COMPARISON OF PSYCHOLOGICAL AND PHYSIOLOGICAL RESPONSES TO IMPOSED VS. SELF-SELECTED HIGH-INTENSITY INTERVAL TRAINING

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ABSTRACT

Kellogg, E, Cantacessi, C, McNamer, O, Holmes, H, von Bargen, R, Ramirez, R, Gallagher, D, Vargas, S, Santia, B, Rodriguez, K, and Astorino, TA. Comparison of psychological and physiological responses to imposed vs. self-selected high-intensity interval training. *J Strength Cond Res* XX(X): 000–000, 2018—High-intensity interval training elicits similar physiological adaptations as moderate intensity continuous training (MICT). Some studies report greater enjoyment to a bout of high-intensity interval exercise (HIIE) vs. MICT, which is surprising considering that HIIE is more intense and typically imposed on the participant. This study compared physiological and perceptual responses between imposed and self-selected HIIE. Fourteen adults (age = 24 ± 3 years) unfamiliar with HIIE initially performed ramp exercise to exhaustion to measure maximal oxygen uptake ($\dot{V}O_2$max) followed by 2 subsequent sessions whose order was randomized. Imposed HIIE consisted of eight 60 seconds bouts at 80 percent peak power output (% PPO) separated by 60 seconds recovery at 10 %PPO. Self-selected HIIE ($HIIE_{SS}$) followed the same structure, but participants freely selected intensity in increments of 10 %PPO to achieve a rating of perceived exertion (RPE) ≥ 7. During exercise, heart rate, $\dot{V}O_2$, blood lactate concentration (BLa), affect (+5 to −5), and RPE were assessed. Physical Activity Enjoyment Scale was measured after exercise. Results showed higher $\dot{V}O_2$ (+10%, $p = 0.013$), BLa ($p = 0.001$), and RPE ($p = 0.001$) in $HIIE_{SS}$ vs. $HIIE_{IMP}$, and lower affect ($p = 0.01$), and enjoyment (87.6 ± 15.7 vs. 95.7 ± 11.7, $p = 0.04$). There was a significantly higher power output in self-selected vs. imposed HIIE (263.9 ± 81.4 W vs. 225.2 ± 59.6 W, $p < 0.001$). Data suggest that intensity mediates affective responses rather than the mode of HIIE performed by the participant.

KEY WORDS affect, blood lactate concentration, cycle ergometry, oxygen uptake, imposed exercise

INTRODUCTION

In the last decade, hundreds of studies have examined the effects of high-intensity interval training (HIIT), defined as repeated bouts of near-maximal to maximal exercise separated by recovery (17), on various health- and fitness-related outcomes. In healthy adults, Milanovic et al. (26) and Sloth et al. (36) demonstrated increases in maximal oxygen uptake ($\dot{V}O_2$max) induced by HIIT and its more intense form, sprint interval training (SIT), which are similar and in some cases superior- vs. moderate-intensity continuous training (MICT). In populations with chronic disease, Weston et al. (40) documented approximately 2-fold greater increases in $\dot{V}O_2$max with HIIT vs. MICT. Overall, HIIT and SIT seem to be a suitable alternative to MICT in many populations.

One additional advantage of high-intensity interval exercise (HIIE) compared with MICT is that it has been viewed as a more enjoyable mode of exercise. This result is important considering that enjoyment is related to exercise adherence (10). In active men (4), interval running led to higher enjoyment compared with prolonged MICT. Similar findings were exhibited in untrained (25) as well as active individuals (37) performing bouts of HIIE and MICT. Although, this result is not universal because other studies showed no difference in enjoyment between HIIE or sprint interval exercise (SIE) and MICT (18,29), or lower enjoyment in response to HIIE vs. MICT (8). Discrepancies in the specific individuals tested as well as characteristics of the HIIE session completed across studies explain much of these disparate results, although additional study is merited to clarify whether enjoyment differs between MICT and HIIE.

One characteristic of most studies using HIIE is that these bouts are imposed on the participant, who has no choice but to react to the workload given to them. This approach is unnatural, considering that in the fitness setting, individuals self-select the modality, intensity, duration, and recovery

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interval of each exercise session. Imposed exercise also eliminates autonomy, which has been cited as an important mediator of exercisers' overall experience (7). Research demonstrates that participants self-select intensities close to their ventilatory threshold (VT) (33) because intensities above this elicit aversive responses (24) in the form of a decline in affect (+5 to −5 Feeling Scale, 19). This decrease in affect is caused by enhanced input from interoceptive cues of the brain (11), which act to encourage the exerciser to reduce intensity. In addition, this decline in affect may alter participants' willingness to perform regular physical activity (41), which emphasizes the importance of understanding changes in affect to various modalities of exercise. Previous studies (33,35) show that self-selected exercise tends to yield more positive affect vs. when exercise is imposed on the participant. This effect also occurs at intensities above the VT (30), which are characteristics of HIIE.

The aim of this study was to compare perceptual and physiological outcomes between imposed and self-selected HIIE. This study will elucidate if self-selected HIIE ($HIIE_{SS}$) may be viewed more favorably than imposed ($HIIE_{IMP}$) by examining changes in affect and enjoyment. To our knowledge, no previous study has examined this topic. Resultant data will add to existing literature regarding how to implement HIIE in various populations and assist clinicians in designing effective interval training regimes to augment fitness and health. This is an important topic, considering that individual preferences are related to individual adherence to exercise programs (9).

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%). On day 1, $\dot{V}O_2max$ and peak power output (PPO) were assessed during progressive exercise, with the latter used to set intensities for $HIIE_{IMP}$. 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 using a written log. Physiological and perceptual responses were measured during each session.

Subjects

Healthy, habitually active men ($n = 7$) and women ($n = 7$) aged 18–32 years participated in this study. Their mean age, body mass index (BMI), amount of physical activity, $\dot{V}O_2max$, maximal heart rate (HRmax), and PPO were equal to mean ± *SD* 23.1 ± 3.4 years, 23.7 ± 2.7 $kg \cdot m^{-2}$, 5.7 ± 2.1 $h \cdot wk^{-1}$, 42.2 ± 9.1 $ml \cdot kg^{-1} \cdot min^{-1}$, 188.4 ± 8.5 $b \cdot min^{-1}$, and 280.2 ± 74.5 W, respectively. Habitually active was defined as completion of greater than 150 $min \cdot wk^{-1}$ 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 (27) completed at study initiation. Inclusion criteria included habitually active, nonobese (BMI <30 $kg \cdot m^{-2}$), age = 18–40 years, nonsmoker, and in the case of women, eumenorrheic. Participants were also required to not have regularly engaged in HIIE 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

Assessment of $\dot{V}O_2max$ and Peak Power Output. Initially, height and body mass were determined to calculate BMI ($kg \cdot m^{-2}$). A heart rate (HR) monitor was placed on the trunk (Polar, Woodbury, NY, USA), and participants initiated ramp-based exercise on an electronically braked cycle ergometer (Velotron Dynafit Pro; Racermate, Seattle, WA, USA). Exercise began with a 2-minute warm-up at 40–70 W with work rate increased 20–35 $W \cdot min^{-1}$ until volitional exhaustion (pedal cadence <50 $rev \cdot min^{-1}$). To determine $\dot{V}O_2$, 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. $\dot{V}O_2max$ was identified as the average of the 2 highest 15-second values from the last 45 seconds of exercise, and attainment of $\dot{V}O_2max$ was confirmed by incidence of a plateau in $\dot{V}O_2$ (≤150 $ml \cdot min^{-1}$) as well as RERmax >1.15 and HRmax 10 $b \cdot min^{-1}$ within 220–age (2). The intensity consequent with volitional exhaustion was identified as PPO. After this session, the participant was familiarized using the handlebar controller to allocate workload as performed in subsequent testing. Settings for the seat and bar height were determined and repeated within subjects for all subsequent trials.

Exercise Regimes. Before all sessions, participants warmed up for 5 minutes at 10 %PPO. $HIIE_{IMP}$ consisted of eight 60-second bouts at 80 %PPO separated by 60 seconds of light pedaling at 10 %PPO. This intensity was used in previous HIIT studies in active men and women (42), sedentary women (3), as well as overweight adults (25), and elicits intensities at or above 90 %HRmax. During $HIIE_{SS}$, participants also performed eight 60-second bouts interspersed with 60-second recovery. However, they were instructed to use the handlebar controller of the cycle ergometer to freely modify work rate in fixed increments (10 %PPO) to attain a minimum rating of perceived exertion (RPE) equal to 7.0 (Borg CR10 scale, 6), which was repeatedly displayed to the participant during exercise. They were encouraged to do as much work as they could during each bout and to pace themselves based on indices of breathing, leg pain, and overall fatigue. In addition, participants were given verbal cues to confirm that they modified the work rate properly and every 15 seconds were reminded of elapsed time of each bout. Within subjects, pedal cadence ranged from 70 to 100 $\text{rev}\cdot\text{min}^{-1}$ during exercise and was maintained across regimes $\pm 10\ \text{b}\cdot\text{min}^{-1}$.

Physiological Measures. Heart rate was continuously measured during exercise with telemetry (Polar), and pulmonary gas exchange data were measured using a metabolic cart (Parvomedics True One, Sandy, UT, USA). Mean $\dot{V}O_2$ and HR were determined as the average value for the entire exercise session not including the warm-up, and peak HR was identified as the highest 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 (22). Pre-exercise and for bouts 2, 4, 6, and 8 (25, 50, 75, and 100% of session duration), values of HR and $\dot{V}O_2$ for each HIIE regime were calculated from the last two 15-second data points and first value in recovery. Self-selected power output (in Watts) was recorded from each bout of HIIE_{SS} and averaged to identify a mean work rate for this 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 blood lactate concentration (BLa), which was measured with a portable meter (Lactate Plus; Nova Biomedical, Waltham, MA, USA). This measure was repeated at 50% of session duration (immediately after bout 4) and 3 minutes after exercise in both regimes.

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 (6) 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 was recorded before exercise and immediately at the end of bouts 2, 4, 6, and 8 (25, 50, 75, and 100% of session completion). Affect (11-point scale, rating from +5 very good to −5 very bad, 19) was recorded at the same time points as RPE, and an additional measure was taken 5 minutes after exercise. Ten minutes after exercise, participants completed the Physical Activity Enjoyment scale (PACES) (20), which required them to answer 18 items on a 1–7 scale.

Statistical Analyses

Data are expressed as mean ± *SD* and were analyzed using SPSS Version 24.0 (Chicago, IL, USA). The Shapiro-Wilks test was used to test normality of all variables. Two-way analysis of variance with repeated measures was used to measure differences in $\dot{V}O_2$, BLa, affect, RPE, and HR across time (3–6 levels) and regime (2 levels). The Greenhouse-Geisser correction was used to account for the sphericity assumption of unequal variances across groups. Tukey's post hoc analysis was used to determine significant differences between mean values when a significant *F* ratio was obtained. Differences in mean and peak HR, power output, and PACES between regimes were determined by a dependent *t*-test. 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 previous studies comparing affect and enjoyment between various HIIE regimes (23,42). G Power (14) was used to confirm that a sample size of 11 is adequate to detect a change in affect equal to 1.0 units, $\dot{V}O_2$ equal to 0.20 $\text{L}\cdot\text{min}^{-1}$, and PACES equal to 10 units between regimes. Statistical significance was equal to $p \leq 0.05$.

RESULTS

Both regimes elicited intensities characteristic of HIIE, with the average power output attained during HIIE_{SS} (263.9 ± 81.4 W) being significantly higher ($p < 0.001$, $d = 0.60$) than that completed in HIIE_{IMP} (225.2 ± 59.6 W). Peak HR of these regimes elicited 95–97% of HRmax, respectively.

Differences in Oxygen Uptake, Heart Rate, and Power Output Between Regimes

Oxygen uptake increased during exercise ($p < 0.001$), and there was a significant main effect ($p = 0.006$) as well as regimeXtime interaction ($p = 0.013$). Post hoc analyses showed that all exercise $\dot{V}O_2$ values were higher ($d = 1.51$–1.85) by 9–11% in HIIE_{SS} vs. HIIE_{IMP} (Figure 1A). Figure 1B demonstrates the change in HR during exercise. There was a main effect of regime ($p = 0.046$) but no regimeXtime interaction ($p = 0.067$), although HR was consistently higher by 5–7 $\text{b}\cdot\text{min}^{-1}$ in the self-selected vs. imposed bout. Mean HR was similar between regimes ($p = 0.16$), although peak HR was higher ($d = 0.51$) in HIIE_{SS} (185.4 ± 7.9 $\text{b}\cdot\text{min}^{-1}$) vs. HIIE_{IMP} (179.3 ± 15.5 $\text{b}\cdot\text{min}^{-1}$).

Differences in Blood Lactate Concentration Between Regimes

These data are shown in Figure 1C. Blood lactate concentration increased during exercise ($p < 0.001$) and there was a significant main effect ($p = 0.001$) as well as regimeXtime interaction ($p = 0.005$). BLa values at 50% of exercise session ($d = 1.53$) and after exercise ($d = 1.68$) were significantly higher in HIIE_{SS} vs. HIIE_{IMP}.

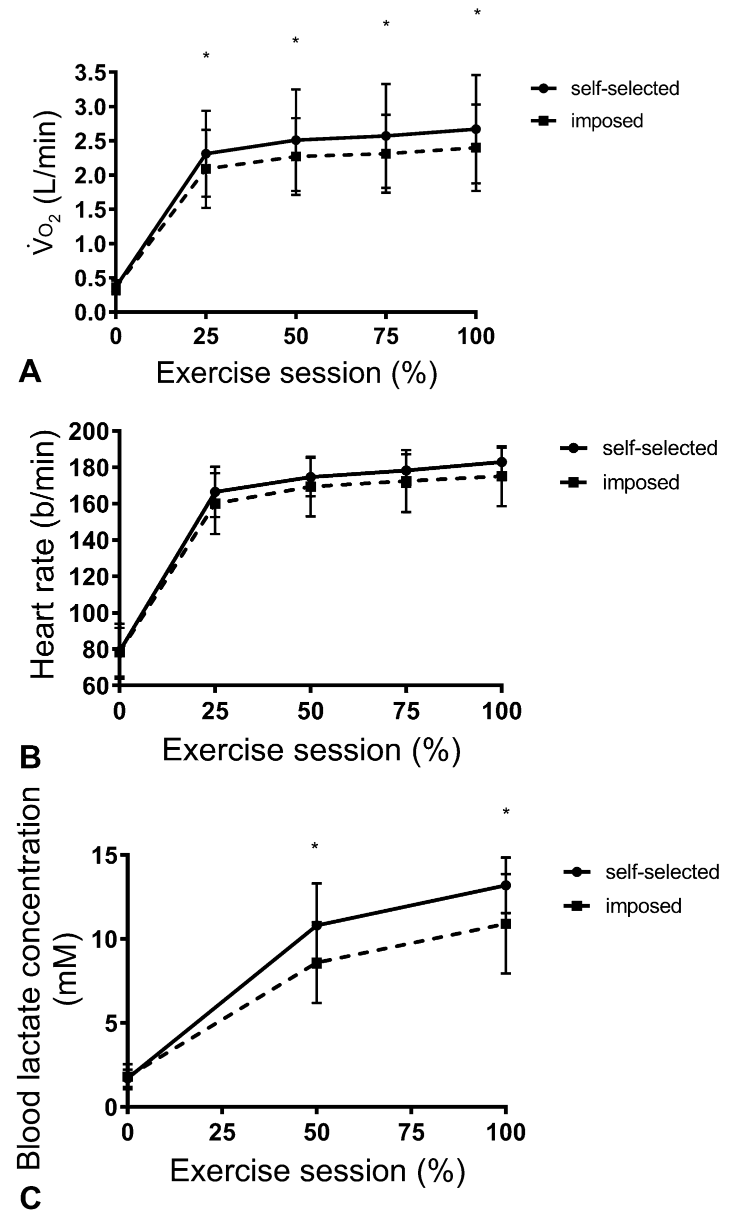

Figure 1. Difference in (A) oxygen uptake, (B) heart rate, and (C) blood lactate concentration between self-selected and imposed HIIT (mean ± *SD*). $^*p \leq 0.05$ vs. imposed at specific time point. HIIT = high-intensity interval training.

Differences in Perceptual Responses Between Regimes

As shown in Figure 2A, RPE was significantly higher ($p = 0.001$) at all exercise time points in HIIE_{SS} vs. HIIE_{IMP} (Cohen's d values ranging from 1.82 to 2.81). Affect declined during exercise ($p < 0.001$), and there was a significant regimeXtime interaction ($p = 0.01$) yet no main effect of regime ($p = 0.09$). Affect was 1.1, 1.2, and 1.1 units lower at 75 ($d = 1.13$) and 100% ($d = 1.21$) of exercise as well as 5 minutes after exercise ($d = 1.13$) in HIIE_{SS} compared with HIIE_{IMP}, and post hoc analyses revealed that these scores differed between regimes. There was a difference ($p = 0.04$, $d = 0.61$) in enjoyment between HIIE_{SS} (87.6 ± 15.7) and HIIE_{IMP} (95.7 ± 11.7). Fifty percent of participants reported lower enjoyment by ≥12 units in the self-selected vs. the imposed bout of HIIE, whereas only 1 participant revealed higher enjoyment by this amount during HIIE_{SS} compared with HIIE_{IMP}.

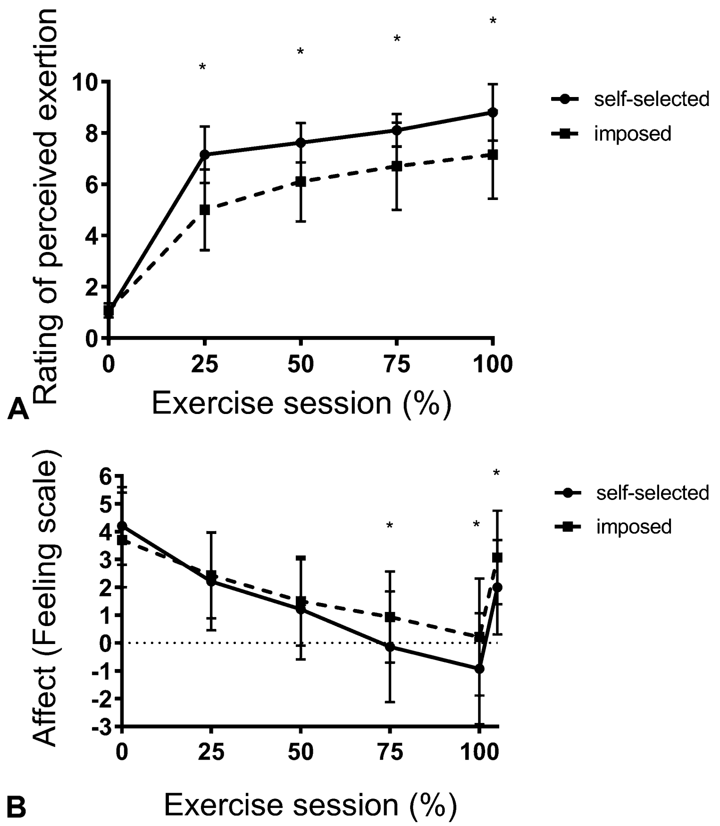

Figure 2. Difference in (A) rating of perceived exertion and (B) affect between self-selected and imposed HIIT (mean ± *SD*). **p* ≤ 0.05 vs. imposed at specific time point. HIIT = high-intensity interval training.

DISCUSSION

Although chronic HIIE has been shown to elicit similar (16) and in some cases (28), superior adaptations vs. MICT, it is typically imposed on the exerciser, which is unnatural and may reduce affectual responses. In the current study, we explored potential differences in physiological and perceptual responses between a bout of self-selected HIIE compared with when it is imposed on the participant. Our results show higher oxygen uptake, RPE, and blood lactate concentration, lower enjoyment, as well as more aversive affectual responses when participants are free to choose the intensity.

Our data showing that a single bout of self-selected HIIE elicits lower enjoyment and affect than when imposed on the participant oppose most of the literature. For example, several studies (33,35) report higher affect in response to self-selected vs. imposed aerobic exercise. This is likely due to the degree of autonomy cited in self-selected exercise, which is eliminated when the intensity and duration of exercise are externally controlled. In the case of this study, several factors explain our findings. First, $\dot{V}O_2$ and BLa were higher in $HIIE_{SS}$ vs. $HIIE_{IMP}$ (Figure 1) because of the participants selecting a 17% higher overall power output, which presents a greater cardiorespiratory and metabolic strain on the participant. In fact, this higher power output equal to 95 %PPO, 15% higher than the imposed work rate, would elicit greater type II fiber recruitment and, in turn, blood lactate concentration as seen in the current study. According to the affect-intensity relationship (13), lactate accumulation leads to a decline in affect. This relationship has been demonstrated in many HIIE studies, in which BLa values above 10 mM are attendant with affect values less than 0 (18,37,42). Moreover, longer HIIE bouts tend to be associated with more aversive responses, and in addition, higher RPE, than shorter ones (21,38). Nevertheless, in one study in sedentary women (3), affect was similar between HIIT regimes of different intensity despite similar duration. During $HIIE_{SS}$, many participants in the current study selected supramaximal work rates in the first one to 3 and/or the latter 2 bouts, which results in substantial perturbation leading to greater elevations in muscle temperature, muscle blood flow, perceptions of fatigue as evidenced by our RPE data (Figure 2), and phosphocreatine degradation.

Our data seem to corroborate the intensity-affect relationship first developed for aerobic exercise (13) and suggest that compared with imposed HIIE of similar duration, a bout of self-selected HIIE performed at higher intensities leads to lower affect.

Our results show that HIIE bouts differing in intensity but identical in duration and number yield different enjoyment values. The literature is mixed in this area, as Tucker et al. (39) showed similar enjoyment when young men completed HIIE consisting of ten 1-minute bouts at 90 %HRmax or the Norwegian 4X4 model, despite higher $\dot{V}O_2$ and energy expenditure in the latter. Townsend et al. (38) showed lower enjoyment for longer bouts of SIT compared with shorter bouts despite a matching of work. Results from Oliveira et al. (30) showed a trend ($p = 0.054$) for higher enjoyment during imposed compared with self-selected MICT at 61 %$\dot{V}O_2$max despite no differences in $\dot{V}O_2$, HR, or BLa between regimes. Overall, we show that when participants are able to freely select the power output during repeated 60-second bouts of HIIE, they attain higher workloads, which are consequent with lower enjoyment values.

During HIIE$_{SS}$, participants were encouraged to continuously modify work rate during each bout. However, not all participants followed this recommendation and it was evident that participants adopted several different strategies. Some individuals selected the same work rate for all 8 bouts, which was always higher than that completed in the imposed regime. By contrast, others elected to use an approach seen in cycling time trials (1), in which power output was near maximal to supramaximal during the early bouts, followed by a reduction in intensity and then finishing with an end "spurt" for bout 8. In addition, a few participants frequently modified work rate up and down during each bout based on how they felt and the elapsed time remaining. This latter approach requires substantial cognitive attention, and it is possible that this may modify perceptual responses to exercise compared with an approach when workload is less frequently changed.

Previous studies (32) using bouts of aerobic exercise show more variability in affect at work rates below rather than above the ventilatory or lactate threshold, where interoceptive cues strongly dictate the perceptual response to exercise. Variability in affect has also been shown when various regimes of HIIE or SIE are imposed on the participant (25,37,42). In the current study in response to HIIE$_{IMP}$, 36% of participants (5/14) demonstrated a $\geq$3 units decline in affect from 25 to 100% of exercise, and the affect value at 25 and 100% of bout duration ranged from 5 to -1 and 4 to -4, respectively. Similar individual variability in affect was shown during HIIE$_{SS}$ at 25% (4 to -2) and 100% (0 to -5) of bout duration. In the current study, a man with the highest $\dot{V}O_2$max equal to 56.6 $ml \cdot kg^{-1} \cdot min^{-1}$ displayed a small decline in affect (2 units) in both HIIE bouts, which was coincident with a higher enjoyment in the self-selected bout. By contrast, 2 women with relatively low $\dot{V}O_2$max equal to 30.0 and 31.0 $ml \cdot kg^{-1} \cdot min^{-1}$ revealed larger declines in affect (4 and 5 units) from 25 to 100% of bout duration. This is explained by data showing that active individuals have more positive affectual responses than less-active individuals at a single intensity (5) and at higher intensities (31). In addition, it is possible that less-active participants are unfamiliar with the discomfort associated with HIIE, leading to highly aversive responses, whereas highly active individuals are more familiar with intense exercise including HIIE, which provides them a degree of competence and predisposition to tolerate discomfort (12) lacking in their less-fit counterparts.

Our results may apply to how HIIE is implemented in various populations. We show that in the case of HIIE using a 1:1 ratio of work:recovery, allowing the participant to control the power output may yield higher training intensities and if maintained long-term, potentially greater adaptation. The higher power output requires greater glycogen depletion, leading to greater activation of AMP-activated protein kinase (17), which potentiates mitochondrial biogenesis. Nevertheless, the lower affect and enjoyment seen with HIIE$_{SS}$ may reduce participants' willingness to perform this regime, which may decrease exercise adherence (41) and acquisition of various potential benefits of HIIT especially when completed by inactive individuals. This is an interesting dilemma because it is unknown whether potentially greater benefits are enough to outweigh onset of more aversive responses. This topic needs to be investigated in future inquiry.

Our study has a few limitations. First, we chose an imposed work rate of 80 %PPO, which is slightly lower than that used in previous studies performed in active individuals. Therefore, the resultant $\dot{V}O_2$ observed from this regime could be lower than the peak value attained during HIIE using a 1:1 work:rest ratio. Second, our data were obtained in active men and women, so these results cannot be generalized to other populations who may have a different tolerance of HIIE. Third, only one self-selected bout was performed, and it is unknown whether an additional bout would modify physiological and psychological measures because of an effect of learning. It has been recommended (34) that a familiarization bout be completed in untrained women to enhance self-efficacy to self-selected exercise. We also did not measure self-efficacy, which is related to affective responses to acute exercise (15). However, the current study is strengthened by use of self-selected exercise during which participants were free to modify intensity continuously throughout each bout, rather than at fixed increments as previously used (33). This approach mirrors typical practice for pacing, which is adjusted continuously during exercise (1). In addition, we recruited individuals unaccustomed to HIIE who likely had no preconceived perceptual opinions about acute bouts of interval training. Different responses may be seen in athletes such as cyclists who are familiar with pacing because they may self-select intensities that may not vary as widely as seen in our participants.

PRACTICAL APPLICATIONS

High-intensity interval training is widely lauded for its fitness and health enhancing effects as well as its relative time efficiency compared with endurance-based exercise. However, interval training is typically imposed on the participant that decreases autonomy and may potentially reduce perceptions of exercise. Our results show that when the participant has the ability to freely control intensity during interval training, they select a higher power output compared with imposed exercise, which leads to greater oxygen uptake, perceived exertion, and blood lactate concentration. This in turn reduces the enjoyment and pleasure experienced by the participant. We recommend that fitness professionals continue to implement HIIE in their clientele but emphasize that, when they give their clients the ability to self-select intensity during interval training, more aversive responses may occur because of selection of a higher intensity.

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