Modified sprint interval training protocols: Physiological and psychological responses to four weeks of training

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ABSTRACT

Sprint interval training (SIT) protocols involving brief (≤15 s) work bouts improve aerobic and anaerobic performance, highlighting peak speed generation as a potentially important adaptive stimulus. To determine the physiological and psychological effects of reducing the SIT work bout duration, while maintaining total exercise and recovery time, forty-three healthy males (n=27) and females (n=16) trained for four weeks (three times/week) using one of the following running SIT protocols: 1) 30:240 (n=11; 4-6 x 30 s bouts, 4 min rest); 2) 15:120 (n=11; 8-12 x 15 s bouts, 2 min rest); 3) 5:40 (n=12; 24-36 x 5 s bouts, 40 s rest); or 4) served as a non-exercising control (CTRL, n=9). Protocols were matched for total work (2-3 min) and rest (16-24 min) duration, as well as the work-to-rest ratio (1:8 s). Pre- and post-training measures included a: graded VO$_{2\text{max}}$ test, 5-km time trial, and 30 s maximal sprint test. Self-efficacy, enjoyment, and intentions were assessed following the last training session. Training improved VO$_{2\text{max}}$ (5.5%; P=0.006) and time trial performance (5.2%; P=0.039), with a main effect of time for peak speed (1.7%; P=0.042), time to peak speed (25%; P<0.001), and body fat % (1.4%; P<0.001) that appeared to be driven by the training. There were no group effects for self-efficacy (P=0.926), enjoyment (P=0.249), or intentions to perform SIT three (P=0.533) or five (P=0.951) times/week. This study effectively demonstrated that the repeated generation of peak speed during brief SIT work bouts sufficiently stimulates adaptive mechanisms promoting increases in aerobic and anaerobic capacity.
Key Words: ANAEROBIC PERFORMANCE; ENJOYMENT; HIGH-INTENSITY INTERVAL TRAINING; SELF-EFFICACY; $\dot{V}O_2$max.
INTRODUCTION

High-intensity interval training (HIIT) involves short, near maximal (80-100% peak heart rate) work bouts interspersed with recovery periods and can promote superior physiological benefits compared to moderate-intensity continuous training (MICT), despite a decreased exercise time and volume (Weston et al. 2014). When performed at supramaximal intensities (≥ 100% $\dot{V}O_{2\text{max}}$) and for shorter durations (≤ 30 s), intermittent exercise can be further classified as sprint interval training (SIT) (Weston et al. 2014). Accumulating evidence supports the ability of SIT to produce cardiovascular and muscular adaptations that facilitate improvements in aerobic (Burgomaster et al. 2006; Burgomaster et al. 2008; Gibala et al. 2006; Gillen et al. 2016; Gist et al. 2014; Hazell et al. 2010; MacPherson et al. 2011; Sloth et al. 2013; Willoughby et al. 2016; Zelt et al. 2014) and anaerobic capacity (Hazell et al. 2010; MacDougall et al. 1998; Willoughby et al. 2016; Zelt et al. 2014); however there is less definitive evidence in support of favorable body composition changes following SIT interventions.

The traditional Wingate-based SIT protocol involves four to six 30 s “all-out” efforts separated by 4 min of rest or active recovery (Burgomaster et al. 2006; Burgomaster et al. 2008; Gibala et al. 2006; Vollaard and Metcalfe 2017), totaling 14-23 min per session with only 2-3 min of intense exercise. Interestingly, several studies have demonstrated that the 30 s work interval duration can be reduced to 20 (Gillen et al. 2014; Gillen et al. 2016; Metcalfe et al. 2012), 15 (Yamagishi and Babraj 2017; Zelt et al. 2014), and even 10 s (Hazell et al. 2010) without attenuating aerobic (i.e., $\dot{V}O_{2\text{max}}$, muscle oxidative capacity) and anaerobic (i.e., Wingate power output) adaptations. This suggests that the generation of peak power/speed may be sufficient for stimulating the
adaptive response to SIT (Hazell et al. 2010). This seems logical as nearly half of the work performed during an “all-out” sprint occurs within the first 10 s (Bogdanis et al. 1996) and as little as 4 s of repeated maximal sprinting stimulates signaling pathways underlying skeletal muscle remodeling (Serpiello et al. 2012). However, the optimal work and/or rest interval duration for maximizing SIT adaptations has yet to be determined.

Another potential benefit of reducing the SIT work bout duration could be an improvement in the psychological perceptions of exercise relative to the traditional 30 s SIT work bout. Given that some have questioned the utility of SIT due to its strenuous nature (Biddle and Batterham 2015; Hardcastle et al. 2014), determining whether shorter work bouts improve psychological perceptions and lead to greater intentions to perform SIT is important. Although we have recently demonstrated that shorter sprint bouts with greater repetitions (24 x 5 s) acutely produce more favorable perceptions of exercise and lead to greater intentions to perform the exercise compared to traditional SIT (Townsend et al. 2017), whether this phenomenon persists after a training intervention remains unknown.

Therefore, the purpose of the present study was to determine the importance of repeated peak speed generation as an adaptive stimulus to SIT by varying the work bout (5, 15, or 30 s) and rest period (40, 120, or 240 s) duration, while also maintaining total exercise session time. All three protocols were matched for the total duration of work (2-3 min) and rest (12-20 min), as well as the work-to-rest ratio (1:8 s). We hypothesized that reducing the SIT work bout duration would lead to improvements in body composition and aerobic and anaerobic performance similar to those of the traditional 30
We also wanted to explore psychological indicators post-training, by measuring task self-efficacy, enjoyment, and behavioral intentions to perform SIT. In this regard, we hypothesized that psychological responses would be more favorable following shorter work bouts. The practical implications of this work could benefit those in the general population (healthy and unhealthy) who might be interested in utilizing a SIT paradigm but struggle to adhere to the traditional protocol.

**MATERIALS AND METHODS**

**Participants.** Forty-eight recreationally active males and females were recruited for this study. This is in line with previous studies assessing similar outcomes that have reported using a similar number of participants (12-15) per training group (Gillen et al. 2016; Hazell et al. 2010; MacPherson et al. 2011; Yamagishi and Babraj 2017). Participants were not using any dietary supplements, were self-reported non-smokers, deemed healthy according to the Physical Activity Readiness Questionnaire (Thomas et al. 1992), recreationally active (exercised less than 3 times per week) according to the Godin Leisure-Time Exercise Questionnaire (Godin and Shephard 1997) and had not engaged in a systematic training program for at least 3 months prior to data collection. Participants were instructed on the importance of, and asked to maintain, pre-training physical activity and dietary habits for the duration of the study, specifically they were instructed not to modify their current lifestyle habits. No alcohol, caffeine, or exercise was allowed for 24 h before each testing or training session. The experimental procedures were explained in detail to all participants and all provided written informed consent prior to data collection.
collection. The institutional Research Ethics Board approved this study in accordance with the ethical standards of the 1964 Declaration of Helsinki.

Study design. Prior to training, all participants completed one week (3 sessions) of testing and were then systematically assigned to one of four groups using stratified randomization based on pre-training \( \dot{V}O_{2\text{max}} \) values. Three groups trained for four weeks (3 supervised sessions/week) whereas the fourth group was a non-exercise control (CTRL). All groups completed a final week of post-testing (3 sessions). Pre- and post-intervention, each participant completed a 30 s “all-out” running sprint test, a graded \( \dot{V}O_{2\text{max}} \) test, and a 5-km running time trial, and had their body composition assessed (see details below).

Pre-training measures. A familiarization session was completed prior to pre-testing to acclimate participants with the testing and training procedures/equipment and to ensure any learning effect was minimal. All tests were performed at the same time of day on separate days, separated by at least 24 h and at least 48 h prior to initiating training. The following baseline tests were performed in the same order for all participants.

1) Body composition. Upon arrival at the laboratory, height and weight were recorded using a mechanical scale (Health-o-meter Professional, Sunbeam Products, Inc., Illinois, USA). Skinfold measurements were then obtained to determine body composition using the sum of 3-site method (Jackson and Pollock 1978; Jackson et al. 1980; Astorino et al. 2013). The same trained researcher completed all measurements for each participant and was blinded to the
participants’ group in order to reduce any potential systematic error. The three sites for males included the chest, abdomen, and thigh, where the triceps, suprailliac, and thigh were used for females. Each skinfold was measured three times in rotational order (on the right side of body) using skinfold calipers (Lange, Beta Technology, California, USA) and converted to body density using established equations (Jackson and Pollock 1978; Jackson et al. 1980). Body fat percentage was derived from body density using the Siri equation.

2) 30 s running sprint. After a standardized 5-min warm-up at 4-5 mph on a motorized treadmill (4Front, Woodway, WI, USA), participants completed a 30 s “all-out” running sprint on a non-motorized interval training treadmill (HiTrainer, QC, Canada; (McKie et al. in press). Treadmill software automatically recorded peak, average, and minimum speed as well as time to peak speed and distance covered. Fatigue index was manually calculated using the peak and minimum speeds. The treadmill prompted participants to start and stop running and the research team provided verbal encouragement throughout the test. Immediately following the sprint, participants walked on the motorized treadmill for a 5-min cool-down.

3) Graded \( \dot{VO}_{2\text{max}} \) test. An incremental test to exhaustion on a motorized treadmill was utilized to determine \( \dot{VO}_{2\text{max}} \) using a metabolic cart (MAX II, AEI Technologies, PA, USA) calibrated before each test using gases of known concentration and a 3 L syringe for flow. Participants were fitted with a heart rate (HR) monitor (FT1, Polar Electro, QC, Canada) and a silicon facemask (Vmask, Hans Rudolph Inc., KS, USA). Following the standardized warm-up, each
participant ran at a self-selected speed between 5.0 and 6.5 mph at 0% grade and
the grade was increased (2%) every two minutes until the test was terminated.

\[ \dot{V}O_{2\text{max}} \] was taken as the greatest 30 s average in the presence of a plateau in \( \dot{V}O_2 \) values (<1.35 mL·kg\(^{-1}\)·min\(^{-1}\)) despite increased workload or two of the following
secondary criteria: 1) a respiratory exchange ratio (RER) greater than 1.15; 2) HR
within ±10 beats per minute (bpm) of age predicted maximal HR (220 bpm –
participant age); or, 3) complete participant exhaustion. Participants were
verbally encouraged throughout the test, which lasted between 7 and 15 minutes.

Pre-training, 37 of 43 participants exhibited plateaus in their \( \dot{V}O_2 \) uptake, three
participants satisfied at least two secondary criteria in the absence of a plateau in
\( \dot{V}O_2 \) values, and the remaining three participants satisfied a single secondary
criterion (namely complete participant exhaustion). At the termination of their
tests, which lasted 14, 12, and 9 min, these three participants had RER values of
1.14, 1.10, and 1.12 respectively.

4) 5-km time trial. A 5-km time trial on a motorized treadmill was used to assess
aerobic performance. Following the standardized warm-up participants were
instructed to complete a 5-km distance (at 0% grade) as quickly as possible and
they had full control to adjust treadmill speed as necessary (no adjustments to
grade were permitted). Participants were able to see speed and distance values
but were blinded to the duration. Pilot data from our lab showed this test to be a
valid measure of aerobic performance, with little variability (\( n=5, \ s^2=0.31 \))
between 3 repeated trials, each separated <1-week (i.e., minimal learning effect).
Training. As mentioned, participants were systematically assigned to one of the following four groups after completing one week of pre-training testing:

1) 30:240 – Traditional SIT consisting of 4-6 x 30 s “all-out” efforts separated by 240 s (4 min) of rest. The number of bouts increased from 4 in week one to 5 in week two, and then to 6 in weeks three and four (Burgomaster et al. 2006; Gibala et al. 2006; MacPherson et al. 2011; Zelt et al. 2014).

2) 15:120 – Modified SIT consisting of 8-12 x 15 s bouts separated by 120 s (2 min) of rest. The number of bouts increased from 8 in week one to 10 in week two, and then to 12 in weeks three and four.

3) 5:40 – Modified SIT consisting of 24-36 x 5 s bouts separated by 40 s rest (5:40). The number of bouts increased from 24 in week one to 30 in week two, and then to 36 in weeks three and four.

4) CTRL – Non-exercise control group. These participants were instructed to maintain their current level of physical activity throughout the study.

All training sessions were performed on a non-motorized sprint interval training treadmill (HiTrainer) with a flat surface and included a standardized 5 min warm-up on a motorized treadmill at 4-5 mph and a self-selected pace for cool-down. Participants were positioned in a sprinting drive phase and propelled the treadmill belt by leaning into shoulder pads fixed onto the treadmill. In between sprints participants were allowed to walk on the treadmill and rest actively.

Post-training measures. Post-training tests were identical to those performed pre-training and were completed within one week of the last training session.
Perceptions of exercise. Immediately following the participants’ final training session, we assessed exercise task self-efficacy (McAuley and Mihalko 1998), intentions (Jung et al. 2014), and enjoyment (Physical Activity Enjoyment Scale; PACES) (Kendzierski and Decarlo 1991) similar to previous work (Jung et al. 2014; Townsend et al. 2017). To measure task self-efficacy we asked “How confident are you that you can perform one bout of exercise/week for the next four weeks that is just like the one you completed today?” Responses were marked on a scale ranging from 0-10 and we compared the mean aggregate of the first 5 items then also each item individually similar to previous work by Jung and colleagues (Jung et al. 2014) as well as work from our lab (Townsend et al. 2017). We then additionally analyzed the individual responses to each item separately to gain a more comprehensive understanding of perceived self-efficacy. For intentions we asked participants to respond to the statement “I intend to engage in the form of exercise I performed today 3x/week over the next month” and “I intend to engage in the form of exercise I performed today 5x/week over the next month” with responses ranging on a 0-7 scale. Each item was compared individually. For enjoyment, the original PACES is an 18-item questionnaire where participants are asked to “rate how you feel at the moment about the physical activity you have been doing”. Responses range on a scale from 1 through 7 (e.g., I feel bored to I feel interested) with several items being reverse scored. Scores are summed for each participant with a range between 18-126. The PACES scale was modified similar to past work (Jung et al. 2014; Townsend et al. 2017) by removing one irrelevant item (current absorption in the activity) and adding 2 questions: “How much did you enjoy the exercise that you completed today?” and “How enjoyable would
you find engaging in this form of exercise three times per week over the next month?”.

The non-exercise control group did not complete this assessment.

Statistical analysis. All data were analyzed using Sigma Stat for Windows (Version 3.5). A one-way analyses of variance (ANOVA) was used to ensure there were no differences in participant characteristics for each group at baseline. A two-way (treatment x time) repeated measures ANOVA was used to test for significance among groups pre- and post-training, with Tukey’s post hoc testing where necessary. In addition, one-way ANOVA were used to examine the group differences in self-efficacy, intentions, and enjoyment following SIT training. Effect sizes were calculated from pre- vs post-training comparisons for each group using Cohen’s $d$. Small effect sizes are $d<0.2$, moderate effect sizes $d=0.2–0.8$, and large effects sizes $d>0.8$ (Cohen 1988). The significance level was set at $P<0.05$ a priori. All data are presented as mean±standard deviation (SD).

RESULTS

Forty-eight participants volunteered to participate but 5 did not complete the intervention (1 in 30:240, 3 in 15:120, 1 in 5:40). Reasons for dropout were due to scheduling conflicts ($n=4$) and an injury unrelated to the study ($n=1$). Therefore, there were 11, 11, and 12 participants who completed the training for the 30:240, 15:120 and 5:40 groups respectively, with 9 participants in the CTRL group. There were no differences ($P>0.05$) in participant characteristics between groups at baseline except for age where the CTRL group was slightly older than the training groups (Table 1).
\( \dot{V}O_{2\text{max}} \). There was a significant group x time interaction \((P=0.006)\) with subsequent post hoc analyses indicating SIT increased \( \dot{V}O_{2\text{max}} \) 5.5% \((2.6\pm2.7 \text{ mL\cdot kg}^{-1}\cdot \text{min}^{-1}; \text{Figure 1A})\) across all training groups. The change in \( \dot{V}O_{2\text{max}} \) was 4.3% \((2.0\pm2.4 \text{ mL\cdot kg}^{-1}\cdot \text{min}^{-1}; d=0.30)\) for 5:40, 3.8% \((1.9\pm2.5 \text{ mL\cdot kg}^{-1}\cdot \text{min}^{-1}; d=0.30)\) for 15:120, and 8.7% \((3.9\pm3.0 \text{ mL\cdot kg}^{-1}\cdot \text{min}^{-1}; d=0.54)\) for 30:240, while the CTRL group did not change \((-0.8\pm3.2 \text{ mL\cdot kg}^{-1}\cdot \text{min}^{-1}; d=-0.15)\). Post-training, 37 of 43 participants exhibited plateaus in their \( \dot{V}O_{2} \) uptake with five participants satisfying at least two secondary criteria in the absence of a plateau in \( \dot{V}O_{2} \) values, and the one remaining participant satisfied the secondary criterion of complete exhaustion (duration: 16 min; RER: 1.17; HR\(_{\text{max}}\) within 10% of age predicted maximum).

5-km time trial. There was a significant group x time interaction \((P=0.039)\) with subsequent post hoc analyses indicating SIT improved time trial performance 5.2% \((1.4\pm1.8 \text{ min}; \text{Figure 1B})\). The improvement in time trial performance was 4.2% \((1.2\pm1.5 \text{ min}; d=-0.33)\) for 5:40, 3.4% \((0.9\pm3.4 \text{ min}; d=-0.21)\) for 15:120, and 8.1% \((2.2\pm2.4 \text{ min}; d=-0.60)\) for 30:240 whereas the CTRL did not change \((-0.01\pm0.83 \text{ min}; d=0.01)\).

30 s running sprint. For peak speed, there was no interaction \((P=0.331)\) or main effect of group \((P=0.834)\), but there was a main effect of time where peak speed increased 1.7% \((P=0.042; \text{Table 2})\). For time to peak speed, there was no interaction \((P=0.293)\) or main effect of group \((P=0.306)\), but there was also a main effect of time where time to peak speed improved 25% \((P<0.001; \text{Table 2})\). There was no interaction, main effect of group,
or main effect of time ($P>0.05$) for any other 30 s running sprint test variables including average speed, minimum speed, or fatigue index (Table 2).

**Body composition.** There was no interaction ($P=0.381$), main effect for group ($P=0.692$), or main effect for time ($P=0.086$) on body mass. For body fat %, there was also no interaction ($P=0.761$) or main effect for group ($P=0.134$), however there was a main effect for time where body fat % decreased 1.4% ($P<0.001$; Figure 1C).

**Training data.** In the first week of training the 5:40 group was able to generate speeds equal to 92.5% of their peak speed output compared to 91.6% in week two, 91.2% in week three, and 89.6% in week four. The average peak speed (across all bouts) for the 5:40 group in week one was 7.15 m·sec$^{-1}$, compared to 7.32, 7.17, and 7.34 m·sec$^{-1}$ in weeks two, three, and four, respectively. The 15:120 group was able to reproduce 89.7% of peak speed in week one, 91.1% in week two, 88.4% in week 3, and 88.8% in week four. The average peak speed for this group in week one was 7.34 m·sec$^{-1}$, compared to 6.95, 7.09, and 7.26 m·sec$^{-1}$ in weeks two, three, and four, respectively. The 30:240 group was able to reproduce 90.7% of peak speed output in week 1, 89.7% in week 2, 90.2% in week 3, and 89.6% in week four. The average peak speed for the 30:240 group in week one was 6.96 m·sec$^{-1}$, compared to 7.03, 6.55, and 6.95 m·sec$^{-1}$ in week two, three, and four, respectively.

**Perceptions of exercise.** There was no effect of group on any measure of perceived self-efficacy ($P>0.05$), however the ability to avoid over-exertion in the 5:40 compared to
30:240 group did approach significance ($P=0.058$; Table 3). There was no effect of group on intentions to perform SIT three ($P=0.533$) or five ($P=0.951$) times per week over the coming month (Table 3). Finally, there was no effect of group on perceived enjoyment ($P=0.249$), expected enjoyment in performing exercise three times per week over the next month ($P=0.440$), or PACES scores ($P=0.854$; Figure 2).

**DISCUSSION**

This study investigated the effects of manipulating the SIT work and rest interval duration, while maintaining the total exercise session time and the work-to-rest ratio (1:8 s) of the traditional SIT protocol, on aerobic and anaerobic performance as well as perceptions of exercise. Specifically, we examined whether the generation of peak speed was sufficient for driving adaptations to SIT. Our results demonstrate that reducing the SIT work bout duration is still sufficient for improving the aerobic adaptive response suggesting that peak speed generation sufficiently stimulates mechanisms underlying aerobic/anaerobic adaptations to training. Moreover, we found that the psychological perceptions of exercise were similar for all groups at the end of the intervention.

**Physiological responses.**

In accordance with our hypothesis, all three training groups improved similarly in $\dot{V}O_{2\text{max}}$ and 5-km time trial performance, though there were no significant differences between groups for either outcome. Our results are in line with previous work demonstrating improvements in $\dot{V}O_{2\text{max}}$ using the traditional (~4.2-13.4% (Gist et al. 2014; Sloth et al. 2013)) and modified (~4-15% (Hazell et al. 2010; Metcalfe et al. 2012; 2014)).
Vollaard et al. 2017; Zelt et al. 2014)) SIT protocols. Given the health implications of \( \dot{V}O_{2\text{max}} \) (Kodama et al. 2009), these findings highlight the important ability of SIT to improve cardiorespiratory fitness in a time-efficient manner (2-3 min of exercise per session). Similar to \( \dot{V}O_{2\text{max}} \), all training groups improved performance on the 5-km running time trial by ~5.2% (1.4 min). In fact, the magnitude of change here is very similar to previous running (4.6-5.9% (MacPherson et al. 2011; Willoughby et al. 2016)) and cycling time trials (3.0-9.6% (Burgomaster et al. 2006; Hazell et al. 2010)).

Although the increase in \( \dot{V}O_{2\text{max}} \) after training was not statistically different between training groups, the magnitude of change from pre- to post-training in the traditional SIT group was ~4.5 mL·kg\(^{-1}\)·min\(^{-1}\) greater than that of the modified groups. While our data does not suggest a type II error due to a lack of statistical power, it is possible that the longer duration work bouts result in a larger magnitude of change in the aerobic adaptive response due to the prolonged stress and disruption in cellular metabolism. However, previous work in individuals of similar fitness (~47 mL·kg\(^{-1}\)·min\(^{-1}\)) demonstrated that two weeks of cycling SIT using a 10:240 s protocol led to comparable increases in \( \dot{V}O_{2\text{max}} \) to that of the traditional 30 s group (9.2 vs 9.3% respectively), with no observable improvements when the rest duration of the 10 s group was reduced to 120 s (Hazell et al. 2010). While the current report maintained the 1:8 s work-to-rest ratio by design it is possible that shorter work bouts require longer rest durations than we provided. Lastly, it has been established that the individual response to different exercise training protocols is highly variable (Bonafiglia et al. 2016; Gurd et al. 2016), and while we did not examine if this was the case in the current study it serves as a
possible explanation for the potentially greater magnitude of change in our traditional versus modified SIT groups.

With regard to the anaerobic adaptations, the results were less robust. All three training groups improved peak speed and time to peak speed, although an examination of these values suggests that the main effect of time could have been driven by the small changes in the training groups. The time to peak speed outcome is noteworthy as it is a measure of how fast the participants attained their peak speed and could provide novel information about power generation during running efforts. There were no effects on other indices of anaerobic performance such as average or minimum speed and fatigue index. It is likely our observed improvements are at least partly explained by increases in anaerobic enzymes such as phosphofructokinase, lactate dehydrogenase, and myokinase (as reviewed in Ross and Leveritt 2001) as has been observed with other SIT protocols utilizing repeated work bout durations of 5-30 s, performed 2-4 times/week. Future work using these modified protocols on anaerobic performance is warranted.

With regard to body mass, there have been equivocal results published in the SIT literature to date with no general consensus as to whether SIT reduces body mass or not (Hazell et al. 2010; Hazell et al. 2014; MacPherson et al. 2011). Regardless, it is the ability to reduce fat mass that is most important for health as improvements in body composition (i.e. decreased fat mass) are highly desirable. The present data demonstrate a main effect for time on body fat %, which is likely driven by the training groups (-1.39% with training vs -0.46% in CTRL). However, these data are on the lower end of previous SIT literature demonstrating fat mass losses of 1.2-3.6 kg with both running- (Hazell et al. 2014; MacPherson et al. 2011) and cycling-based (Gillen et al. 2016;
Nalcakan 2014) protocols. As the training program was only four weeks, greater improvements could be a result of a longer intervention as seen in previous literature. Moreover, while skinfolds have been used in previous research (Astorino et al. 2013), superior methods to measure body composition were not available in the present study. Therefore, our precision to detect meaningful changes in body composition may have been affected and future investigations focussing on a potential time-course of changes with longer duration training programs and more robust body composition measurements are warranted.

Interestingly, our training data illustrate a remarkable similarity between all groups in their ability to generate peak speed throughout the four weeks of training. The sprint-to-sprint reproducibility of peak speed (>88%) suggests that regardless of the number of bouts performed per session (i.e. 4-36) the quality of each sprint, specifically each group’s ability to consistently regenerate speeds close to peak output, was relatively similar among groups (Vollaard et al. 2017). These high reproducibility rates also give an indication that our participants were compliant with exerting “all-out” efforts throughout training. This finding is contrary to acute training data from our group using identical SIT protocols that showed a greater average speed in the 5:40 compared to 30:240 and 15:120 groups, suggesting this group had greater reproducibility of peak speed from sprint-to-sprint (Islam et al. 2017). While we can only speculate, perhaps improvements in fitness over the course of the training program allowed participants to generate high quality efforts during each subsequent training session.
Psychological responses. Finally, it is well established that perceptions of exercise, including enjoyment (Rhodes and Kates 2015) and self-efficacy (Trost et al. 2002), positively influence future physical activity participation and thus the efficacy of a training program. Thus, it is important to consider psychological responses to gain a more comprehensive representation of SIT’s potential to improve health and fitness (Townsend et al. 2017). We previously reported that our 5:40 protocol was acutely perceived as more enjoyable and that participants had increased confidence and intentions to perform this protocol compared to the traditional 30 s protocol (Townsend et al. 2017). As such, we hypothesized that perceptions would be more favourable for the modified SIT protocols in the present study. However, we found that self-efficacy, perceived enjoyment, and intentions were similar between groups following a four-week training period. Recently, affect was shown to become progressively more positive over 6 SIT sessions (Saanijoki et al. 2015) and enjoyment of HIIT has been reported to increase over six weeks of training, distinct from MICT (Heisz et al. 2016). This information may help to explain our current findings in that shorter sprint bouts may be perceived more favourably when beginning an exercise program, but over time the perceptions of various HIIT/SIT protocols converge, perhaps due to the increasing fitness of participants. Alternatively, Jung and colleagues hypothesized that breaking exercise into small, more achievable, bouts may allow participants more opportunities to experience success over previous sprints (Jung et al. 2014), which could be particularly important for novice exercisers and imply that our 5:40 protocol would be beneficial for individuals beginning an exercise program. Nonetheless, this result warrants future investigation, as this information could
be very important for implementing and adhering to exercise interventions. Future work
should also employ a crossover design to allow for a determination of participants’
preferences for specific protocols, something our present design precluded us from
concluding.

There are a few important limitations to consider when interpreting the present
results. First, despite our best efforts to accommodate schedules we could not ensure that
participants trained at the same time of day every session. Second, despite our
participants’ being a representative sample of a recreationally active university
population, their baseline fitness levels were quite high and any generalization of our
results to other populations should be done with caution. Additionally, a small number of
participants did not achieve their true $\dot{V}O_{2max}$ in this study and to avoid this, future work
should employ constant work rate verification testing in accordance with recent
suggestions (Poole and Jones 2017). Lastly, we recognize the inherent limitations to
utilizing skinfolds to estimate body fat; however, superior methods for assessing body
composition were unavailable.

In summary, by manipulating the work and rest interval duration of the traditional
30 s SIT protocol we have been able to demonstrate that the repeated generation of peak
speed is sufficient to induce improvements in performance suggesting that repeated peak
speed generation is an important component in the adaptive response to SIT.
Furthermore, given that psychological perceptions were similar between all groups, our
modified SIT protocols may offer a comparable alternative to traditional SIT, which is of
potential importance to unfit populations. Future research should examine the efficacy of
these modified SIT protocols in less fit or sedentary populations, while paying particular
attention to their psychological perceptions towards exercise.

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Table 1: Participant characteristics for each group at baseline

<table>
<thead>
<tr>
<th>Participant Characteristics</th>
<th>30:240</th>
<th>15:120</th>
<th>5:40</th>
<th>CTRL</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>n (M/F)</td>
<td>11 (6/5)</td>
<td>11 (7/4)</td>
<td>12 (7/5)</td>
<td>9 (7/2)</td>
<td>-</td>
</tr>
<tr>
<td>Age (y)</td>
<td>21.0±1.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>20.4±1.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.4±1.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>23.1±2.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.0001</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>172.6±7.2</td>
<td>175.5±7.9</td>
<td>173.9±8.8</td>
<td>175.3±10.4</td>
<td>0.8492</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>71.2±11.3</td>
<td>76.6±8.9</td>
<td>73.6±11.0</td>
<td>74.0±12.7</td>
<td>0.7110</td>
</tr>
<tr>
<td>Body Fat (%)</td>
<td>19.2±9.2</td>
<td>18.3±9.7</td>
<td>17.3±9.2</td>
<td>17.7±6.4</td>
<td>0.4579</td>
</tr>
<tr>
<td>VO&lt;sub&gt;2max&lt;/sub&gt; (mL·kg&lt;sup&gt;-1&lt;/sup&gt;·min&lt;sup&gt;-1&lt;/sup&gt;)</td>
<td>46.3±8.4</td>
<td>46.8±7.1</td>
<td>46.2±7.3</td>
<td>50.3±5.7</td>
<td>0.5598</td>
</tr>
</tbody>
</table>

**NOTE:** All data are presented as the mean±SD.
Unlike letters denote significant difference.
Table 2. Anaerobic measures of sprint performance from the 30 s running sprint test

<table>
<thead>
<tr>
<th>Anaerobic Parameter</th>
<th>30:240</th>
<th>15:120</th>
<th>5:40</th>
<th>CTRL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Peak speed (m·sec(^{-1}))</td>
<td>7.24±1.09</td>
<td>7.39±0.90</td>
<td>7.63±0.81</td>
<td>7.68±1.06</td>
</tr>
<tr>
<td>TPS (s)</td>
<td>2.81±1.26</td>
<td>1.97±0.67</td>
<td>3.30±1.13</td>
<td>2.07±1.30</td>
</tr>
<tr>
<td>Avg speed (m·sec(^{-1}))</td>
<td>5.41±0.66</td>
<td>5.32±0.57</td>
<td>5.59±0.61</td>
<td>5.50±0.69</td>
</tr>
<tr>
<td>Min speed (m·sec(^{-1}))</td>
<td>3.57±0.97</td>
<td>3.63±0.69</td>
<td>3.72±0.94</td>
<td>3.70±0.54</td>
</tr>
<tr>
<td>FI (%)</td>
<td>50.40±13.17</td>
<td>50.47±9.52</td>
<td>50.03±11.67</td>
<td>51.33±7.13</td>
</tr>
</tbody>
</table>

NOTE: All data are presented as mean±SD.
TPS = time to peak speed; Avg = average; Min = minimum; FI = fatigue index.
* - Main effect of time (P<0.001).
<table>
<thead>
<tr>
<th>Construct</th>
<th>Variable</th>
<th>Training Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5:40</td>
</tr>
<tr>
<td>Task Self-efficacy</td>
<td>Confidence in performing 1/wk for next month</td>
<td>9.6±0.7</td>
</tr>
<tr>
<td></td>
<td>Confidence in performing 2/wk for next month</td>
<td>9.2±1.2</td>
</tr>
<tr>
<td></td>
<td>Confidence in performing 3/wk for next month</td>
<td>8.1±2.2</td>
</tr>
<tr>
<td></td>
<td>Confidence in performing 4/wk for next month</td>
<td>6.2±3.0</td>
</tr>
<tr>
<td></td>
<td>Confidence in performing 5/wk for next month</td>
<td>4.7±3.1</td>
</tr>
<tr>
<td></td>
<td>Carry out the SIT session for the planned duration?</td>
<td>9.6±1.0</td>
</tr>
<tr>
<td></td>
<td>Avoid over-exertion?</td>
<td>9.4±0.8</td>
</tr>
<tr>
<td></td>
<td>Perform all required movements?</td>
<td>9.5±0.7</td>
</tr>
<tr>
<td></td>
<td>Check how hard your activity is making you work?</td>
<td>8.4±1.4</td>
</tr>
<tr>
<td></td>
<td>Follow the directions of the instructor/trainer?</td>
<td>9.5±0.5</td>
</tr>
<tr>
<td></td>
<td>Aggregate self-efficacy score$^5$</td>
<td>7.6±1.8</td>
</tr>
<tr>
<td>Intentions</td>
<td>Perform 3/wk for next month</td>
<td>3.8±1.3</td>
</tr>
<tr>
<td></td>
<td>Perform 5/wk for next month</td>
<td>1.9±1.5</td>
</tr>
<tr>
<td></td>
<td>“How much did you enjoy…?”</td>
<td>6.7±2.1</td>
</tr>
<tr>
<td>Enjoyment</td>
<td>Enjoyment performing 3/wk for next month</td>
<td>6.5±1.8</td>
</tr>
<tr>
<td></td>
<td>Modified PACES$^5$</td>
<td>65.2±6.1</td>
</tr>
</tbody>
</table>

$^5$ - In line with methods from Jung et al. 2014
**Figure Legend**

**Figure 1:** The change in (A) VO$_{2\text{max}}$ (mL·kg$^{-1}$·min$^{-1}$); (B) 5-km running time trial performance (min); and (C) body fat % for each group pre- to post-training.  
*Note:* * - significantly different vs pre-training; VO$_{2\text{max}}$ - maximal oxygen consumption.

**Figure 2:** Scores on the physical activity enjoyment scale for each group post-training. 
*Note:* No significant differences were found.
The change in (A) VO$_{2\text{max}}$ (mL·kg$^{-1}$·min$^{-1}$); (B) 5-km running time trial performance (min); and (C) body fat % for each group pre- to post-training.

Note: * - significantly different vs pre-training; VO$_{2\text{max}}$ - maximal oxygen consumption.
Figure 2: Scores on the physical activity enjoyment scale for each group post-training. Note: No significant differences were found.

172x115mm (300 x 300 DPI)