensified training, especially within extreme environmental conditions (Peiffer and Abbiss, 2011; Buchheit et al., 2012; Meeusen et al., 2013). As such, daily monitoring of perceptual wellbeing (e.g. perceived fatigue) and/or psychological status (e.g. mood, stress and anxiety) of high-performance athletes is common-place within elite sport (Halson, 2014; Saw et al., 2015) and has demonstrated positive relationships with physical performance in training (Gallo et al., 2016).

One method to alleviate the aforementioned physiological and perceptual consequences of exercise-heat stress, is heat acclimation (HA) (Sawka et al., 2011), which is a chronic heat alleviation strategy recommended for athletes (Racinais et al., 2015) to be implemented in the preceding months before the Tokyo 2020 Olympic and Paralympic Games (Gerrett et al., 2019; Griggs et al., 2019; Pryor et al., 2019a). Physiological and perceptual adaptations following HA are well documented (Sawka et al. [2011], Tyler et al. [2016], Daanen et al. [2018]), however, an individual's sensations of fatigue towards acute exercise-heat stress and subsequent adaptations following repeated exposures during HA of differing time-scales are less well understood (Willmott et al., 2017). This is a pertinent issue, given the required stimuli to optimise adaptations (e.g. elevated T_{re} and skin temperature, and profuse sweating)

(Sawka et al., 2011) within challenging environmental conditions (~40°C, 40% RH [Tyler et al., 2016]) are also those which induce increased sensations of fatigue (Willmott et al., 2017). Additionally, a better understanding of the effects of acute heat stress on perceived fatigue is necessary, because HA interventions are commonly implemented alongside ongoing technical training and other physical preparation priorities. Previously, lower sensations of fatigue have been reported following four (Willmott et al., 2017), seven (Tian et al., 2011), ten (Tamm et al., 2015) and ten/eleven days of HA (Pryor et al., 2019), alluding to a desirable negative relationship with the length of HA. However, in these experiments the HA method did not reflect the empirically recommended medium- to long-term isothermic model (e.g. 10-14 days of controlled hyperthermia [T_{re} ≥38.5°C]) (Racinais et al., 2015), therefore, the perceived fatigue following this specific HA intervention remains unknown. Whilst single, once-daily HA (ODHA) sessions across a medium-term timescale are recommended (Racinais et al 2015), it has recently been observed that non-consecutive twice-daily HA (TDHA) presents similar heat adaptations, with no apparent differences in inflammatory/stress responses to ODHA (Willmott et al., 2018a). The non-consecutive TDHA intervention presents individuals with a greater flexibility when prescribing HA, however it is unclear whether TDHA over short- and medium-term time-scales (e.g. 5 *vs.* 10-sessions) induces greater sensations of fatigue than ODHA.

Although the contributing factors to sensations of fatigue are multi-faceted, data suggest they may be influenced by inflammatory/stress markers. Following 4-weeks of repeated occupational specific-heat stress, fire service instructors reported increased *General Fatigue*, alongside chronic physiological strain and augmented inflammatory/stress responses, indicating an overtraining-type response (Watt et al., 2016). Though inflammatory markers (e.g. interleukin-6 [IL-6]) and/or stress responses (e.g. cortisol) during HA (Guy et al., 2016; Willmott et al., 2017, 2018a; Costello et al., 2018) have been investigated, this data in conjunction with the sensations of fatigue has not been reported and may be an important element of an athlete-focused wellbeing monitoring strategy (Pyne et al., 2014; Costa et al., 2019). This requires attention given higher concentrations of IL-6 and cortisol appear to augment perceived fatigue and subsequently impair aerobic endurance (Robson-Ansley et al., 2004) and cognitive performance (McMorris et al., 2006), with evidence indicating correlations between perceived fatigue and cortisol concentrations, and body mass loss (e.g. dehydration) during exercise-heat stress (McMorris et al., 2006).

Therefore, this study had the following aims; 1) describe the magnitude of sensations of fatigue during an acute exercise-heat stress exposure; 2) investigate whether STHA and MTHA reduce the sensations of fatigue; 3) understand whether training frequency elicited differences in the sensations of fatigue between ODHA and TDHA protocols; and 4) investigate factors which contribute to the changes in perceived fatigue. It was hypothesised that; 1) the sensations of fatigue will increase following an acute exercise-heat stress exposure; 2) MTHA would confer greater improvements in the sensations of fatigue compared to STHA, due to a greater dose of HA (e.g. 10- sessions [600-min] *vs.* 5-sessions [300-min]), thus enhancing heat acclimation state and alleviating any undesirable effects of repeated exercise-heat stress; 3) no differences would occur in the sensations of fatigue between ODHA and TDHA protocols, due to the same weekly dose of HA and similar physiological strain; and 4) increased physiological strain is associated with higher sensations of fatigue scores.

2. Methods

2.1 Participants and ethical approval

Twenty moderately-trained males volunteered to participate in this study having provided written informed consent. This study was approved by the institution's Research Ethics and Governance Committee and conducted in accordance with the principles of the Declaration of Helsinki (2013). Data presented within this study formed part of a larger study (Willmott et al., 2018a), however, the current study investigated different hypotheses and data focussing on the sensations of fatigue during HA over differing time-scales and with variances in HA protocols.

2.2 Experimental design and protocols

Following a graded cycling exercise test (SRM high performance model, Germany) within temperate conditions (22°C, 40% RH) to determine $\dot{V}O_{2peak}$ (Hayes et al., 2014) and a heat acclimation state test (Willmott et al., 2015) (as described further in Willmott et al. [2018a]), participants were matched for biophysical characteristics and aerobic capacity, and assigned to consecutive ODHA (n=10, age: 23±6 years, body mass: 77.2±10.0 kg, stature: 1.78±0.08 m, $\dot{V}O_{2peak}$: 3.76±0.46 $L{\cdot}min^{-1}$, body surface area: 1.95±0.16 m^2 and body fat: 14.9±2.7 %) or non-consecutive TDHA (n=10, 25±7 years, 75.3±9.5 kg, 1.79±0.04 m, 3.74±0.50 $L{\cdot}min^{-1}$, 1.94±0.13 m^2 and 14.3±3.7%). All participants completed ten, 60-min sessions in hot conditions (45°C, 20% RH) over a 12-day period. Isothermic HA was implemented to ensure equal absolute thermoregulatory strain was elicited throughout the intervention thus giving sufficient physiological strain for adaptation and providing equal strain to make comparisons across sessions (Taylor, 2014). HA started at a power output of 2.3 $W{\cdot}kg^{-1}$ (Gibson et al., 2017) and a cadence of 80 $rev{\cdot}min^{-1}$, which was subsequently altered every 15-min corresponding with the participants' ΔT_{re} and perceived effort (Gibson et al., 2015, Neal et al., 2016a) to target T_{re} of ≥38.5°C (Taylor, 2014). Participants avoided alcohol and caffeine 12-h before each visit and arrived euhydrated, as determined by urine; osmolality <700 $mOsmol.kg^{-1}$ (Osmocheck, Vitech Scientific Ltd, Japan) specific gravity <1.020 (refractometer, Atago, Japan) and colour <3 (Sawka et al., 2007).

2.3 Perceptual measures

Thirty minutes pre and post session 1, 5 and 10, the sensations of fatigue via five subscales (*General, Physical, Emotional, Mental, Vigor*) and an overall *Total Fatigue* scale were measured using the multi-dimensional fatigue symptom inventory-short form (MFSI-SF) (Stein et al., 2004). The MFSI-SF has been validated (Stein et al., 1998; 2004), implemented within previous heat stress research (Watt et al., 2016; Willmott et al., 2017) and is assessed using 30 statements on a Likert scale from 0 (*Not at all*) to 4 (*Extremely*). Fatigue scores are added together as per Stein et al. (2004), with high scores indicating larger levels of; *General, Physical, Emotional, Mental* and *Total Fatigue*, and low scores indicating lower levels of *Vigor*. Perceptions of RPE (Borg, 1982) from 6 (*No exertion*) to 20 (*Maximal Exertion*), thermal sensation (TSS [Toner et al., 1986]) from 0 (*Very Very Cold*), 4 (*Neutral*) to 8 (*Very Very Hot*), and TC (Zhang et al., 2004) from 0 (*Very Comfortable*) to 5 (*Very Uncomfortable*), were collected during exercise at 5-min intervals during exercise heat stress. Familiarisation to scales were provided and time was enabled for questions before each session.

2.4 Physiological measures

Participant's T_{re} (Henley Medical Supplies rectal thermistor, UK and YSI 4600 Series Precision™ Thermometer, USA [accuracy: ± 0.115˚C]) and HR (Polar, Electro Oy, Finland) were continuously monitored and recorded at 5-min intervals during exercise heat stress. Fluid intake was restricted for sessions 1, 5 and 10, to estimate whole-body sweat loss (WBSL) via pre-to-post session changes in nude body mass. Sweat samples were collected using an absorbent pad (Tegaderm+Pad 3M™, USA) to assess sodium concentration ($[Na^+]$) (Sweat-Chek™ Eli Tech Group, Wescor Inc., USA). To estimate ΔPV (Dill and Costill, 1974) between session 1, 5 and 10, a fingertip capillary blood sample was collected in triplicate and assessed for haemoglobin concentration (HemoCue, Ltd., Sweden) and haematocrit (Hawksley and Sons Ltd, England). A 10 mL venous blood sample was also analysed for plasma IL-6 (*Ready Set Go!*®, eBioscience, Affymetrix Inc., USA) and cortisol (Sigma-Aldrich, USA) using commercially available ELISA kits. Data were corrected for ΔPV.

2.5 Data and statistical analyses

All data are reported as mean ± SD, with statistical significance set at $P<0.05$. Data were assessed and conformed to normality and sphericity prior to further statistical analysis. Analysis of data for HA (n=20) combines data sets from both ODHA (n=10) and TDHA (n=10). To investigate intervention efficacy for HA, physiological data were analysed using one-way repeated measures ANOVA, whereas perceptual data were analysed using a Friedman test. To investigate changes following ODHA and TDHA, physiological and perceptual data were analysed using two-way repeated measures ANOVA (*Group*Time*) for *Group* (ODHA and TDHA) and *Time* (session 1, 5 and 10, and, Δ between session 1-5 and 1-10). Following a significant F- (ANOVA) or X^2-value (Friedman test), follow up Bonferroni-corrected post-hoc comparisons and Wilcoxon signed-rank tests were used, respectively. Relationships between perceptual and physiological measures, and the sensations of fatigue were examined using Spearman's rank-order correlation coefficient (*r*), as per previous work (Watt et al., 2016; Willmott et al., 2017, 2018b). Following the determination of significant linear relationships, statistically significant variables were entered into stepwise multiple regression analysis to better understand the correlations associated with the sensations of fatigue, as per previous work (Gibson et al., 2014, James et al., 2017a). Relationships were interpreted as; <0.3 = weak, 0.3-0.5 = moderate, 0.5-0.7 = strong, 0.7-0.9 = very strong, 0.9-1.0 near perfect (Hopkins, 2002).

3. Results

3.1 Heat adaptations and exercise intensity data

Key markers of physiological (reductions in resting T_{re} and HR, conserved sweat [Na^{+}], increased WBSL and PV expansion) and perceptual adaptations (reductions in RPE, TSS [e.g. "*feeling cooler*"] and TC [e.g. "*feeling more comfortable*"]) to heat stress were observed following 5 and 10-sessions of HA, ODHA and TDHA (all $P<0.05$) (Table 1). These physiological and perceptual adaptations were greater following 10-sessions compared to 5 for both ODHA and TDHA ($P<0.05$), with no between-group differences found ($P>0.05$) (see Willmott et al. [2018]). No main effect or interaction (all $P>0.05$) for exercise intensity (e.g. total work completed and mean power [W, % of $\dot{V}O_{2peak}$ and $W.kg^{-1}$]) were found between sessions 1, 5 and 10 for HA, ODHA and TDHA (Table 1). However, there was a main effect for ΔT_{re} (P=0.001), where a larger ΔT_{re} was observed during session 5 and 10 compared to session 1 ($P<0.05$), but no interaction occurred (P=0.597).

Table 1. Mean ± SD changes (Δ) in heat adaptations for session 1-5 and 1-10 and exercise intensity data for sessions 1, 5 and 10.

	ODHA and TDHA Combined (n=20)			ODHA (n=10)			TDHA (n=10)		
Heat Adaptation	**1-5**		**1-10**	**1-5**		**1-10**	**1-5**		**1-10**
ΔRest T_{re} (°C)	-0.20 ± 0.21*		-0.28 ± 0.16*	-0.18 ± 0.27*		-0.28 ± 0.22*	-0.22 ± 0.17*		-0.28 ± 0.19*
ΔRest HR ($b \cdot min^{-1}$)	-5 ± 4*		-10 ± 4*	-5 ± 1*		-10 ± 3*	-5 ± 5*		-10 ± 4*
ΔPV (%)	+5.6 ± 3.9		+9.1 ± 4.4*	+6.3 ± 4.0		+10.1 ± 5.6*	+5.4 ± 4.0		+8.5 ± 3.1*
ΔWBSL (mL)	+202 ± 176*		+463 ± 200*	+230 ± 207*		+533 ± 261*	+178 ± 142*		+398 ± 97*
Δ[Na^+] ($mmol \cdot L^{-1}$)	-10 ± 10*		-20 ± 14*	-13 ± 13*		-27 ± 19*	-7 ± 6		-14 ± 5*
ΔRPE_{peak}	-1 ± 1		-2 ± 1*	-1 ± 1		-2 ± 1*	-1 ± 1		-2 ± 1*
ΔTSS_{peak}	-0.5 ± 0.5		-0.9 ± 0.6*	-0.3 ± 0.4		-0.7 ± 0.5*	-0.5 ± 0.5		-0.9 ± 0.5*
ΔTC_{peak}	-1 ± 1		-1 ± 1*	-1 ± 1		-1 ± 1*	0 ± 1		-1 ± 1*
Δ[IL-6] ($pg.mL \cdot L^{-1}$)	+0.1 ± 0.8		-0.1 ± 0.7	+0.2 ± 0.8		-0.1 ± 0.8	0.0 ± 0.8		-0.1 ± 0.6
Δ[Cortisol] ($nmol \cdot L^{-1}$)	+6 ± 25		-17 ± 29	+5 ± 20		-26 ± 28	+8 ± 31		-8 ± 28
Exercise Intensity	**1**	**5**	**10**	**1**	**5**	**10**	**1**	**5**	**10**
Exercise time (min)	60 ± 0	60 ± 0	60 ± 0	60 ± 0	60 ± 0	60 ± 0	60 ± 0	60 ± 0	60 ± 0
Total work (kJ)	474 ± 51	482 ± 63	496 ± 52	476 ± 61	485 ± 56	490 ± 47	472 ± 41	479 ± 60	502 ± 58
Mean power (W)	137 ± 10	140 ± 10	143 ± 15	141 ± 10	141 ± 9	142 ± 16	134 ± 10	139 ± 11	144 ± 15
Mean power (% $\dot{V}O_{2peak}$)	48 ± 5	49 ± 6	50 ± 5	49 ± 5	49 ± 5	50 ± 3	47 ± 4	49 ± 8	50 ± 6
Mean power ($W \cdot kg^{-1}$)	1.7 ± 0.1	1.8 ± 0.1	1.8 ± 0.2	1.8 ± 0.1	1.8 ± 0.1	1.8 ± 0.2	1.7 ± 0.1	1.8 ± 0.1	1.8 ± 0.2
ΔT_{re} (°C)	1.39 ± 0.23	1.54 ± 0.23	1.61 ± 0.27	1.42 ± 0.23	1.53 ± 0.23	1.58 ± 0.26	1.37 ± 0.24	1.56 ± 0.25	1.64 ± 0.28
Mean HR ($b \cdot min^{-1}$)	151 ± 12	150 ± 10	147 ± 11	151 ± 14	155 ± 9	150 ± 12	151 ± 9	145 ± 8	144 ± 9
Δbody mass (%)	1.4 ± 0.4	1.6 ± 0.4	2.0 ± 0.4	1.2 ± 0.3	1.4 ± 0.4	1.9 ± 0.4	1.5 ± 0.5	1.8 ± 0.3	2.1 ± 0.5

*represents a significant (*P*<0.05) pre- to post-intervention difference. Tabular data are adapted from Willmott et al. (2018a).

3.2 Sensations of fatigue

The sensations of fatigue data are presented in Table 2 and Figure 1 for HA, ODHA and TDHA.

Pre and post fatigue scores: No differences occurred for pre session fatigue scores ($P>0.05$) during HA however, there were lower *General*, *Physical* and *Total Fatigue* scores and higher *Vigor* scores ($P<0.05$) observed following session 10 compared to session 1 of HA. No differences ($P>0.05$) between ODHA and TDHA occurred for pre or post scores across each session.

Within-session: General, *Physical* and *Total Fatigue* increased from pre to post in session 1, 5 and 10 ($P<0.05$), whereas, *Vigor* reduced from pre to post in session 1 and 5 ($P<0.05$) for HA, ODHA and TDHA. No differences were observed in *Emotional* or *Mental Fatigue* ($P>0.05$). The changes in *General, Physical* and *Total Fatigue* scores from pre to post were larger ($P<0.05$) in session 5 for the TDHA group compared to ODHA, but no differences were found for session 1 or 10 ($P>0.05$).

Between-session: The pre to post change in *General*, *Physical* and *Total Fatigue* and *Vigor* were smaller in session 10 compared to session 1 for HA ($P<0.05$), but no changes were found for *Emotional* or *Mental Fatigue* ($P>0.05$). During ODHA, the pre to post change in *General*, *Physical* and *Total Fatigue* and *Vigor* were smaller ($P<0.05$) in session 5 and 10, compared to session 1. Whereas, during TDHA, the pre to post change in *General*, *Physical* and *Total Fatigue* were smaller ($P<0.05$) for session 10 only compared to session 1 and 5. Pre to post change in *Vigor* were also lower for session 10 compared to session 1 only for TDHA ($P<0.05$).

Table 2. Mean ± SD pre, post and changes in the sensations of fatigue for sessions 1, 5 and 10 during combined ODHA and TDHA

Group	ODHA and TDHA Combined					
Session	**1**		**5**		**10**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
General	3.7 ± 3.0	10.6 ± 4.3*	3.6 ± 2.4	8.2 ± 7.9*	3.8 ± 3.6	6.0 ± 5.1*†
Physical	1.9 ± 2.3	5.5 ± 4.0*	1.8 ± 1.2	5.4 ± 5.2*	2.1 ± 2.4	3.5 ± 3.1*†
Emotional	1.7 ± 2.5	1.8 ± 2.7	0.5 ± 0.8	0.8 ± 1.0	1.6 ± 2.9	1.2 ± 2.7
Mental	1.8 ± 2.5	2.1 ± 2.7	1.1 ± 1.6	0.5 ± 1.5	1.2 ± 1.9	1.1 ± 2.6
Vigor	12.5 ± 4.9	7.6 ± 5.4*	12.8 ± 5.2	10.1 ± 8.0*	12.1 ± 5.8	12.5 ± 7.1†
Total Fatigue	-2.8 ± 9.0	12.4 ± 12.2*	-4.1 ± 6.3	4.8 ± 20.7*	-3.5 ± 10.0	2.7 ± 13.1*†
	Within-session change					
	1		5		10	
General	+6.9 ± 4.4*		+4.6 ± 7.4*		+2.2 ± 4.9*	
Physical	+3.6 ± 4.3*		+3.7 ± 5.3*		+1.5 ± 2.7*	
Emotional	+0.1 ± 1.7		+0.4 ± 1.2		-0.4 ± 2.1	
Mental	+0.3 ± 1.7		-0.6 ± 2.0		-0.1 ± 1.3	
Vigor	-4.9 ± 3.9*		-2.8 ± 5.9*		+0.4 ± 2.6	
Total Fatigue	+15.2 ± 12.2*		+8.9 ± 20.3*		+6.2 ± 7.4*	
	Between-session change difference					
	1-5		**5-10**		**1-10**	
General	-2.3 ± 7.3		-2.5 ± 7.0		-4.8 ± 4.4†	
Physical	+0.1 ± 6.3		-2.2 ± 5.1		-2.2 ± 3.9†	
Emotional	+0.3± 1.3		-0.7 ± 2.5		-0.5 ± 2.3	
Mental	-0.9 ± 2.5		+0.5 ± 2.5		-0.4 ± 2.4	
Vigor	+2.2 ± 5.4		+2.0 ± 3.9		+5.3 ± 3.9†	
Total Fatigue	-6.3 ± 18.1		-2.7 ± 17.5		-9.0 ± 9.4†	

Note: * difference (P<0.05) within session, † difference (P<0.05) between session 1 and 10.

Table 3. Mean ± SD pre, post and changes in the sensations of fatigue for sessions 1, 5 and 10 during ODHA and TDHA

Group	ODHA						TDHA					
Session	**1**		**5**		**10**		**1**		**5**		**10**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
General	2.7 ± 2.2	9.2 ± 2.1*	3.7 ± 3.0	5.5 ± 6.2*	2.0 ± 2.4	4.4 ± 2.9*	4.7 ± 3.6	12.0 ± 5.5*	3.5 ± 1.8	10.9 ± 8.7*	5.6 ± 3.7	7.5 ± 6.4*
Physical	1.5 ± 1.2	4.7 ± 2.2*	1.7 ± 1.6	3.1 ± 3.8*	1.0 ± 1.3	2.5 ± 2.0*	2.3 ± 3.1	6.3 ± 5.2*	1.8 ± 0.6	7.7 ± 5.7*	3.1 ± 2.7	4.5 ± 3.7*
Emotional	1.7 ± 2.4	2.0 ± 2.4	0.4 ± 1.0	1.0 ± 1.3	0.5 ± 0.8	0.3 ± 0.5	1.6 ± 2.8	1.5 ± 3.1	0.5 ± 0.5	0.6 ± 0.5	2.6 ± 3.7	2.1 ± 3.7
Mental	2.2 ± 2.3	2.5 ± 2.6	1.1 ± 1.9	0.9 ± 2.0	0.3 ± 0.7	0.1 ± 0.3	1.4 ± 2.9	1.7 ± 2.8	1.0 ± 1.4	0.0 ± 0.0	2.0 ± 2.4	2.0 ± 3.6
Vigor	15.0 ± 4.5	9.5 ± 5.4*	16.1 ± 5.1	14.1 ± 8.2*	14.7 ± 5.3	16.3 ± 6.9	10.0 ± 4.2	5.7 ± 4.9*	9.5 ± 2.5	6.0 ± 5.6*	9.5 ± 5.2	8.6 ± 5.1
Total Fatigue	-6.4 ± 7.0	8.9 ± 8.5*	-6.5 ± 7.6	-3.6 ± 18.5*	-9.5 ± 5.5	-3.7 ± 8.4*	0.8 ± 9.7	15.8 ± 14.6*	-1.7 ± 2.5	13.2 ± 20.0*	2.5 ± 10.1	9.1 ± 14.1*

Within-session change

	1	5	10	1	5	10
General	+6.5 ± 3.3*	+1.8 ± 6.7*$^{\partial}$	+2.4 ± 4.1*	+7.3 ± 5.4*	+7.4 ± 7.4*	+1.9 ± 5.9*
Physical	+3.2 ± 2.5*	+1.4 ± 4.1*$^{\partial}$	+1.5 ± 1.2*	+4.0 ± 5.8*	+5.9 ± 5.6*	+1.4 ± 3.7*
Emotional	+0.3 ± 1.9	+0.6 ± 1.5	-0.2 ± 0.4	-0.1 ± 1.4	+0.1 ± 0.9	-0.5 ± 3.0
Mental	+0.3 ± 1.8	-0.2 ± 2.5	-0.2 ± 0.6	+0.3 ± 1.6	-1.0 ± 1.4	0.0 ± 1.7
Vigor	-5.5 ± 4.3*	-2.0 ± 5.8*	+1.6 ± 2.4	-4.3 ± 3.6*	-3.5 ± 6.3*	-0.9 ± 2.1
Total Fatigue	+15.3 ± 10.5*	+2.9 ± 17.8*$^{\partial}$	+5.8 ± 7.2*	+15.0 ± 14.3*	+14.9 ± 21.7*	+6.6 ± 7.9*

Between-session change difference

	1-5	**5-10**	**1-10**	**1-5**	**5-10**	**1-10**
General	-4.7 ± 6.6‡$^{\partial}$	+0.6 ± 6.6$^{\partial}$	-4.1 ± 3.3†	+0.1 ± 7.5	-5.5 ± 6.3$^{\#}$	-5.4 ± 5.3†
Physical	-1.8 ± 5.8‡	+0.1 ± 4.1$^{\partial}$	-1.7 ± 2.7†	+1.9 ± 6.5	-4.5 ± 5.1$^{\#}$	-2.6 ± 4.9†
Emotional	+0.3 ± 1.5	-0.8 ± 1.7	-0.5 ± 2.1	+0.2 ± 1.1	-0.6 ± 3.1	-0.4 ± 2.5
Mental	-0.5 ± 2.1	0.0 ± 3.1	-0.5 ± 2.3	-1.3 ± 1.8	+1.0 ± 1.9	-0.3 ± 2.6
Vigor	+3.5 ± 5.5‡	+1.8 ± 4.6	+7.1 ± 2.7†	+0.8 ± 5.2	+0.1 ± 2.9	+3.4 ± 4.2†
Total Fatigue	-12.4 ± 17.1‡$^{\partial}$	+2.9 ± 16.7$^{\partial}$	-9.5 ± 7.1†	-0.1 ± 17.7	-8.3 ± 17.3$^{\#}$	-8.4 ± 11.6†

Note: * difference ($P<0.05$) within session, † difference ($P<0.05$) between session 1 and 10, and ‡ difference ($P<0.05$) between session 1 and 5, $^{\#}$ difference ($P<0.05$) between session 5 and 10, and $^{\partial}$ difference ($P<0.05$) between ODHA and TDHA.

3.3 Inflammatory and stress markers

[IL-6] and [cortisol] increased from pre to post for session 1, 5 and 10 of ODHA and TDHA (all $P<0.05$) as per Willmott et al. (2018a), but no differences ($P>0.05$) were found within- or between-groups for the baseline levels or Δ[IL-6] and Δ[cortisol] across sessions 1, 5 or 10.

3.4 Relationships between parameters

The Δ*General* and Δ*Physical Fatigue* scores for session 1, 5 and 10 correlated with the Δbody mass, ΔT_{re}, RPE_{peak}, Δ[IL-6] and Δ[cortisol], but as expected not with exercise intensity data (e.g. total work completed, mean power [W, $W.kg^{-1}$ or % of $\dot{V}O_{2peak}$] or mean HR) (Table 4).

For combined HA data (n=20), significant models (all $P<0.001$) from stepwise multiple regression analysis predicted Δ*General Fatigue* scores for session 1 ($r^2=0.69$: Δ[cortisol] and ΔT_{re}) and 5 ($r^2=0.84$: ΔT_{re}, RPE_{peak} and Δ[cortisol]), and; Δ*Physical Fatigue* scores for session 1 ($r^2=0.59$: Δbody mass and Δ[IL-6]), 5 ($r^2=0.83$: Δbody mass, Δ[cortisol] and RPE_{peak}) and 10 ($r^2=0.85$: Δbody mass, Δ[IL-6] and RPE_{peak}). Significant models (all $P<0.05$) were also found for ODHA, which predicted; Δ*General Fatigue* scores for session 1 ($r^2=0.75$: Δ[cortisol] and ΔT_{re}) and 5 ($r^2=0.83$: ΔT_{re} and Δbody mass), and; Δ*Physical Fatigue* scores for session 5 ($r^2=0.97$: Δbody mass, Δ[IL-6] and Δ[cortisol]). Likewise, a significant model ($P<0.001$) was found for TDHA, predicting; Δ*General Fatigue* scores for session 1 ($r^2=0.94$: RPE_{peak} and Δ[cortisol]) (full data is displayed in supplemental material).

Table 4. Correlation coefficients (r) between the within-session Δ*General* and Δ*Physical Fatigue* scores and, physiological and perceptual data during HA, ODHA and TDHA for sessions 1, 5 and 10.

	Δ*General Fatigue* score			Δ*Physical Fatigue* score		
	1	**5**	**10**	**1**	**5**	**10**
n = 20	**ODHA and TDHA Combined**					
Δbody mass (%)	-0.64*	-0.71*	-0.75*	-0.67*	-0.75*	-0.80*
ΔT_{re} (°C)	0.66*	0.76*	0.65*	0.57*	0.62*	0.62*
RPE_{peak}	0.67*	0.62*	0.48*	0.41	0.66*	0.52*
Δ[cortisol] ($nmol \cdot L^{-1}$)	0.75*	0.60*	0.58*	0.60*	0.66*	0.62*
Δ[IL-6] ($pg \cdot mL \cdot L^{-1}$)	0.45*	0.68*	0.34	0.63*	0.70*	0.64*
Total work (kJ)	0.19	0.13	0.21	0.21	0.14	0.04
Mean power (W)	0.12	0.15	0.06	0.10	0.10	0.02
Mean HR ($b \cdot min^{-1}$)	0.17	0.13	0.13	0.13	0.01	0.22
n = 10	**ODHA**					
Δbody mass (%)	-0.37	-0.76*	-0.61*	-0.05	-0.81*	-0.73*
ΔT_{re} (°C)	0.40	0.76*	0.36	-0.10	0.53	0.50
RPE_{peak}	0.33	0.74*	0.32	0.11	0.73*	0.11
Δ[cortisol] ($nmol \cdot L^{-1}$)	0.67*	0.45	0.57*	0.55*	0.63*	0.77*
Δ[IL-6] ($pg \cdot mL \cdot L^{-1}$)	0.00	0.64*	0.10	0.29	0.63*	0.12
Total work (kJ)	0.05	0.10	0.21	0.20	0.10	0.22
Mean power (W)	0.25	0.04	0.09	0.12	0.12	0.32
Mean HR ($b \cdot min^{-1}$)	0.06	0.19	0.14	0.17	0.14	0.35
n = 10	**TDHA**					
Δbody mass (%)	-0.75*	-0.54*	-0.89*	-0.84*	-0.62*	-0.86*
ΔT_{re} (°C)	0.78*	0.78*	0.84*	0.79*	0.75*	0.66*
RPE_{peak}	0.92*	0.63*	0.58*	0.57*	0.69*	0.71*
Δ[cortisol] ($nmol \cdot L^{-1}$)	0.82*	0.74*	0.62*	0.66*	0.73*	0.59*
Δ[IL-6] ($pg \cdot mL \cdot L^{-1}$)	0.57*	0.65*	0.55*	0.71*	0.71*	0.84*
Total work (kJ)	0.28	0.16	0.20	0.21	0.20	0.11
Mean power (W)	0.27	0.21	0.03	0.11	0.13	0.19
Mean HR ($b \cdot min^{-1}$)	0.20	0.14	0.12	0.19	0.17	0.28

Note: *P<0.05. Highlighted moderate-correlations (r = >0.5)

4. Discussion

This study investigated the acute sensations of fatigue to an initial exercise heat stress session, and then investigated these responses following STHA and MTHA, as well as between ODHA and TDHA protocols. Our first aim was to describe changes in sensations of fatigue following acute exercise-heat stress. In line with our first hypothesis, *General* and *Physical Fatigue* scores increased, and *Vigor scores* decreased following session 1 of HA. Our second aim was to understand whether isothermic HA (irrespective of training frequency) would reduce sensations of fatigue. In agreement with our hypothesis, our data displays smaller within-session changes in *General* and *Physical Fatigue* scores following 10 sessions of HA, but not 5, thus supporting our hypothesis and reaffirming MTHA is both effective at inducing greater physiological adaptations and attenuates the increased sensations of fatigue reported during acute exercise-heat stress. Our third aim was to investigate whether training frequency influenced sensations of fatigue. Contrary to our third hypothesis, ODHA conferred smaller within-session changes in perceived fatigue following 5 and 10 sessions of HA, in comparison to non-consecutive TDHA, where lesser changes were only apparent after 10 sessions. Although lower scores in the sensation of fatigue occurred following STHA (ODHA only) and MTHA (both ODHA and TDHA), our results indicate an increased perceived fatigue is sustained during early stages of HA if completed twice-daily. Finally, our fourth aim was to explore the predictors of perceived fatigue, whereby, in agreement with our hypothesis, moderate-strong correlations are found between increased physiological strain (e.g. ΔT_{re} and Δbody mass) and Δ*General* and Δ*Physical Fatigue* scores. As ODHA and TDHA provide comparable heat adaptations, biomarker responses, and aerobic performance improvements (Willmott et al., 2018a), should practitioners wish to utilise the flexible non-consecutive TDHA approach, wellness monitoring (e.g. perceived fatigue) and recovery strategies (e.g. cooling) may be necessary. This may assist with the prevention of cumulative perceived fatigue and/or over-reaching responses, especially within the first 5 sessions of TDHA.

4.1 Overview of the sensations of fatigue

Acute

As expected during session 1 of HA, *General, Physical* and *Total Fatigue* scores increased, yet no between-group differences transpired. The increased sensations of fatigue within an acute exercise-heat stress exposure (*General*: +7 ± 4*, Physical*: +4 ± 4 and *Total Fatigue*: +15 ± 12) agree with previous findings from the first of four HA sessions (+6 ± 7, +3 ± 3 and +13 ± 15, respectively [Willmott et al., 2017]) and are largely dependent upon the physiological strain experienced.

Chronic

Whilst STHA induced adaptation (Table 1), it was ineffective in reducing the degree of perceived fatigue experienced in this timescale when combing data from both HA groups (Table 2). However, when investigating HA protocols independently, ODHA exhibited smaller changes in perceived fatigue (i.e. *General, Physical* and *Total Fatigue*) following 5 sessions (i.e. STHA), thus confirming previous findings within ultra-marathon runners (Willmott et al., 2017), and also, after 10 sessions (i.e. MTHA) compared to session 1 (Table 3). Interestingly, the within-session change in fatigue scores during ODHA were lower compared to TDHA, with reductions during TDHA only found following session 10 (Table 3). Nonetheless, the sensations of fatigue were lower following MTHA when implementing ODHA, in agreement with previous literature (Tamm et al., 2015; Pryor et al., 2019b), and during non-consecutive TDHA, although between-group differences remain in the time-scale for perceptual improvements. Therefore, whilst ODHA and TDHA induce comparable physiological adaptations and exercise performance improvements (Willmott et al., 2018a), distinct differences arise in time-scales for improved sensations of fatigue. Interestingly, this is despite both HA groups completing the same weekly 'dose' of HA (e.g. exposure time [300-min·week^{-1}] and frequency [5-sessions·week^{-1}]) and may be partly explained by recovery time during interventions and/or the inter-individual variability within the sensations of fatigue (Willmott et al., 2018a).

The sensations of fatigue are complex and central in origin, yet likely influenced by thermal and non-thermal feedback from the periphery (Bainbridge, 1919; Toner et al., 1986; Gagge et al., 1969; Borg, 1998; St Clair Gibson 2003; Floris and Schlader, 2015). This is in keeping with the contribution of skin temperature to TSS, reflecting the relative magnitude of perceived ambient temperature (Attia, 1984) and TC reflecting the perceptual indifference between T_{re} and the environmental conditions (Mercer, 2001; Flouris and Schlader 2015). Therefore, improvements in the sensations of fatigue are in part, likely explained by the repeated experience of exercise-heat stress (Tamm et al., 2015), and conceivably, the induced physiological (i.e. reductions in resting T_{re} and sweat setpoint, and augmented WBSL) and perceptual adaptations (i.e. lower TSS and RPE, and improved TC [Table 1]) (Willmott et al., 2018a). The combination of these multi-factored reductions in perceived fatigue, exertion, thermal sensation and improved comfort are intriguing findings, particularly considering the physiological strain (e.g. ΔT_{re}), and total work completed and exercise intensity (e.g. mean power), were maintained throughout HA. Moreover, the specific subscales of the sensations of fatigue (Stein et al., 2004), indicate lower reported whole-body muscle aches and headache/syncope symptoms (i.e. *Physical Fatigue*), alongside lessened feelings of lethargy and tiredness (e.g. *General Fatigue*). As such, the consistent accumulation of these signs and symptoms of fatigue may lead to illnesses, maladaptation and/or over-reaching/training effects (Peiffer and Abbiss, 2011; Buchheit et al., 2012). This is especially likely if individuals are not monitored frequently for health status (Borresen and Lambert, 2009). Interestingly, no alterations appeared within *Emotional* nor *Mental Fatigue* scores throughout both protocols, suggesting a different mechanism to that which leads to impaired cognitive performance (e.g. attention tasks) in heat stress (Qian et al., 2015).

4.2 Predictors of the sensations of fatigue

Several potentially important contributors to changes in fatigue scores during HA were identified through Spearman's rank-order correlations (Table 4) and stepwise multiple regression analysis (supplemental material) including; Δbody mass, ΔT_{re}, RPE_{peak}, Δ[cortisol] and Δ[IL-6]. However, it is acknowledged data should be interpreted with caution as some of the contributing variables are likely to be interlinked across physiological systems. Nonetheless, moderate-strong correlations were observed between Δbody mass and, Δ*General* and Δ*Physical Fatigue* scores (Table 4), potentially indicating that larger WBSL influences perceived fatigue (as per previously identified relationships by McMorris et al. [2006]). Consequently, dehydration, which has been shown to increase Δ[cortisol] during HA when fluid intake is restricted (Neal et al., 2016b; Costello et al.,2018), may occur alongside feelings of stress (Vedhara et al., 2000) and impair cognitive performance (Hoffman et al., 1994; McMorris et al., 2006). As such our data indicates that heightened WBSL may induce perceived fatigue, especially during the initial stages of HA, which could be counterintuitive to preparation strategies. The relevance of *ad libitum* drinking *vs.* progressive dehydration on perceived fatigue during HA should therefore be examined.

Correlations were also observed between Δ[IL-6] and Δ*Physical Fatigue* scores during TDHA (Table 4), supporting indications that IL-6 may form one pathway that induces perceived fatigue (Robson-Ansley et al., 2004) and may interfere with the central nervous system through the proposed neuro-inflammation model (Vargas and Marino 2014). A likely reason for this only appearing during TDHA is the shorter-duration of recovery between sessions (Ronsen et al., 2002, 2004), as no between- or within-group differences in resting or Δ[IL-6] were observed. Nonetheless, TDHA provides ~6-h recovery during 'HA specific days' (i.e. between sessions 1-2, 3-4, 6-7 and 8-9) followed by ~39-h between non-consecutive HA sessions (i.e. between session 2-3, 4-5, 7-8 and 9-10), whereas, ODHA offers ~23-h of consistent recovery. As such, varying recovery times are a likely contributor to larger sensations of fatigue (Ronsen et al. 2002), especially within STHA time-scales, as physiological data for each session did not differ between-groups (Willmott et al., 2018a).

Finally, relationships between ΔT_{re} and, Δ*General* and Δ*Physical Fatigue* scores were observed for TDHA (Table 4 and supplemental material), indicating within- and/or between-group variation, as no differences occurred in T_{re} responses between HA protocols (Table 1). With each group completing the same weekly 'dose' of HA and perceived fatigue being assessed at the same time-of-day (i.e. session 1, 5 and 10 at 08:30 and 10:30-h), the TDHA group may have had a greater sensory association with their T_{re} (and plausibly TC, as no adaptation occurred following STHA [Δ0 ± 1], although T_{re} reduced [Δ-0.22 ± 0.17°C] [Table 1]). This may also explain the unaltered perceived fatigue scores in session 5 during TDHA. Nonetheless, whilst attenuated changes in perceived fatigue scores for session 10 were observed for both HA protocols, physiological signals from T_{re} continued to be an indicator of perceived fatigue during TDHA. Our findings agree with chronic heat exposure data within an occupational setting (Watt et al., 2016), but contrast data from STHA (Willmott et al., 2017) and MTHA studies (Tamm et al., 2015), which indicated heat acclimated individuals were less affected by temperature modulation, resulting in lower perceived fatigue. In agreement with the sensory association hypothesis for T_{re} (Watt et al., 2016) and disassociation of T_{re} signals following STHA (Willmott et al., 2017), an intriguing interpretation of our data indicates a potential sensory associated learning and/or training effect during HA, where mean T_{re} was maintained yet larger sensations of fatigue were not observed. This is likely due to the repeated exercise-heat stress experience (Tamm et al., 2015) and induced heat adaptations (Willmott et al., 2018a).

4.3 Application

An understanding of the perceptual responses and subsequent time-course for adaptations is important for those prescribing HA, allowing perceived fatigue to be somewhat predicted and potentially mitigated. As such, our research supports anecdotal evidence of increased tiredness and lethargy following exercise-heat stress (Willmott et al., 2017), which is important to consider when prescribing HA, such as that for the Tokyo 2020 Olympic and Paralympic Games (Gerrett et al., 2019; Griggs et al., 2019). The cumulative effect of combined stressors and progressive physiological strain (e.g. controlled-hyperthermia, dehydration and/or biomarker responses) may induce negative and augmented sensations of fatigue within the initial HA session (Willmott et al., 2017), thus affecting adherence and/or performance during subsequent HA sessions. However, chronic exposures of repeated exercise-heat stress can mitigate prevailing detriments (James et al., 2017b), with perceptual adaptations that may in turn, aid endurance performance in the heat to a greater extent than in cool conditions (James et al., 2017a). Particular attention to the sensations of fatigue is necessary during STHA, which may be more preferable to athletes (Garrett et al., 2011) preparing for Tokyo 2020, who must balance HA requirements and a need to maintain training quality. As such, whilst post-HA session recovery strategies (cooling interventions [e.g. cold-water immersion]) (Vaile et al., 2008; Skein et al., 2018), seem counterintuitive (e.g. reducing the extended time spent with an augmented T_{re}), they may help athletes feel, sleep and/or perform better during the subsequent HA session and requires further investigation.

4.4 Limitations

It is acknowledged that the absence of a control group exercising in temperate conditions, the lack of female participants and recreationally active, rather than well-trained athletes as participants are limitations of this study. Follow up data should examine responses in these groups.

5. Conclusion

Acute exercise-heat stress increases the sensations of fatigue, which can be attenuated by implementing chronic HA strategies. Whilst comparative heat adaptations followed ODHA and non-consecutive

TDHA, the increased sensation of fatigue during TDHA was only reduced after 10 sessions, whereas this response occurred by session 5 of ODHA. Monitoring wellness and/or undertaking recovery strategies may be considered when utilising flexible TDHA interventions to optimise heat adaptations and exercise performance, especially within the initial stages.

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7. Declarations of interest:

None

8. Abbreviations

Δ – Change
ANOVA – Analysis of variance
HA – Heat acclimation
HR – Heart rate
IL-6 – Interleukin-6
MFS-SF – Multi-dimensional fatigue symptom inventory-short form (MFSI-SF)
MTHA – Medium-term heat acclimation
Na^+ – Sodium
ODHA – Once daily heat acclimation
PV – Plasma volume
RH – Relative humidity
RPE – Rating of perceived exertion
SD – Standard deviation
SE – Standard error of the slope coefficient or intercept
SE_E – Standard error of the estimate for the regression equation
STHA – Short-term heat acclimation
TDHA – Twice daily heat acclimation
TC – Thermal Comfort
T_{re} – Rectal temperature
TSS – Thermal sensation
$\dot{V}O_{2peak}$ – Peak oxygen uptake
WBSL – whole-body sweat loss

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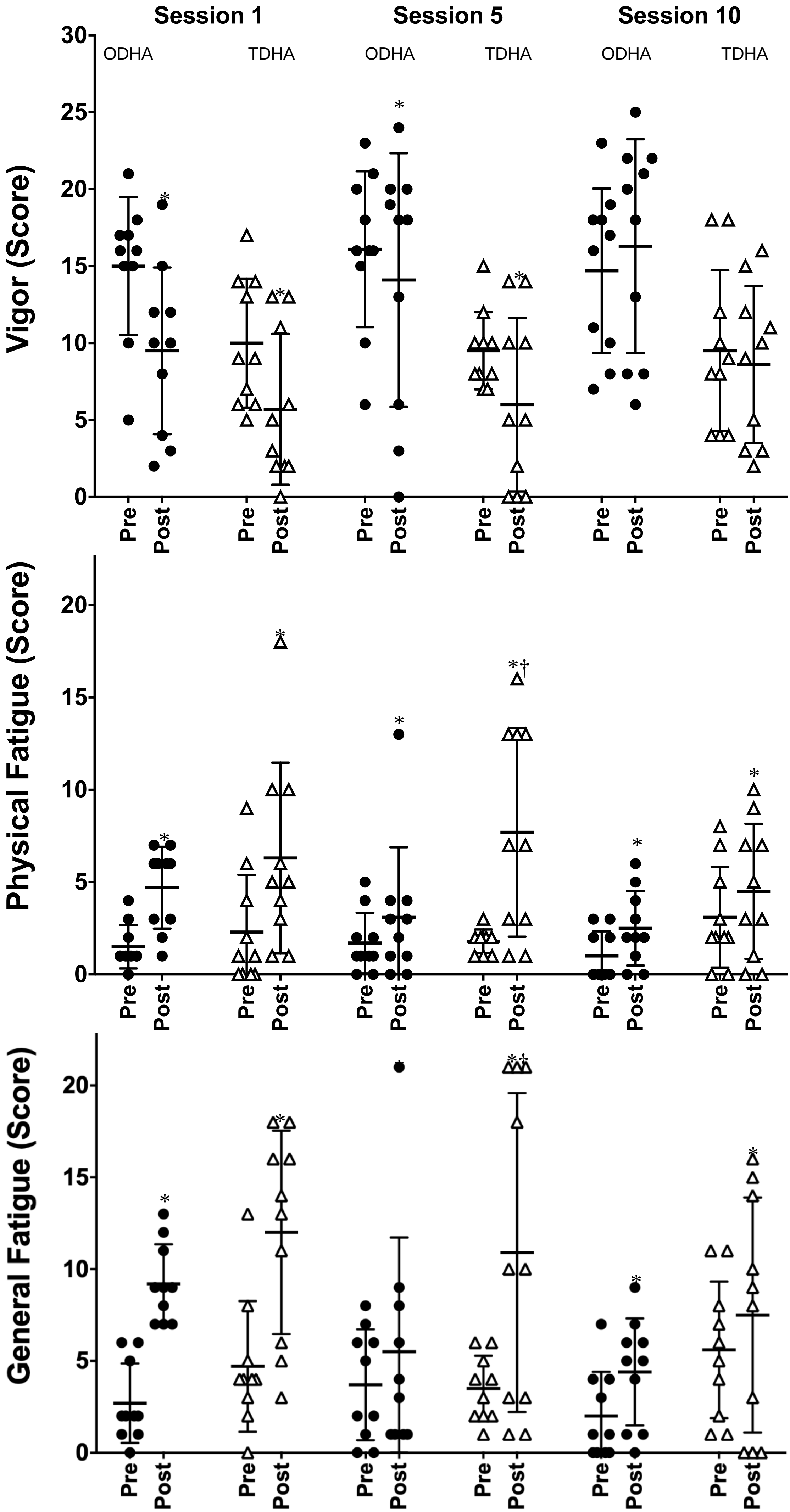

Session 1
Session 5
Session 10
ODHA
TDHA
ODHA
TDHA
ODHA
TDHA
Vigor (Score)
Physical Fatigue (Score)
General Fatigue (Score)
Pre
Post
*
*†

Stepwise multiple regression data for Δ*General* and Δ*Physical Fatigue* scores for HA, ODHA and TDHA sessions 1, 5 and 10.

	Δ*General Fatigue* score						**Δ*Physical Fatigue* score**					
	Variable	r^2	SE_E	***beta***	***SE***	***Tolerance***	**Variable**	r^2	SE_E	***beta***	***SE***	***Tolerance***
Session	**ODHA and TDHA Combined (n = 20)**											
	Model	0.69*	2.57	-16.75	3.98		*Model*	0.59*	2.94	-10.59	3.03	
1	Δ[cortisol]	0.57*		0.81	0.22	0.78	Δbody mass	0.44*		-4.79	1.72	0.81
	ΔT_{re}	0.12*		7.38	2.88	0.78	Δ[IL-6]	0.15*		2.99	1.22	0.81
	Model	0.84*	3.27	-57.96	7.12		*Model*	0.83*	2.39	-33.46	4.96	
5	ΔT_{re}	0.58*		16.71	3.60	0.89	Δbody mass	0.57*		-5.09	1.61	0.67
	RPE_{peak}	0.16*		1.56	0.43	0.86	Δ[cortisol]	0.15*		0.08	0.02	0.84
	Δ[cortisol]	0.09*		0.09	0.03	0.81	RPE_{peak}	0.11*		1.08	0.34	0.76
							Model	0.85*	0.81	-9.92	1.51	
10							Δbody mass	0.65*		-2.55	0.48	0.79
	-	-	-	-	-	-	Δ[IL-6]	0.12*		0.87	0.26	0.83
							RPE_{peak}	0.09*		0.32	0.10	0.93
Session	**ODHA (n = 10)**											
	Model	0.75*	1.87	-20.71	6.24							
1	Δ[cortisol]	0.45*		0.09	0.02	9.57	-	-	-	-	-	-
	ΔT_{re}	0.30*		9.87	3.39	9.57						
	Model	0.83*	3.10	-30.46	5.78		*Model*	0.97*	0.881	-24.39	2.28	
5	ΔT_{re}	0.58*		13.08	4.04	0.84	Δbody mass	0.65*		-3.87	0.98	0.56
	Δbody mass	0.25*		-9.06	2.82	0.84	Δ[IL-6]	0.18*		3.19	0.44	0.82
							Δ[cortisol]	0.14*		0.07	0.01	0.60
Session	**TDHA (n = 10)**											
	Model	0.94*	1.48	-28.12	3.48							
1	RPE_{peak}	0.85*		1.79	0.32	0.60	-	-	-	-	-	-
	Δ[cortisol]	0.09*		0.07	0.02	0.60						

*Note: *P<0.05,* r^2: *r* square, SE_E: standard error of the estimate for the regression equation, *beta*: unstandardized regression coefficients, *SE*: standard error of the slope coefficient or intercept, *Tolerance:* collinearity.