COMPARISON OF ACUTE PHYSIOLOGICAL AND PSYCHOLOGICAL RESPONSES BETWEEN MODERATE-INTENSITY CONTINUOUS EXERCISE AND THREE REGIMES OF HIGH-INTENSITY INTERVAL TRAINING

NICOLE OLNEY,[1] TIMOTHY WERTZ,[1] ZACHARY LAPORTA,[1] ADAM MORA,[1] JASMINE SERBAS,[1,2] AND TODD A. ASTORINO[1]

[1]*Department of Kinesiology, CSU–San Marcos, San Marcos, California; and* [2]*Department of Physical Therapy, Rocky Mountain University, Provo, Utah*

ABSTRACT

Olney, N, Wertz, T, LaPorta, Z, Mora, A, Serbas, J, and Astorino, TA. Comparison of acute physiological and psychological responses between moderate-intensity continuous exercise and three regimes of high intensity interval training. *J Strength Cond Res* 32(8): 2130–2138, 2018—High-intensity interval training (HIIT) elicits similar physiological adaptations as moderate-intensity continuous training (MICT) despite less time commitment. However, there is debate whether HIIT is more aversive than MICT. This study compared physiological and perceptual responses between MICT and 3 regimes of HIIT. Nineteen active adults (age = 24.0 ± 3.3 years) unfamiliar with HIIT initially performed ramp exercise to exhaustion to measure maximal oxygen uptake ($\dot{V}O_2$max) and determine workload for subsequent sessions, whose order was randomized. Sprint interval training (SIT) consisted of six 20-second bouts of “all-out” cycling at 140% of maximum watts (Wmax). Low-volume HIIT ($HIIT_{LV}$) and high-volume HIIT ($HIIT_{HV}$) consisted of eight 60-second bouts at 85% Wmax and six 2-minute bouts at 70% Wmax, respectively. Moderate-intensity continuous training consisted of 25 minutes at 40% Wmax. Across regimes, work was not matched. Heart rate (HR), $\dot{V}O_2$, blood lactate concentration (BLa), affect, and rating of perceived exertion (RPE) were assessed during exercise. Ten minutes postexercise, Physical Activity Enjoyment (PACES) was measured via a survey. Results revealed significantly higher ($p \leq 0.05$) $\dot{V}O_2$, HR, BLa, and RPE in SIT, $HIIT_{LV}$, and $HIIT_{HV}$ vs. MICT. Despite a decline in affect during exercise ($p < 0.01$) and significantly lower affect ($p \leq 0.05$) during all HIIT regimes vs. MICT at 50, 75, and 100% of session duration, PACES was similar across regimes ($p = 0.65$), although it was higher in women ($p = 0.03$). Findings from healthy adults unaccustomed to interval training demonstrate that HIIT and SIT are perceived as enjoyable as MICT despite being more aversive.

KEY WORDS sprint interval training, oxygen consumption, PACES, blood lactate concentration, affect

INTRODUCTION

The American College of Sports Medicine recommends that adults complete at least 30 minutes of moderate-intensity continuous exercise training (MICT) on most days of the week (15). Nevertheless, participation in physical activity is low which compromises health status and augments chronic disease risk. One common barrier to regular exercise is lack of time (42), which has caused health professionals to explore alternative exercise approaches to MICT.

High-intensity interval training (HIIT) is characterized by brief, intense efforts separated by recovery. Typically, HIIT requires lower exercise duration than MICT, which makes it more time-efficient (16). Studies in healthy adults show that chronic HIIT at submaximal or supramaximal intensities promotes similar (12,32) and in some cases superior adaptations (35) compared with MICT. A recent review of 28 studies including 723 healthy participants (33) demonstrated superior increases in maximal oxygen uptake ($\dot{V}O_2$max) in response to HIIT vs. MICT. In clinical populations, HIIT typically elicits greater health-related adaptations, such as increased vascular function, insulin sensitivity, and $\dot{V}O_2$max vs. MICT (38,44). Consequently, there is growing interest in the potential of HIIT to improve health and fitness in adults.

Despite the widespread use of chronic HIIT in various populations, fewer studies have explored acute responses to HIIT, especially to the most intense form of HIIT, sprint interval training (SIT). In men and women, it was reported that SIT in the form of repeated Wingate tests elicits intensities equal to 80% $\dot{V}O_2$max (14). In young men and women, Wood et al. (45) showed significantly higher $\dot{V}O_2$

Address correspondence to Dr. Todd A. Astorino, astorino@csusm.edu.

32(8)/2130–2138

Journal of Strength and Conditioning Research

in response to HIIT (eight 60-second bouts at 85% Wmax) vs. SIT (eight 30-second bouts at 130% Wmax), although blood lactate concentration (BLa) and rating of perceived exertion (RPE) were lower. To our knowledge, no study has examined acute responses to SIT and various modalities of HIIT and compared them with exercise following the public health guidelines (MICT). One great advantage of HIIT is that it allows infinite permutations in intensity, duration, and recovery, which can be tailored to the unique needs of the individual. Unfortunately, complete characterization of acute responses to HIIT or SIT bouts differing from the Norwegian 4 × 4 model (41), low-volume HIIT (45), or repeated Wingate tests (14) is relatively unclear. Additional investigation of these bouts will allow the fitness professional to better understand the unique cardiorespiratory strain of this widely used mode of exercise training.

Gender differences in response to exercise exist, showing that women are typically less fatigable than men (23). However, these potentially unique responses between men and women are rarely identified in the HIIT literature. For example, many studies only included men (7,36) or used populations of men and women (25,45) in which gender was not considered. One study (30) demonstrated that women performing repeated 4-minute bouts of treadmill-based HIIT reveal different physiological and perceptual responses than men. Similar long-term adaptations to HIIT have been demonstrated between genders (1,2), although data from two studies show dissimilar responses in men vs. women (17,31). These equivocal data merit further study to potentially identify unique responses to HIIT between genders.

Affective variables are important predictors of physical activity (7). It has been reported (39) that positive affective responses to exercise mediate future participation in physical activity. High-intensity interval training is typically viewed as more aversive than MICT (25), and SIT has been criticized for being too complex and eliciting aversive responses that will cause extreme avoidance by most exercisers (20). However, no study has compared affective responses between SIT and MICT. A better understanding of how SIT is viewed in comparison with HIIT and MICT will clarify the potential of SIT to improve health and fitness in the general population.

The purpose of this study was to compare acute physiological and perceptual responses between MICT and 3 unique HIIT regimes in men and women. We hypothesized that low-volume HIIT ($HIIT_{LV}$), high-volume HIIT ($HIIT_{HV}$), and SIT will elicit significantly higher $\dot{V}O_2$, HR, and BLa than MICT, with no differences between HIIT regimes (45). In addition, we hypothesized that women would exhibit similar physiological responses yet different perceptual responses vs. men. Little data have examined acute responses to SIT, and to our knowledge, no study has compared these responses between multiple SIT and HIIT regimes varying in intensity and volume. These results apply to health professionals including personal trainers by identifying acute changes in $\dot{V}O_2$, BLa, and heart rate (HR) to various HIIT regimes and can be used to create targeted exercise prescription to prevent chronic inactivity-related diseases.

Methods

Experimental Approach to the Problem

All sessions were performed at the same time of day within subjects and occurred in a temperature-controlled laboratory (temperature and relative humidity = 20–23° C and 40–50%). Testing occurred from March 2016 to July 2016. On day 1, $\dot{V}O_2$max and maximal work rate (Wmax) were assessed and used to set specific intensities for the different regimes, which were subsequently completed over 4 separate sessions. A minimum of 48 hours of recovery was allotted between sessions, whose order was randomized and counterbalanced across participants. Participants were asked to maintain their regular diet and to refrain from vigorous exercise 24 hours before each session and not eat for 3 hours before. Participants were instructed to come to each session well-rested and hydrated, which were confirmed via a written log. Physiological and perceptual responses were measured during each session.

Subjects

Healthy, habitually active men ($n = 10$) and women ($n = 9$) with similar $\dot{V}O_2$max (42.6 ± 6.5 ml·kg^{-1}·min^{-1} vs. 38.0 ± 4.2 ml·kg^{-1}·min^{-1}, $p = 0.07$) and physical activity (6.4 ± 3.1 h·wk^{-1} vs. 9.2 ± 3.7 h·wk^{-1}, $p = 0.10$) participated in this study. Their demographic characteristics are shown in Table 1.

Habitually active was defined as completion of greater than 150 min·wk^{-1} of physical activity during the last year consisting of resistance training, CrossFit, aerobic exercise, noncompetitive sport, or group exercise, which was confirmed with a survey (Past Year Total Physical Activity Questionnaire (34)) completed at study initiation. Inclusion criteria included habitually active, nonobese (body mass index <30 kg·m^{-2}), age = 18–40 years, nonsmoker, and in the case of women, eumenorrheic. Participants were also required to not have engaged in HIIT in the past year. All participants completed a medical history questionnaire to ensure absence of known cardiorespiratory or muscular contraindications or any medication use modifying study outcomes. All participants provided written informed consent before participating in the study, whose procedures were approved by the California State University, San Marcos, Institutional Review Board.

Procedures

Baseline Testing. Initially, height and body mass were determined to calculate body mass index (kg·m^{-2}). A HR monitor was placed on the trunk (Polar, Woodbury, NY, USA), and participants began ramp-based exercise on an electronically braked cycle ergometer (Velotron Dynafit Pro; Racermate, Seattle, WA, USA). Participants began pedaling with a 2-minute warm-up at 40–60 W with workload increased 20–30 W·min^{-1} until volitional exhaustion (pedal cadence below 50 revolutions per minute). To determine

Table 1. Participant physical characteristics (N = 19, mean ± SD).*

Parameter	Mean ± SD	Range	Men	Women
Age (y)	24.0 ± 3.3	20–31	24.0 ± 3.4	23.3 ± 3.3
Gender (men/women)	NA	10/9	NA	NA
Mass (kg)	67.1 ± 9.4	53.6–83.9	73.5 ± 6.9	60.1 ± 6.0†
Body mass index ($kg \cdot m^{-2}$)	23.1 ± 3.9	19.7–29.0	25.2 ± 2.3	21.0 ± 4.4†
PA ($h \cdot wk^{-1}$)	8.0 ± 4.9	3.0–14.0	6.4 ± 3.1	9.2 ± 3.7
$\dot{V}O_2$max ($ml \cdot kg^{-1} \cdot min^{-1}$)	40.3 ± 5.9	31.3–52.9	42.0 ± 6.5	38.0 ± 4.2
Wmax (W)	256.0 ± 52.0	176.0–350.0	285.1 ± 47.0	224.0 ± 36.2†
HRmax ($b \cdot min^{-1}$)	188.4 ± 8.7	169.0–202.0	188.1 ± 24.3	192.6 ± 19.5

*PA = habitual physical activity; $\dot{V}O_2$max = maximal oxygen uptake; W = workload; HR = heart rate.
†$p \leq 0.05$ vs. men.

$\dot{V}O_2$, pulmonary gas exchange data were obtained every 15 seconds using a metabolic cart (Parvomedics True One, Sandy, UT, USA), which was calibrated before testing according to the manufacturer. Verbal encouragement was provided throughout the test. Variables obtained from this test included maximal $\dot{V}O_2$ ($L \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$) and HR. $\dot{V}O_2$max was identified as the highest 15 seconds value from the last 30 seconds of exercise, and attainment of $\dot{V}O_2$max was confirmed by incidence of a plateau in $\dot{V}O_2$ ($\leq$150 $ml \cdot min^{-1}$) and RERmax >1.10 and HRmax 10 $b \cdot min^{-1}$ within 220–age (5). From this bout, Wmax was noted and used to set intensities for subsequent exercise sessions.

Exercise Regimes. Before all sessions, participants warmed up for 5 minutes at 20% Wmax. The bouts that were completed are similar to regimes implemented in inactive men and women (SIT (17,18)), active men and women (HIIT (2)) and sedentary women (HIIT (4)) resulting in increases in $\dot{V}O_2$max. Sprint interval training consisted of 6 "all-out" 20-second bouts at 140% Wmax separated by 140 seconds at 20% Wmax, low-volume HIIT consisted of eight 60-second bouts at 85% Wmax separated by 75 seconds at 20% Wmax, and high-volume HIIT required six 2-minute bouts at 70% Wmax separated by 60 seconds at 20% Wmax. Moderate-intensity continuous training was performed for 25 minutes at 40% Wmax, which follows the Physical Activity guidelines for all adults (15). Work was not matched between bouts to take advantage of the time efficiency of HIIT vs. MICT. Training time was equal to 2 (SIT), 8 ($HIIT_{LV}$), and 12 minutes ($HIIT_{HV}$), and total session duration ranged from 21 (SIT), 23 ($HIIT_{LV}$ and $HIIT_{HV}$), and 30 minutes (MICT), respectively.

Physiological Measures. Continuously during exercise, HR was measured with telemetry (Polar, Woodbury, NY, USA) and pulmonary gas exchange data were measured using a metabolic cart (Parvomedics True One, Sandy, UT, USA). Mean $\dot{V}O_2$ was determined as the average oxygen uptake for the entire exercise session not including the warm-up, and peak $\dot{V}O_2$ was identified as the highest oxygen uptake value attained at any time point during exercise. Any $\dot{V}O_2$ value ± 3 SD from the mean $\dot{V}O_2$ value for each subject during each regime was excluded (29). At baseline and at 25, 50, 75, and 100% of session duration, values of HR and $\dot{V}O_2$ were calculated from the last two 15-second data points and first value in recovery for each HIIT regime. Values from MICT were calculated pre-exercise and at 6.25, 12.5, 18.75, and 25 minutes of the exercise session.

Before the warm-up with the participant seated in a chair, a fingertip blood sample was obtained using a 23-gauge lancet (Owen Mumford, Inc., Marietta, GA, USA) to determinate BLa, which was measured with a portable meter (Lactate Plus, Nova Biomedical, Waltham, MA, USA).

This measure was repeated at 75% of session duration and 3 minutes postexercise for all regimes. During HIIT sessions, this sample was taken immediately at the end of each respective bout.

Perceptual Measures. Before each trial, participants were read specific instructions according to what each measure encompassed. They were asked to respond to each scale in terms of how they felt at that moment. The meaning of the CR-10 scale (8) was communicated by instructing participants to report perceptions of their exertion in terms of their breathing, HR, and level of fatigue. For affect, they were read the following text: *While participating in exercise, it is common to experience changes in mood. Some individuals find exercise pleasurable; whereas, others find it to be unpleasant. Additionally, feeling may fluctuate across time. That is, one might feel good and bad a number of times during exercise.* Rating of perceived exertion (RPE) was recorded pre-exercise and at 25, 50, 75, and 100% of session completion. Affect (11-point scale, rating from +5 very good to −5 very bad (21)) was recorded at the same time points as RPE. During MICT, these were acquired at 6.25, 12.5, 18.75, and 25 minutes; whereas, during HIIT and SIT, these variables were measured immediately at the end of the respective bout. Perceptual responses to HIIT vs. MICT are well-understood (7,25,40); however, little data have examined these responses to SIT. Ten minutes postexercise, participants completed the PACES scale (26), which required them to answer 18 items on a 1–7 scale.

Statistical Analyses

Data are expressed in mean ± *SD* and were analyzed using SPSS Version 20.0 (Chicago, IL, USA). The Shapiro-Wilks test was used to test normality of all variables. Two-way analysis of variance (ANOVA) with repeated measures was used to measure differences in $\dot{V}O_2$, BLa, PACES, and HR across session time (3–5 levels) and regime (4 levels). Tukey's post hoc analysis was used to determine significant differences between mean values when a significant *F* ratio was obtained. Differences in mean $\dot{V}O_2$, peak $\dot{V}O_2$, and energy expenditure between sessions were determined by 1-way ANOVA with repeated measures (regime = 4 levels), and post hoc testing was performed using the Bonferroni test. In all ANOVA analyses, gender was used as a between-subjects factor. The Greenhouse-Geisser correction was used to account for the sphericity assumption of unequal variances across groups. Cohen's *d* was used as an estimate of effect size, with a small effect = 0.15–0.40, medium effect = 0.40–0.75, large effect = 0.75–1.1, very large effect = 1.1–1.45, and huge effect >1.45, respectively. Sample size was comparable with a previous study comparing gender differences to HIIT (30). G Power (11) was used to confirm that a sample size of 9 per group is adequate to detect a change in $\dot{V}O_2$ equal to 0.20 $L \cdot min^{-1}$ across regimes and PACES equal to 10 units between men and women. Statistical significance was equal to $p \leq 0.05$.

Results

Sessions of HIIT were well-tolerated, although 2 participants who performed SIT could not complete the entire session, so HR, $\dot{V}O_2$, and BLa data presented for this regime are derived from 17 men and women. When no interaction or between-subjects effect occurred, as was the case with HR and RPE, data were combined for men and women, signifying no unique effect of gender. However, peak and mean oxygen uptake and calorie expenditure were higher ($p \leq 0.05$) in men vs. women, which is attributed to their greater body mass.

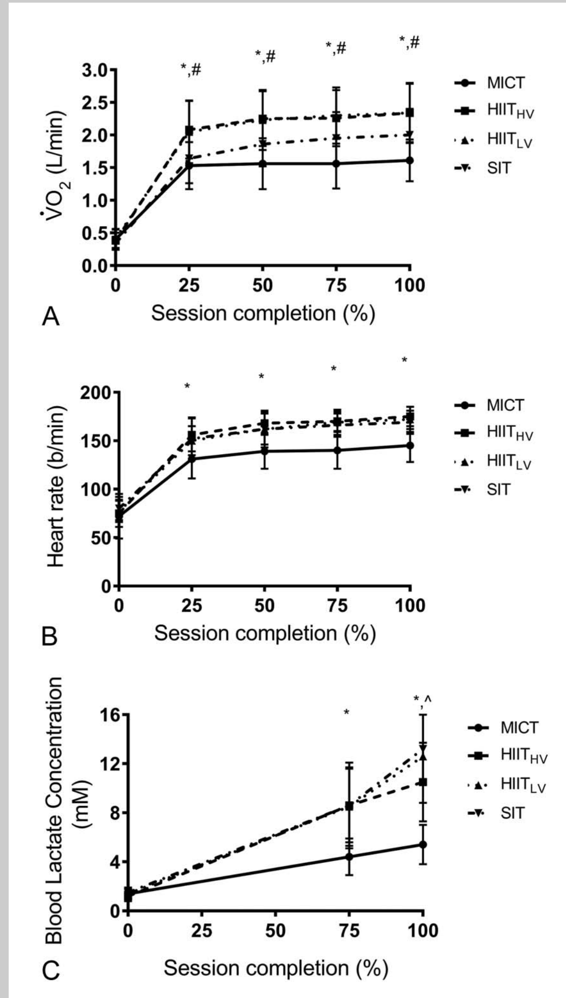

Figure 1. Change in (A) oxygen uptake, (B) heart rate, and (C) blood lactate concentration in response to moderate-intensity continuous training (MICT) and 3 distinct high-intensity interval training (HIIT) regimes (mean ± *SD*). *$p \leq 0.05$ between MICT and all HIIT regimes; #$p \leq 0.05$ between sprint interval training (SIT) and HIIT$_{HV}$ and HIIT$_{LV}$; ^$p \leq 0.05$ between HIIT$_{HV}$ and SIT.

Change in $\dot{V}O_2$ Across Regimens

Data showed a main effect of time ($p < 0.001$) and regimen ($p < 0.001$) and a regimen × time interaction ($p < 0.01$). A significant gender × regimen × time interaction ($p = 0.008$) was shown, documenting lower $\dot{V}O_2$ in women during exercise vs. men. Post hoc analyses showed that $\dot{V}O_2$ in MICT was significantly lower ($p \leq 0.05$) at 25, 50, 75, and 100% of session duration compared with all HIIT regimes. $\dot{V}O_2$ in SIT was significantly lower ($p \leq 0.05$) than HIIT$_{LV}$ and HIIT$_{HV}$ during exercise, yet there was no difference between HIIT$_{LV}$ and HIIT$_{HV}$. Data are shown in Figure 1A.

Change in Heart Rate Across Regimens

Similar to $\dot{V}O_2$, there was a main effect for HR across time ($p < 0.001$), regimen ($p < 0.001$), and a regimen × time interaction ($p < 0.001$) (Figure 1B). Data showed lower HR in MICT vs. all HIIT regimes throughout the bout. No interaction effect of gender was reported ($p > 0.15$). The HR response across SIT, HIIT$_{LV}$, and HIIT$_{HV}$ was not different ($p > 0.05$).

Change in Blood Lactate Concentration Across Regimens

Blood lactate concentration significantly increased during all exercise bouts ($p < 0.001$) (Figure 1C). A significant regimen × time ($p < 0.001$) and gender × time interaction ($p < 0.001$) was revealed. Post hoc analyses showed that BLa during MICT was significantly different ($p \leq 0.05$) than all HIIT regimes at 75 and 100% of bout duration; however, there was no difference ($p > 0.05$) in BLa between the HIIT regimes and SIT with exception of the 100% value, which was higher ($p \leq 0.05$) in response to SIT vs. $HIIT_{HV}$ (Cohen's $d = 1.1$). Women exhibited lower BLa ($p < 0.001$) during exercise compared with men across all regimes (Table 2).

Change in Calorie Expenditure Across Regimens

Calorie expenditure differed across regimens ($p < 0.001$), and post hoc analyses showed that it was higher in MICT (204.1 ± 37.8 kcal) compared with $HIIT_{LV}$ (173.6 ± 30.0 kcal, $d = 1.9$), $HIIT_{HV}$ (181.1 ± 35.3 kcal, $d = 1.4$), and SIT (131.9 ± 20.6 kcal, $d = 4.6$), which was significantly different vs. all other regimes. There was no significant difference ($p > 0.05$, $d = 0.4$) in calorie expenditure between $HIIT_{HV}$ and $HIIT_{LV}$. Women burned significantly fewer calories than men ($p = 0.04$) and there was a significant regime × gender interaction ($p < 0.001$).

Mean and Peak $\dot{V}O_2$ Response Across Regimens

Mean $\dot{V}O_2$ in MICT (1.53 ± 0.32 $L \cdot min^{-1}$) was significantly ($p = 0.017$) lower than $\dot{V}O_2$ in $HIIT_{HV}$ (1.92 ± 0.41 $L \cdot min^{-1}$, $d = 3.3$), $HIIT_{LV}$ (1.84 ± 0.36 $L \cdot min^{-1}$, $d = 2.6$), and SIT (1.68 ± 0.38 $L \cdot min^{-1}$, $d = 1.3$). Mean $\dot{V}O_2$ in SIT was significantly lower than both HIIT regimes ($p = 0.001$, $d = 2.0$ and 1.3), and $\dot{V}O_2$ in $HIIT_{LV}$ was lower than $HIIT_{HV}$ ($p = 0.002$, $d = 0.70$). Relative $\dot{V}O_2$ across regimens was equal to 56% $\dot{V}O_2max$ for MICT, 61% $\dot{V}O_2max$ for SIT, and 67 and 70% $\dot{V}O_2max$, respectively, for $HIIT_{LV}$ and $HIIT_{HV}$.

Peak $\dot{V}O_2$ differed across regimes ($p < 0.001$) but there was no regime × gender interaction ($p = 0.18$). Moderate-intensity continuous training yielded the lowest peak $\dot{V}O_2$ (1.92 ± 0.40 $L \cdot min^{-1}$), which was significantly ($p = 0.001$) lower than both HIIT regimes ($d = 3.3$) and SIT ($d = 2.0$). Sprint interval training (2.29 ± 0.53 $L \cdot min^{-1}$) was significantly different than both HIIT regimes ($p = 0.001$, $d = 1.3$). Peak $\dot{V}O_2$ in $HIIT_{LV}$ (2.54 ± 0.55 $L \cdot min^{-1}$) and $HIIT_{HV}$ (2.53 ± 0.57 $L \cdot min^{-1}$) was similar. Peak $\dot{V}O_2$ across regimes increased from MICT (69% $\dot{V}O_2max$) to SIT (83% $\dot{V}O_2max$) and $HIIT_{LV}$ and $HIIT_{HV}$ (92% $\dot{V}O_2max$).

Change in Affect, Rating of Perceived Exertion, and Physical Activity Enjoyment Across Regimens

Affect declined during exercise ($p < 0.001$) and there was a main effect across regime ($p < 0.001$). In all HIIT regimes, affect gradually declined throughout exercise; whereas, in MICT, it was reduced from baseline (4.68 ± 0.52) to 25% (3.30 ± 0.94) after which it was maintained. There was a regime × time ($p < 0.001$) and time × gender ($p = 0.01$) interaction, yet no regime × gender interaction ($p = 0.17$) was shown. Affect was significantly more positive ($p \leq 0.05$) in MICT at 50, 75, and 100% of session duration vs. HIIT or SIT, with no difference seen between

Table 2. Blood lactate concentration (mean ± *SD* in mM) in response to various exercise regimes in men and women.*†

Parameter	Men	Women	Cohen's *d*
MICT			
Pre-exercise	1.3 ± 0.4	1.6 ± 0.2	0.1
75%	5.1 ± 1.3	3.3 ± 1.3‡	0.7
100%	4.9 ± 1.9	2.9 ± 1.2‡	0.8
$HIIT_{HV}$			
Pre-exercise	1.0 ± 0.3	1.5 ± 0.5	0.2
75%	11.1 ± 2.8	7.0 ± 3.4‡	1.6
100%	12.2 ± 1.6	7.6 ± 2.8‡	1.8
$HIIT_{LV}$			
Pre-exercise	1.3 ± 0.4	1.6 ± 0.4	0.1
75%	10.6 ± 2.5	6.9 ± 1.0‡	1.4
100%	14.5 ± 3.9	9.4 ± 1.2‡	2.0
SIT			
Pre-exercise	1.4 ± 0.4	1.7 ± 0.3	0.1
75%	10.8 ± 2.4	6.9 ± 1.7‡	1.5
100%	14.2 ± 2.5	11.6 ± 2.9‡	1.0

*MICT = moderate-intensity continuous exercise training; $HIIT_{HV}$ = high-volume high-intensity interval training; $HIIT_{LV}$ = low-volume high-intensity interval training; SIT = sprint interval training.

†Cohen's *d* = effect size score for magnitude of difference in BLa between men and women.

‡$p \leq 0.05$ between men and women for that regime.

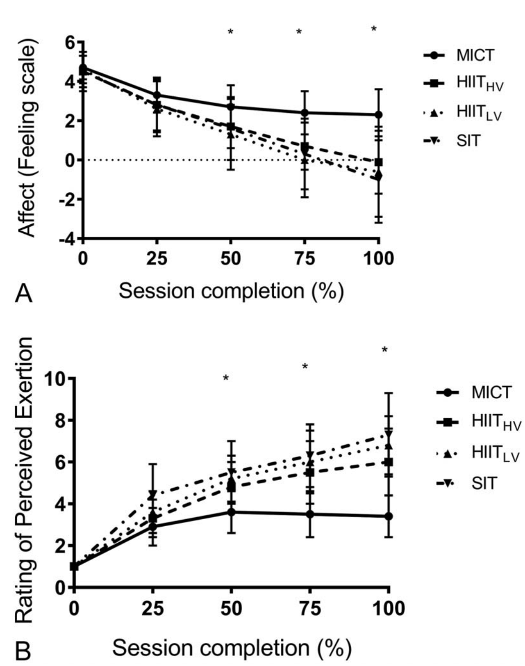

Figure 2. Change in (A) affect and (B) rating of perceived exertion in response to moderate-intensity continuous training (MICT) and 3 distinct high-intensity interval training (HIIT) regimes (mean ± *SD*). *$p \leq 0.05$ between MICT and all HIIT regimes.

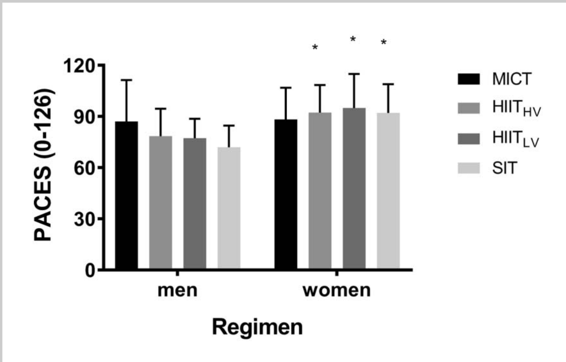

Figure 3. Change in Physical Activity Enjoyment (PACES) in men and women in response to moderate-intensity continuous training (MICT) and 3 distinct high-intensity interval training (HIIT) regimes (mean ± *SD*); Cohen's $d = 1.5$, 1.0, 1.3, and 0.1 between men and women for MICT, $HIIT_{HV}$, $HIIT_{LV}$, and sprint interval training (SIT), respectively.

these regimens (Figure 2A). Rating of perceived exertion increased during exercise ($p < 0.001$), and there was a main effect of regime ($p < 0.001$) and regime × time interaction ($p < 0.001$), but no gender × time ($p = 0.08$) or gender × regime interaction ($p = 0.26$). Rating of perceived exertion was significantly lower ($p \leq 0.05$) during MICT at 50, 75, and 100% of session duration vs. HIIT and SIT, with no difference between these regimens (Figure 2B). The mean PACES value was similar across regimes ($p = 0.65$) and was equal to 81.4 ± 17.7 (MICT), 85.6 ± 18.0 ($HIIT_{LV}$), 85.2 ± 17.3 ($HIIT_{HV}$), and 87.6 ± 21.2 (SIT), respectively. There was no regime × gender interaction ($p = 0.19$), although between-subjects ANOVA revealed that women demonstrated higher PACES ($p = 0.03$) vs. men. These data are shown in Figure 3.

Discussion

The present study compared acute physiological and perceptual responses to MICT vs. distinct regimens of HIIT and low-volume SIT between men and women. The hypothesis was met as $\dot{V}O_2$, HR, and BLa were higher in SIT, $HIIT_{LV}$, and $HIIT_{HV}$ compared with MICT. Most variables were similar in $HIIT_{LV}$ vs. $HIIT_{HV}$, which suggests that these regimes elicit similar cardiorespiratory and perceptual strain despite different intensity and work duration. Despite the greater metabolic and cardiorespiratory strain of HIIT/SIT, enjoyment was similar across regimes, although women perceived SIT and the 2 HIIT regimes to be more enjoyable than men.

Our findings show that $HIIT_{HV}$ and $HIIT_{LV}$ elicit a higher mean and peak $\dot{V}O_2$ compared with MICT and low-volume SIT, likely because of enhanced recruitment of type I and IIa fibers and greater dependence on aerobic metabolism. These data corroborate findings from a previous study (45) showing higher $\dot{V}O_2$ in response to HIIT vs. SIT. Gosselin et al. (19) showed that repeated 90-second bouts of HIIT at 90% $\dot{V}O_2max$ led to higher $\dot{V}O_2$ vs. 30- and 60-second bouts. Similarly, 4 × 4 HIIT exhibited higher mean $\dot{V}O_2$ compared with low-volume HIIT (43). Together, these findings suggest that higher volume HIIT optimizes the $\dot{V}O_2$ response to exercise vs. lower volume regimes. In addition, Islam et al. (24) showed higher $\dot{V}O_2$ in response to brief bouts of "all-out" SIT consisting of treadmill running (twenty-four 5-second bouts with 40-second recovery) compared with four 30-second bouts and eight 15-second bouts, although the exercise duration (2 minutes) was matched across protocols. Data from Horn et al. (22) demonstrated submaximal $\dot{V}O_2$ yet attainment of maximal cardiac output. This substantial cardiorespiratory stimulus may induce significant long-term increases in $\dot{V}O_2max$ whether training includes HIIT (4,12), SIT (3,31), or a combination of both (2). Training at a higher fraction of $\dot{V}O_2max$ characteristic of $HIIT_{HV/LV}$ may be the optimal approach for improving fitness and health-related outcomes (33).

Our data show that low-volume and high-volume HIIT varying in intensity and duration of work and recovery elicit similar changes in physiological and perceptual variables with exception of mean $\dot{V}O_2$. To our knowledge, this is the first study comparing acute responses with various submaximal HIIT regimes differing in work and intensity. Data (27,37) demonstrate that longer intervals at the same intensity elicit higher exertion vs. shorter intervals, which is explained by higher glycolytic flux, BLa accumulation, and disturbance to acid-base balance (9). However, our data showed similar RPE, enjoyment, BLa, HR, and peak $\dot{V}O_2$ between $HIIT_{HV}$ and $HIIT_{LV}$, which is likely because of the lower volume (8 minutes vs. 12 minutes) and higher intensity of $HIIT_{HV}$ (85% Wmax) compared with $HIIT_{LV}$ (70% Wmax). However, the majority of our participants preferred the shorter to the longer intervals, likely because of the more frequent transition from work to recovery and greater feeling of accomplishment (25).

Level of enjoyment is one of the primary factors related to physical activity participation in adults (42), so understanding how various regimes of exercise modify enjoyment is an important issue for fitness professionals. Our PACES scores (Figure 3) are comparable with previously reported values (7,24,36,43) in healthy men completing 2 regimes of HIIT (92 ± 13), active men completing treadmill-based HIIT (88 ± 6), active men performing various SIT regimes (83–97), and healthy men completing HIIT (98 ± 17). Our results show that PACES was similar across regimes, which corroborates findings in active men (43) who reported similar PACES scores in response to low-volume and high-volume HIIT despite significant differences in $\dot{V}O_2$ and HR, supporting previous work (36). In contrast, higher enjoyment of low-volume HIIT compared with MICT was reported in untrained men and women (25) and healthy, active men and women (40). Methodological differences across studies including the specific structure of HIIT and use of mixed gender samples likely explain these discrepant results.

Alternatively, it is plausible that active individuals are accustomed to exercise durations characteristic of MICT, so they do not view this bout as being unpleasant. In contrast, sedentary men and women as previously used (25) may view any prolonged exercise bout as not enjoyable. In regards to SIT, Hardcastle et al. (20) criticized its practicality in sedentary populations and stated that the unpleasantness of SIT would cause exercisers to avoid it. Our data do not support this claim as enjoyment was not lower in response to SIT despite its supramaximal intensity. Shorter (5 seconds) SIT bouts led to higher enjoyment and greater intention to engage in these regimes vs. longer bouts (41). A reduced time commitment coupled with the dynamic nature of SIT likely contribute to the similar or higher enjoyment in comparison with MICT. In a 12-week randomized controlled study, only 3 $\text{min}\cdot\text{wk}^{-1}$ of SIT led to similar increases in $\dot{V}O_2$max, insulin sensitivity, and oxidative capacity vs. 150 $\text{min}\cdot\text{wk}^{-1}$ of MICT in untrained men (18). The substantial disturbance to physiological homeostasis induced by SIT likely activates signaling pathways, which induce these chronic adaptations.

Our data show that SIT is viewed as significantly more aversive than MICT, likely because of the higher BLa demonstrated in response to SIT vs. MICT (Figure 1C and Table 2). Nevertheless, data showed no difference in affect across all HIIT regimes despite different exercise durations and intensities, which suggests that submaximal and supramaximal HIIT may be perceived similarly. This lack of difference in affect between HIIT and SIT is similar to a previous study (45). At exercise cessation, our affect values ranged from -0.95 ± 2.50 (SIT) to -0.64 ± 2.33 ($HIIT_{LV}$) and -0.11 ± 1.66 ($HIIT_{HV}$). These values are comparable with affect ~0 reported in active men completing ten 1-minute bouts of HIIT at 90% peak treadmill velocity (13). Nevertheless, our affect data are more positive than values (~−2.0) exhibited by inactive men performing treadmill-based HIIT (13) and active men performing "all-out" treadmill-based SIT (−1.0 to −3.0 at exercise cessation) (41), which is likely because of the lower relative intensity of our HIIT regimes and brief exercise duration (~2 minutes) of SIT. The finding that affect is more aversive in response to HIIT vs. MICT, and the more positive affect seen in active vs. inactive individuals (13), can be explained by enhanced reliance on nonoxidative metabolism and consequently greater BLa response to exercise (Figure 2 and Table 2). Despite MICT showing higher affect vs. HIIT and SIT, it did not elicit higher enjoyment, suggesting that affect may be unrelated to exercise enjoyment as measured with PACES. This may be because affect typically rebounds to baseline values after exercise (25) when the PACES scale is administered. Despite consistent findings (1,12,17,31) reporting the efficacy of SIT to augment various health-related outcomes, it is still unknown whether SIT is more aversive than MICT in sedentary individuals.

Across regimes, MICT demonstrated the lowest RPE, which was significantly different from SIT and the 2 HIIT regimes (Figure 2B). Peak RPE of SIT (7.3 ± 2.1) was higher by 0.5 units and 1.2 units compared with $HIIT_{LV}$ and $HIIT_{HV}$, but these differences were not significant, which supports some data (43) but is opposed by other work showing higher RPE with SIT compared with HIIT (45). This similar RPE response may be because of the similar HR (Figure 1B) and BLa response to exercise with exception of the 100% value, which was highest in SIT (Figure 1C).

A novel finding of the present study was the significantly lower PACES scores shown in men vs. women for SIT (20 units), $HIIT_{HV}$ (14 units), and $HIIT_{LV}$ (17 units) (Figure 3). Participants had similar age, physical activity, and cardiorespiratory fitness, so discrepancies in physical characteristics do not seem to explain this result. This gender difference may be explained by significantly higher BLa accumulation in men vs. women during all regimes (Table 2). Data reveal that men are more fatigable than women (23), and they have a higher muscle mass, larger fast twitch fibers (28), and higher lactate dehydrogenase activity (28). This suggests that at a similar relative intensity, men have greater contribution of glycolysis, which would elicit substantial increases in BLa and, according to the Dual-Mode theory (10), lead to reductions in pleasure experienced during exercise. Fitness professionals may need to consider gender when prescribing HIIT to various clientele, as our data suggest that men and women do not perceive these bouts similarly.

There were a few limitations of our study. Data from this study can only be applied to healthy young, habitually active men and women rather than those with any preexisting conditions. Our regimes were not matched for work; moreover, the 2 HIIT sessions were lower volume than the Norwegian 4 × 4 model widely used (6). We did not measure self-efficacy responses to each regime. In a recent study (25), data showed that self-efficacy to perform HIIT or MICT was higher than that for vigorous MICT. This has been identified as a significant predictor of physical activity in adults (42). Although all participants were quite tolerant of HIIT, 1 male participant and 1 female participant were unable to complete all 6 bouts of SIT because of extreme fatigue and dizziness. Therefore, it is possible that SIT may not be well-tolerated in all populations, especially when performed "all-out" as completed in the present study.

Our findings reveal similar ratings of enjoyment across exercise bouts differing in cardiorespiratory and perceptual strain, indicating that in healthy men and women unfamiliar with interval training, this mode of exercise is not viewed as less enjoyable than MICT. In addition, high-volume and low-volume HIIT elicited a higher $\dot{V}O_2$ than SIT or MICT yet showed markedly similar levels of cardiorespiratory and perceptual strain.

Practical Applications

Our results apply to fitness professionals who prescribe HIIT to foster similar if not greater health benefits than those experienced via MICT and solve the lack of time and reduced enjoyment cited by many individuals. Our findings show that oxygen uptake, perceived exertion, and blood lactate were higher and affect was lower during HIIT compared with MICT, but the overall enjoyment reported was not different, which suggests that clients may perceive these regimes similarly. In addition, $\dot{V}O_2$ was higher in both HIIT regimes vs. SIT. If personal trainers implement SIT and HIIT, they should realize that these regimes elicit a slightly different cardiorespiratory stimulus despite similar HR and RPE. In addition, women reported higher levels of enjoyment compared with men. Practitioners should understand that men and women may perceive various exercise bouts differently despite similar exercise intensity.

Acknowledgments

The authors thank the participants for their effort in completion of this study and thank the assistance of Erica Dory, Cienna Norton, Caylyn Rodriguez, Rachel Berman, Rashell Mascardo, Julie Cross, Sofia Kabir, Adan Sanchez, Jerry Rodriguez, Luigi Bunyi, and Ashley Acosta during data collection. The results of the present study do not constitute endorsement of the product by the authors or the National Strength and Conditioning Association. The authors have no conflicts of interest to disclose.

References

1. Astorino, TA, Allen, RP, Roberson, DW, Jurancich, M, Lewis, R, McCarthy, K, and Trost, E. Adaptations to high-intensity training are independent of gender. *Eur J Appl Physiol* 111: 1279–1286, 2011.
2. Astorino, TA, Edmunds, RM, Clark, A, King, L, Gallant, RM, Namm, S, Fischer, A, and Wood, KA. High intensity interval training increases cardiac output and VO2max. *Med Sci Sports Exerc* 49: 265–273, 2017.
3. Astorino, TA and Schubert, MM. Individual responses to completion of short-term and chronic interval training: A retrospective study. *PLoS One* 9: e97638, 2014.
4. Astorino, TA, Schubert, MM, Palumbo, E, Stirling, D, McMillan, DW, Cooper, C, and Gallant, R. Magnitude and time course of changes in maximal oxygen uptake in response to distinct regimens of chronic interval training in sedentary women. *Eur J Appl Physiol* 113: 2361–2369, 2013.
5. Astorino, TA, White, AC, and Dalleck, LC. Supramaximal testing to confirm attainment of VO2max in sedentary men and women. *Int J Sports Med* 32: 1–6, 2008.
6. Bartlett, JD, Close, GL, Maclaren, DP, Gregson, W, Drust, B, and Morton, JP. High-intensity interval running is perceived to be more enjoyable than moderate-intensity moderate intensity exercise: Implications for exercise adherence. *J Sports Sci* 29: 547–553, 2011.
7. Bauman, AE, Reis, RS, Sallis, JF, Wells, JC, Loos, RJ, and Martin, BW. Correlates of physical activity: Why are some people physically active and others not? *Lancet* 380: 258–271, 2012.
8. Borg, G. *Borg's Perceived Exertion and Pain Scales.* Champaign, IL: Human Kinetics, 1998.
9. Christmass, MA, Dawson, B, and Arthur, PG. Effect of work and recovery duration on skeletal muscle oxygenation and fuel use during sustained intermittent exercise. *Eur J Appl Physiol* 80: 436–447, 1999.
10. Ekkekakis, P, Parfitt, G, and Petruzzello, S. The pleasure and displeasure people feel when they exercise at different intensities. *Sports Med* 41: 641–671, 2011.
11. Faul, F, Erdfelder, E, Lang, AG, and Buchner, A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Meth* 39: 175–191, 2007.
12. Foster, C, Farland, CV, Guidotti, F, Harbin, M, Roberts, B, Schuette, J, Tuuri, A, Doberstein, ST, and Porcari, JP. The effects of high intensity interval training vs steady state training on aerobic and anaerobic capacity. *J Sports Sci Med* 14: 747–755, 2015.
13. Frazao, DT, Junior, LF, Dantas, TCB, Krinski, K, Elsangedy, HM, Prestes, J, Hardcastle, SJ, and Costa, EC. Feeling of pleasure to high-intensity interval exercise is dependent of the number of work bouts and physical activity status. *PLoS One* 11: e0153986, 2016.
14. Freese, EC, Gist, NH, and Cureton, KJ. Physiological responses to an acute bout of sprint interval cycling. *J Strength Cond Res* 27: 2768–2773, 2013.
15. Garber, CE, Blissmer, B, Deschenes, MR, Franklin, BA, Lamonte, MJ, Lee, IM, Neiman, DC, and Swain, DP. Quantity and quality of exercise for developing and maintaining cardio-respiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. *Med Sci Sport Exerc* 43: 1334–1359, 2011.
16. Gibala, MJ, Gillen, JB, and Percival, ME. Physiological and health-related adaptations to low-volume interval training: Influences of nutrition and sex. *Sports Med* 44: 127–137, 2014.
17. Gillen, JB, Percival, ME, Skelly, LE, Martin, BJ, Tan, RB, Tarnopolsky, MA, and Gibala, MJ. Three minutes of all-out intermittent exercise per week increases skeletal muscle oxidative capacity and improves cardiometabolic health. *PLoS One* 9: 0111489, 2014.
18. Gillen, JB, Martin, BJ, MacInnis, MJ, Skelly, LE, Tarnopolsky, MA, and Gibala, MJ. Twelve weeks of sprint interval training improves indices of cardiometabolic health similar to traditional endurance training despite a five-fold lower exercise volume and time commitment. *PLoS One* 11: e0154075, 2016.
19. Gosselin, LE, Kozlowski, KF, DeVinney-Boymel, L, and Hambridge, C. Metabolic response of different high-intensity aerobic interval exercise protocols. *J Strength Cond Res* 26: 2866–2871, 2012.
20. Hardcastle, SJ, Ray, H, Beale, L, and Hagger, MS. Why sprint interval training is inappropriate for a largely sedentary population. *Front Psychol* 5: 1505, 2014.
21. Hardy, CJ and Rejeski, WJ. Not what, but how one feels: The measurement of affect during exercise. *J Sport Exerc Psychol* 11: 304–317, 1989.
22. Horn, T, Roverud, G, Sutzko, K, Browne, M, Parra, C, and Astorino, TA. Single session of sprint interval training elicits similar cardiac output but lower oxygen uptake versus ramp exercise to exhaustion in men and women. *Int J Physiol Pathophysiol Pharmacol* 8: 87–94, 2016.
23. Hunter, SK. Sex differences and mechanisms of task-specific muscle fatigue. *Exerc Sport Sci Rev* 37: 113–122, 2009.
24. Islam, H, Townsend, LK, and Hazell, TJ. Modified sprint interval training protocols. Part 1: Physiological responses. *Appl Phys Nutr Metab* 42: 339–346, 2017.
25. Jung, ME, Bourne, JE, and Little, JP. Where does HIT fit? An examination of the affective response to high-intensity intervals in comparison to continuous moderate- and continuous vigorous-intensity exercise in the exercise intensity-affect continuum. *PLoS One* 9: e11454, 2014.
26. Kendzierski, D and DeCarlo, KJ. Physical activity enjoyment scale: Two validation studies. *J Sport Exerc Psychol* 13: 50–64, 1991.
27. Kilpatrick, MW and Greeley, SJ. Exertional responses to sprint interval training: A comparison of 30-sec and 60-sec conditions. *Psychol Rep* 114: 854–865, 2014.
28. Komi, PV and Karlsson, J. Skeletal muscle fiber types, enzyme activities, and physical performance in young males versus females. *Acta Physiol Scand* 103: 210–218, 1978.

29. LaMarra, N, Whipp, BJ, Ward, SA, and Wasserman, K. Effect of interbreath fluctuations on characterizing exercise gas exchange kinetics. *J Appl Physiol* 62: 2003–2012, 1987.

30. Laurent, CM, Vervaecke, LS, Kutz, MR, and Green, JM. Sex-specific responses to self-paced, high-intensity interval training with variable recovery periods. *J Strength Cond Res* 28: 920–927, 2014.

31. Ma, JK, Scribbans, TD, Edgett, BA, Boyd, JC, Simpson, CA, Little, JP, and Gurd, BJ. Extremely low-volume, high-intensity interval training improves exercise capacity and increases mitochondrial protein content in human skeletal muscle. *Open J Mol Integr Physiol* 3: 202–210, 2013.

32. Metcalfe, RS, Koumanov, F, Ruffino, JS, Stokes, KA, Holman, GD, Thompson, D, and Vollaard, NBJ. Physiological and molecular responses to an acute bout of Reduced-Exertion High-Intensity Interval Training (REHIT). *Eur J Appl Physiol* 115: 2321–2334, 2015.

33. Milanovic, Z, Sporis, G, and Weston, M. Effectiveness of High-Intensity Interval Training (HIT) and continuous endurance training for VO2max improvements: A systematic review and meta-analysis of controlled trials. *Sports Med* 45: 1469–1481, 2015.

34. National Cancer Institute. *Past Year Total Physical Activity Questionnaire*. Bethesda, MD: National Institutes of Health, 2013. pp. 1–2.

35. Nybo, L, Sundstrup, E, Jakobsen, MD, Mohr, M, Hornstrup, T, Simonsen, L, Bülow, J, Randers, MB, Nielsen, JJ, Aagaard, P, and Krustrup, P. High-intensity training versus traditional exercise interventions for promoting health. *Med Sci Sports Exerc* 42: 1951–1958, 2010.

36. Oliveira, BRR, Slama, FA, Deslandes, AC, Furtado, ES, and Santos, TM. Continuous and high-intensity interval training: Which promotes higher pleasure? *PLoS One* 8: e79965, 2013.

37. Price, M and Moss, P. The effects of work:Rest duration on physiological and perceptual responses during intermittent exercise and performance. *J Sports Sci* 25: 1613–1621, 2007.

38. Ramos, JS, Dalleck, LC, Tjonna, AE, Beetham, KS, and Coombes, JS. The impact of high-intensity interval training versus moderate-intensity continuous training on vascular function: A systematic review and meta-analysis. *Sports Med* 45: 679–692, 2015.

39. Rhodes, RE, Fiala, B, and Conner, M. A review and meta-analysis of affective judgments and physical activity in adult populations. *Ann Behav Med* 38: 180–204, 2010.

40. Thum, JS, Parsons, G, Whittle, T, and Astorino, TA. High-intensity interval training elicits higher enjoyment than moderate intensity continuous exercise. *PLoS One* 12: e0166299, 2017.

41. Townsend, LK, Islam, H, Dunn, E, Eys, M, Robertson-Wilson, J, and Hazell, TJ. Modified sprint interval training protocols. Part II: Psychological responses. *Appl Physiol Nutr Metab* 42: 347–353, 2017.

42. Trost, SG, Owen, N, Bauman, AE, Sallis, JF, and Brown, W. Correlates of adults' participation in physical activity: Review and update. *Med Sci Sports Exerc* 34: 1996–2001, 2002.

43. Tucker, WJ, Sawyer, BJ, Jarrett, CL, Bhammar, DM, and Gaesser, GA. Physiological responses to high-intensity interval exercise differing in interval duration. *J Strength Cond Res* 29: 3326–3335, 2015.

44. Weston, KS, Wisloff, U, and Coombes, JS. High-intensity interval training in patients with lifestyle-induced cardiometabolic disease: A systematic review and meta-analysis. *Br J Sports Med* 48: 1227–1234, 2014.

45. Wood, KA, LaValle, K, Greer, K, Bales, B, Thompson, H, and Astorino, TA. Effects of two regimens of High Intensity Interval Training (HIIT) on acute physiological and perceptual responses. *J Strength Cond Res* 30: 244–250, 2016.