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Psychological and behavioral responses to interval and continuous exercise

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Abstract

Purpose: To compare psychological responses to, and preferences for, moderate-intensity continuous training (MICT), high-intensity interval training (HIIT), and sprint interval training (SIT) among inactive adults; and to investigate the relationships between affect, enjoyment, exercise preferences, and subsequent exercise behavior over a 4-wk follow-up period. **Methods:** Thirty inactive men and women (21.23±3.81 y), inexperienced with HIIT or SIT, completed three trials of cycle ergometer exercise in random order on separate days: MICT (45min continuous; ~70-75% of heart rate maximum (HRmax)); HIIT (10x1 min bouts at ~85-90%HRmax with 1-min recovery periods); and SIT (3x20-s "all-out" sprints with 2-min recovery periods). Perceived exertion (RPE), affect, and arousal were measured throughout the trials and enjoyment was measured post-exercise. Participants rank-ordered the protocols (#1-3) according to preference and logged their exercise over a 4-week follow-up. **Results:** Despite elevated HR, RPE, and arousal during work periods (*p*s<0.05), and negative affect during HIIT and SIT, enjoyment and preferences for MICT, HIIT, and SIT were similar (*p*s>0.05). In-task affect was predictive of post-exercise enjoyment for each type of exercise (*r*s=0.32 to 0.47; *p*s<0.05). In-task affect and post-exercise enjoyment predicted preferences for HIIT and SIT (r_ss=-0.34 to -0.61; *p*s<0.05), but not for MICT (*p*s>0.05), respectively. Over the follow-up, participants completed more MICT (*M*=6.11±4.12) than SIT sessions (*M*=1.39±1.85; *p*<0.01, *d*=1.34). Although participants tended to complete more sessions of MICT than HIIT (*M*=3.54±4.23; *p*=0.16, *d*=0.56), and more sessions of HIIT than SIT (*p*=0.07, *d*=0.60), differences were not significant. In-task affect predicted the number of sessions of MICT (*r*=0.40; *p*<0.05), but not HIIT or SIT (*p*s>0.05). **Conclusion:** This study provides new evidence that a single session of HIIT and SIT can be as enjoyable and preferable as MICT among inactive individuals and that there may be differences in the exercise affect-behavior relationship between interval and continuous exercise.

Keywords: Interval Training, Inactive Adults, Affective Responses, Enjoyment, Exercise Preferences, Exercise Behavior

Introduction

Physical inactivity and sedentary lifestyles have become a pervasive public health problem (1), with up to 85% of adults failing to meet physical activity (PA) guidelines (2). Identifying practical strategies to increase PA participation has become a public health priority (1). There is increasing recognition of interval exercise training as a time-efficient alternative to traditional endurance training to elicit physiological adaptations linked to improved health (e.g., 3, 4).

Interval exercise refers to intermittent bouts of relatively intense effort interspersed by periods of recovery within a single training session (3). In studies involving healthy individuals and those at-risk for or living with cardiometabolic diseases, interval exercise training has been shown to induce meaningful physical health benefits similar to traditional moderate-intensity continuous exercise training (MICT), but in significantly less time (3, 4). As a result, there has been growing public health interest in advocating interval exercise as a time-efficient exercise option for the largely inactive general population (5).

One of the most intense forms of interval exercise is sprint interval training (SIT; 6). Traditional SIT protocols consist of 4-6 x 30-s "all-out" bouts separated by 4 min of recovery, typically lasting ~20-25 min (6). However, adaptations of traditional SIT protocols have since been implemented in order to provide variations of SIT that are more practical for sedentary individuals in terms of being shorter in duration and more feasible to complete (7). An example of a more *practical* SIT protocol consists of 3 x 20-s "all-out" bouts, separated by 2 min rest periods and lasts only 10 min in total, including a warm-up and cool-down (8, 9). Importantly, this SIT protocol has been shown to improve indices of cardiometabolic health to the same extent as MICT among inactive individuals (9).

A somewhat less intense form of interval exercise is high-intensity interval training (HIIT; 6). One of the most frequently studied HIIT protocols consists of 10 x 1-min bouts of exercise at ~85-90% heart rate maximum (HRmax), separated by 1-min periods of rest (5, 6). This HIIT protocol has been tested with inactive individuals (3, 4) and is still relatively time-efficient (24 min total exercise), but may be considered to be more tolerable than the "all-out" supramaximal intensity of a SIT protocol given that the work bouts are performed at a relatively lower intensity.

Although SIT and HIIT can both elicit important physiological adaptations comparable to MICT (3, 4, 6, 9), some scientists have questioned whether these interval exercise protocols should be promoted to the inactive population (10, 11). Consistent with the dual-mode theory (12), studies among inactive individuals have shown a decline in pleasure as exercise intensity increases and approaches maximal capacity (13). Thus, there is concern that inactive people may find the high-intensity nature of SIT and HIIT unpleasant, which may subsequently deter future exercise participation (10, 11). Another apprehension is that people generally do not enjoy high-intensity exercise (10, 11), and enjoyment is an important predictor of exercise behavior and adherence (14, 15). It is important to note, however, that these concerns are largely based on research examining people's responses to high-intensity *continuous* exercise (see also 5). It is not clear if the predictions of dual-mode theory and the psychological responses to continuous exercise are the same as those for *interval* exercise (see also 5).

Interestingly, most studies have reported that participants experienced equal or greater enjoyment of, and preferences for, interval exercise protocols in comparison to continuous exercise (5). For instance, a study of inactive adults found similar post-exercise enjoyment between the HIIT and MICT conditions, and overall preferences for HIIT (6/10 participants) were comparable to MICT (4/10 participants; 16). In another study (17), adolescent boys and girls reported higher levels of post-exercise enjoyment for HIIT than MICT, and 81% of participants preferred HIIT over MICT. Although these studies did not include a SIT protocol for comparison, another study found that recreationally active participants had relatively positive attitudes (M=5.03 out of 7) and intentions (M=4.80 out of 7) towards SIT after trying multiple SIT sessions for the first time (18). Together, such findings suggest that SIT and HIT may be more tolerable and enjoyable than one might expect (5).

It is not known, however, which interval exercise protocols are perceived most favorably by inactive individuals and may be conducive to subsequent exercise behavior. Furthermore, despite suggestions that inactive individuals will not enjoy SIT (11), limited research to date has directly tested this proposition. Thus, the primary objective of this study was to compare the psychological responses (i.e., affect, arousal, and enjoyment) to acute sessions of MICT, HIIT, and SIT, and to determine which exercise protocol is preferred among a sample of inactive adults. Additionally, little is known about how people's affective responses to interval exercise may relate to their enjoyment of, preferences for, and participation in, interval exercise (5). As such, the secondary objective was to investigate the relationships between psychological responses to acute lab-based sessions of MICT, HIIT, and SIT and participants' subsequent exercise behavior over a 4-week follow-up. This study is the first to: a) compare affect, enjoyment and preferences between MICT, HIIT, and SIT among inactive adults, b) examine the psychological responses to a more practical 3 x 20-s, 10-min SIT protocol, and c) investigate the relationships between acute psychological responses to HIIT and SIT and real-world HIIT and SIT exercise behavior.

Based on a recent synthesis of research examining psychological responses to HIIT and SIT in comparison to MICT (5), we hypothesized that affect would be similar or more negative during HIIT and SIT in comparison to MICT, and the enjoyment of HIIT would be equal to, or greater than, MICT. Given the "all-out" nature of SIT, suggestions that SIT may be inappropriate for inactive individuals (e.g., 11), and findings from one training study (19), we anticipated that enjoyment would be lower for SIT than HIIT or MICT. Further, following similar rationale, we anticipated that participants would prefer HIIT the most, followed by MICT, and then SIT.

Consistent with findings from a study of continuous and interval exercise protocols (20), we hypothesized that in-task affect would be predictive of post-exercise enjoyment for each type of exercise, respectively. Based on evidence that in-task affective responses to continuous exercise are predictive of self-reported physical activity behavior (21), we hypothesized that affective responses to a lab-based MICT protocol would predict participants' subsequent MICT behavior over a 4-week follow-up. In the absence of any research evaluating the relationship between in-task affective responses to HIIT or SIT and subsequent HIIT or SIT behavior, we anticipated that, consistent with the hypothesis regarding MICT, in-task affect during HIIT would predict subsequent HIIT behavior and in-task affect during SIT would predict subsequent SIT behavior.

Methods

Participants

Based on previous literature that found effect sizes ranging from 0.5 to 1.4 for differences in affect and enjoyment between HIIT and continuous exercise conditions (e.g., 22, 23), we estimated conservatively and powered for an effect of 0.6. Using a repeated measures analysis of variance (ANOVA) statistical test in G*Power 3 (24), a sample size of 27 was estimated to have 80% power to detect an effect of 0.6 (25). Thirty-two inactive men and women (20 women) inexperienced with HIIT or SIT were recruited and enrolled in the study. Participants were excluded from the study if they had previously participated in the HIIT or SIT protocols administered in the study or had contraindications to exercise based on the Physical Activity Readiness Questionnaire (PAR-Q). As in previous interval exercise studies (e.g., 8), "inactive" was defined as ≤ 2 sessions/week of structured exercise (26) over the past 6 months. In addition to reporting low levels of activity, participants' average maximal oxygen uptake (VO_2max) was

31.3±6.2 mL-kg^{-1}-min^{-1}, providing further evidence that this sample was relatively inactive. The McMaster Research Ethics Board approved the study protocol and participants were recruited through poster advertisements on campus and via email. All participants provided written informed consent and received an honorarium of $60 CAD in order to compensate them for their participation in the study.

Study Design

This study used a repeated measures crossover design, whereby each participant completed a total of three different exercise trials: MICT, HIIT, and SIT. The exercise testing order was randomized and counterbalanced using a 3 by 6 Williams Square design (27). Participant randomization was stratified by gender in blocks of 6. Each participant made a total of five visits to the lab over the course of approximately 8 weeks.

Manipulation Checks

Perceived exertion. Borg's (28) CR-10 rating of perceived exertion (RPE) scale was used, which ranges from "Nothing at all" (0) to "Absolute Maximum" (10). The RPE scale is a valid and reliable measure of physical exertion during exercise (28).

Heart rate. Participants' heart rate (HR) was continuously recorded throughout fitness testing and each of the exercise trials using a HR monitor (Polar S625X).

Main Outcome Measures.

Affect. Hardy and Rejeski's (29) Feeling Scale (FS) was used to measure affective valence before, during and following the exercise trials. The FS is an 11-point bipolar, single-item scale that ranges from "Very Bad" (-5) to "Very Good" (+5) along a displeasure-pleasure continuum. The FS has been established as a reliable and valid measure of exercise-related affective states (e.g., 29). It has been suggested that the three most meaningful affective responses people experience in-task during exercise are: 1) the magnitude of the negative or positive peaks, 2) the rate of change in affect, and 3) affect experienced at the very end of the exercise session (5, 30). Considering that fluctuations in affect are typically observed in-task for HIIT or SIT protocols (e.g., 30, 31) and the three exercise protocols in this study varied in total duration, we decided that the magnitude of the peak negative affect was the most appropriate in-task measure of affect for the current study[1]. The peak negative in-task FS responses experienced by each participant during the exercise trials were calculated by determining each participant's lowest FS score at any time point in-task for MICT, HIIT and SIT. The FS change scores for each participant during the exercise trials were calculated by subtracting each participant's pre-task FS score from their peak negative FS score for MICT, HIIT and SIT.

Arousal. Svebak and Murgatroyd's (32) Felt Arousal Scale (FAS) was used to measure perceived activation (arousal) before, during and following the exercise trials. The FAS is a 6-point, single-item scale that ranges from "Low Arousal" (1) to "High Arousal" (6). The concurrent use of the FS and FAS strengthens their discriminant validity (33).

Exercise enjoyment. Enjoyment of each exercise trial was measured immediately post-exercise using the Physical Activity Enjoyment Scale (PACES; 34). The PACES was modified slightly such that each item was re-worded from the present to past tense (see also 18, 31). This scale has 11 negatively worded and 7 positively worded items that participants rated on a 7-point bipolar scale (from 1 to 7), indicating how they felt about the exercise they completed. The internal consistency was acceptable at each administration (Cronbach's $\alpha s \geq .94$).

Exercise preferences. Following completion of all three exercise trials, participants were given a list of the three protocols and asked to "rank them (1, 2, 3) in order of preference with a '1' indicating the exercise you liked the most." They first completed these rankings with reference to the exercises performed *in the lab,* and then they ranked their preferences for activity to be completed during their own *free time*.

[1]Note: Analyses were also replicated using the magnitude of the peaks of positive FS, the FS change score, and the end-of-task FS scores. The results were fundamentally the same with respect to each of these variables. Considering these non-differences and the factors raised here, the magnitude of the peak negative in-task FS was considered the most meaningful FS outcome to report.

Exercise behavior. Each participant was asked to complete an exercise log sheet and recorded exercise behavior over the course of 4 weeks. Participants were instructed to record any daily exercise activities they engaged in and the modality they used, and to classify each aerobic activity as either MICT, HIIT, or SIT. Participants were asked to refer to the following definition of "exercise" while reporting answers to any questions: "A planned, structured, and repetitive bodily movement done to improve or maintain one or more components of physical fitness" (35). This definition of exercise, along with brief descriptions of MICT ("continuous moderate intensity"), HIIT ("10x1-min high-intensity bouts, 1-min rest between"), and SIT ("3x20-s 'all-out' bouts, 2-min rest between"), were provided at the bottom of the log sheets. Log-sheet data were used to calculate the *frequency* of MICT, HIIT and SIT exercise sessions enacted by each participant over a 4-week period. Exercise sessions were reviewed and coded for accuracy and exercise that was not characteristic of either of the three types of protocols were coded as "other" (e.g., a game of soccer, rock climbing, etc.) and were excluded from the analyses. The number of sessions of each type of exercise was compared, rather than the number of minutes spent on each type of exercise, given that HIIT and SIT are typically performed for shorter durations than MICT.

Protocol

Baseline testing (visit 1). Following confirmation of eligibility, participants provided their written informed consent. Participants then performed an incremental VO_2max test on an electronically braked cycle ergometer (Lode Corival, Groningen, The Netherlands). Following a 1-min warm up at 50W resistance, the resistance on the cycle ergometer was automatically increased by 1W every 2 seconds until volitional exhaustion or the point at which the participants' pedal cadence fell below 50 RPM. A metabolic cart with an on-line gas collection system (Medisoft Ergocard) was used to collect oxygen consumption and carbon dioxide production data. VO_2max was calculated using the highest average oxygen consumption over a 15-s period. In addition to measuring VO_2max, this baseline fitness test was also used to assess peak power output in Watts (Wmax) and HRmax in order to determine individualized training intensities.

Exercise trials (visits 2-4). All three exercise trials included a 2-min warm-up at 50W and a 3-min cool-down at 25W, and were completed using the same cycle ergometer (Lode Corival, Groningen, The Netherlands). The cycle ergometer was set up so participants were directly facing a wall on which the three measurement scales were posted. The scales were color-coded to clearly differentiate between each and minimize common-method variance (see 5). During the rest periods of HIIT and SIT, participants were given the option to completely rest or pedal very lightly, without physically exerting themselves any more than a 1 ("very weak") on the RPE scale. For all three protocols, participants were asked to remain seated on the bike at all times, including work bouts and rest periods. Following the cool-down, participants were asked to remain in the lab for 20 min. ***MICT protocol.*** Participants completed 45 min of continuous cycling at 35% Wmax in order to elicit ~70-75% HRmax (50 min total exercise; 4, 6) and were prompted to report their RPE, FS, and FAS scores before, during (at 5, 10, 15, 20, 25, 30, 35, 40 and 42.5 min), and immediately following the MICT work period, and during the cool-down. ***HIIT protocol.*** Participants completed 10 x 1-min bouts of exercise at 70% Wmax in order to elicit ~85-90% HRmax, separated by 1-min periods of rest (24 min total exercise; 6). Participants were prompted to report RPE, FS, and FAS before, during (immediately following each of the work bouts and during the last ~20s of the rest periods), and immediately following the HIIT protocol, and during the cool-down. ***SIT protocol.*** Participants completed 3 x 20-s "all-out" sprints, separated by 2-min periods of rest (10 min total exercise; 8, 9). These "all-out" sprints were performed with an applied resistance added to the cycle ergometer, calculated as 5% of body weight (9). Participants were prompted to report RPE, FS, and FAS before, during (immediately following each of the sprint bouts and during the last ~40s of the rest periods) and immediately following the SIT protocol, and during the cool-down. Participants were prompted to report RPE, FS, and FAS ~20s later for the SIT than HIIT protocol because the rest periods were longer and to allow time for verbal prompting leading into the 20-s "all out" sprints. This was also done in order to ensure participants were performing the sprints at the desired "all out" intensity.

Reports of RPE, FS, and FAS were prompted immediately following the work bouts for both the HIIT and SIT protocols due to logistical constraints with collecting scale responses during "all-out" and high-intensity cycling efforts. At these time points, participants were carefully instructed to report how they "felt *during* the exercise" bouts. At all other time-points (including rest periods), participants were instructed to indicate how they "feel *right now*." Participants were reminded of these explicit instructions prior to each exercise trial. Participants were also prompted to report FS and FAS and filled out the PACES immediately following each exercise trial (following cool-down), and were prompted to report FS and FAS at 10- and 20-min post-exercise. A visual representation of the MICT, HIIT, and SIT protocols is presented in Figure 1.

Each exercise trial was scheduled at least 72 hours apart and most trials were completed about 7 days apart (*M*=7.07, *SD*=2.45 days). Participants were instructed to maintain consistent dietary and sleep habits and to avoid any physical activity for the entire day of their visits to the lab. In order to control for diurnal variations, participants were scheduled at approximately the same time of day for their exercise trials. Participants were made aware of the exercise protocol to be completed when they arrived at the lab. In order to control for motivational influence, the same scripted set of instructions were provided throughout each exercise trial by the same experimenter (MJS). One male experimenter (MJS) and one female volunteer were present for all exercise trials.

Following their final exercise trial, participants completed the exercise preferences measures. Participants were then given the exercise log sheets and instructions. Participants were encouraged to try variations of any of the three exercise protocols completed in the lab using any modality (e.g., biking, running, swimming), but were reminded that they were not obligated to do so. Two weeks later, participants were sent an email reminder to fill out their log sheets.

Follow-up visit (visit 5). Four weeks later, participants returned to the lab and submitted their completed log sheets. Finally, participants were debriefed, and remunerated for their participation in the study.

Statistical Analyses

A separate one-way repeated measures ANOVA was conducted to assess differences between the MICT, HIIT, and SIT conditions for each of the six outcome measures (i.e., RPE, HR, FS, FAS, PACES, and exercise behavior). Chi-squared tests and Friedman's ANOVAs were used to determine differences in exercise preferences. When sphericity was violated, the Greenhouse-Geisser correction was applied (36). Significant main effects were followed by post hoc pairwise comparisons using Bonferroni corrections in order to account for multiple comparisons. The magnitude of the observed effects were calculated as standardized Cohen's *d*s (25) and uncertainty in the estimates were reported as 95% confidence intervals using Hopkin's (37) spreadsheet for repeated measures crossover designs. The effects were interpreted according to Cohen's (25) conventions (0.2 = small, 0.5 = medium, 0.8 = large).

Pearson and Spearman's correlation coefficients were computed in order to determine the relationships between affect, enjoyment, exercise preferences, and exercise behavior. One-tailed tests were used due to the directionality of the hypotheses, and Spearman's rho was used instead of Pearson's correlation coefficient for rank-ordered variables (i.e., exercise preferences; 36). All analyses were initially conducted to test for the potential moderating effects of gender. No significant differences were found, so data were collapsed across men and women for the final analyses. SPSS version 21.0 was used for all analyses, and significance was set at $p<0.05$.

Results

Two female participants withdrew from the study unexpectedly (one due to illness and another for an undisclosed reason) and their data were not included in the analyses. Thus, 30 participants (18 women) completed the study and their characteristics are presented in Table 1. Two participants had missing exercise log data (1 male participant did not return the log and 1 female reported an extended illness).

The magnitude of the observed effects (*d*) and 95% confidence intervals based on comparisons between MICT, HIIT, and SIT for RPE, HR, FS, FAS, PACES, and exercise behavior are presented in Table 2.

Manipulation Checks

Manipulation checks verified that participants were exercising at the intended training intensity for each protocol. Mean RPE during the work periods differed across trials, $F(2, 58)=71.17$, $p<0.01$, $h^2=0.71$ (see Fig. 2). RPE differed between all three conditions (*p*s<0.01) with RPE being lowest during MICT (*M*=4.06, *SD*=1.68), higher during HIIT (*M*=6.63, *SD*=1.35) and highest during SIT (*M*=7.81, *SD*=1.52; *d*s=0.80-2.28). Mean percentage (%) of HRmax during the work periods also differed across trials, $F(2, 58)=69.16$, $p<0.01$, $h^2=0.71$. %HRmax differed between all three conditions (*p*s<0.01) with %HRmax being lowest during MICT (*M*=77.68%, *SD*=5.64), higher during SIT (M=84.02%, SD=5.64), and highest during HIIT (*M*=89.30%, *SD*=3.97; *d*s=1.06-2.32). Mean HR over the entire exercise protocols were 76.39±5.65%, 84.74±4.54%, and 76.83±5.75% of HRmax for MICT (50min), HIIT (24min), and SIT (10min), respectively. The work periods of the exercise trials were performed at a mean of 68.50±13.33W for MICT, 137.00±26.67W for HIIT, and 314.37±87.30W for SIT. During SIT, participants performed "all-out" efforts at a variable power output corresponding to a mean of 158.71±18.96% of Wmax over the three sprint intervals.

Main Outcome Measures

Affect. The peak negative FS responses experienced in-task differed across the exercise trials, F(2, 58)=8.67, *p*<0.01, η^2=0.23 (see Fig. 3). The peak negative FS for HIIT (*M*=-1.47, *SD*=2.30) was more negative than for MICT (*M*=0.27, *SD*=1.76; *p*<0.01, *d*=0.82). No statistically significant differences in negative FS peaks were detected between MICT and SIT (*M*=-0.80, *SD*=2.20; *p*=0.07, *d*=0.52) or HIIT and SIT (*p*=0.34, *d*=0.29). However, a medium-sized effect was found between MICT and SIT (*d*=0.52, 95% CI [0.07, 0.97]), suggesting that peak negative FS was more negative for SIT than MICT (see Table 2). FS ratings declined during all three exercise trials. Specifically, the FS change scores differed across the exercise trials, F(2, 58)=8.30, *p*<0.01, η^2=0.22. The FS change score for HIIT (*M*=-3.80, *SD*=2.91) was greater than for MICT (*M*=-1.83, *SD*=2.00; *p*<0.01, *d*=0.77). No statistically significant differences in FS change scores were detected between MICT and SIT (*M*=-2.73, *SD*=2.52; *p*=0.19, *d*=0.39) or HIIT and SIT (*p*=0.11, *d*=0.38). However, small to medium-sized effects were found between MICT and SIT (*d*=0.39, 95% CI [-0.02, 0.80]) and between HIIT and SIT (*d*=0.38, 95% CI [0.03, 0.74]), suggesting that affect may have declined in-task to a greater extent during SIT than MICT and during HIIT than SIT (see Table 2).

FS ratings immediately (0-min) post-exercise differed across the exercise trials, F(2, 58)=5.02, *p*=0.01, η^2=0.15. At 0-min post-exercise, FS was more positive for MICT (*M*=2.30, *SD*=1.53) than for SIT (*M*=1.23, *SD*=1.94; *p*<0.05, *d*=0.59). No differences in FS 0-min post-exercise were detected between MICT and HIIT (*M*=2.17, *SD*=1.42; *p*=1.00, *d*=0.09) or HIIT and SIT (*p*=0.09, *d*=0.53). However, a medium-sized effect was found between HIIT and SIT (*d*=0.53, 95% CI [0.05, 1.01]), suggesting that FS 0-min post-exercise was more positive for HIIT than SIT (see Table 2). There were no differences in FS scores pre-task or 10- and 20-min post-exercise across the three exercise trials (*p*s>0.05, *d*s=0.02-0.24).

Arousal. FAS during the work periods differed across the exercise trials, F(1.42, 41.18)=15.31, *p*<0.01, η^2=0.35 (see Fig. 4). FAS during the work period of MICT (*M*=2.86, *SD*=0.90) was lower than during the work periods of HIIT (*M*=3.84, *SD*=1.28; *p*<0.01, *d*=0.89) and SIT (*M*=3.92, *SD*=1.28; *p*<0.01, *d*=0.93). No differences in FAS were detected between the work periods of HIIT and SIT (*p*=1.00, *d*=0.06). FAS scores were not different pre-task or 0-min, 10-min, and 20-min post-exercise across the three exercise trials (*p*s>0.05, *d*s=0.03-0.34).

Exercise enjoyment. There were no differences in participants' PACES between the three exercise protocols immediately post-exercise (mean scores: MICT=83.70±19.20, HIIT=84.43±18.47, SIT=81.63±18.78), F(2, 58)=0.27, *p*=0.76, η^2=0.01.

Exercise preferences. Based on the #1-ranked (i.e., most preferred) protocol participants completed *in the lab*, 13/30 (43.3%) participants preferred HIIT, 10/30 (33.3%) preferred MICT, and 7/30 (23.3%) preferred SIT, with no differences in the frequency of #1 rankings, χ^2(2)=1.80, *p*=0.41. Further, there were no differences in overall rank-ordered (#1-3) exercise preferences (in lab) between the three exercise protocols, χ^2(2)=0.20, *p*=0.94. Based on #1-ranked protocols participants would prefer to complete on their own *free time*, 15/30 (50.0%) preferred MICT, 8/30 (26.7%) participants preferred HIIT, and 7/30 (23.3%) preferred SIT, with no differences in the frequency of #1 rankings, χ^2(2)=3.80, *p*=0.15. Further, there were no differences in overall rank-ordered (#1-3) exercise preference (free time) between the three exercise protocols, χ^2(2)=3.27, *p*=0.21.

Exercise behavior. Participants exercised using a variety of modalities such as running outside, swimming, biking, and using a treadmill, and completed a mean total of 11.04±5.29 sessions of MICT, HIIT, and SIT exercise combined over 4 weeks. The frequency of exercise sessions completed over 4 weeks differed between the three exercise types, F(1.53, 41.38)=10.77, *p*<0.01, η^2=0.29. Participants completed more MICT sessions (*M*=6.11, *SD*=4.12) than SIT sessions (*M*=1.39, *SD*=1.85; $p<0.01$, $d=1.34$). No statistically significant differences in the number of sessions of MICT versus HIIT (*M*=3.54, *SD*=4.23; $p=0.16$, $d=0.56$) or HIIT versus SIT ($p=0.07$, $d=0.60$) were detected. However, medium-sized effects were found between MICT and HIIT ($d=0.56$, 95% CI [-0.01, 1.12]) and between HIIT and SIT ($d=0.60$, 95% CI [0.08, 1.11]), suggesting that participants tended to complete more sessions of MICT than HIIT, and more sessions of HIIT than SIT (see Table 2).

Correlational analyses. For MICT, the peak negative in-task FS was correlated with MICT enjoyment ($r=0.47$, $p<0.01$) and frequency of MICT behavior ($r=0.40$, $p=0.02$), but not with preferences for MICT in the lab or during free time (*p*s>0.05; see Table 3). Enjoyment of MICT was not correlated with preferences for MICT in the lab or during free time, or MICT behavior (*p*s>0.05; see Table 3).

For HIIT, the peak negative FS was correlated with HIIT enjoyment ($r=0.45$, $p<0.01$) and preferences for HIIT in the lab ($r_s=-0.41$, $p=0.01$), but not preferences for HIIT during free time or frequency of HIIT behavior (*p*s>0.05; see Table 3). Enjoyment of HIIT was correlated with preferences for HIIT in the lab ($r_s=-0.61$, $p<0.01$) and during free time ($r_s=-0.46$, $p<0.01$), but not with HIIT behavior ($p=0.28$; see Table 3).

For SIT, the peak negative FS was correlated with SIT enjoyment ($r=0.32$, $p=0.04$) and preferences for SIT in the lab ($r_s=-0.47$, $p<0.01$) and during free time ($r_s=-0.38$, $p=0.02$), but not with frequency of SIT behavior ($p=0.36$; see Table 3). Enjoyment of SIT was correlated with preferences for SIT in the lab ($r_s=-0.50$, $p<0.01$) and during free time ($r_s=-0.34$, $p=0.04$), but not with SIT behavior ($p=0.19$; see Table 3).

Overall, smaller declines in in-task FS were associated with greater enjoyment of MICT, HIIT, and SIT, respectively. Further, smaller declines in in-task FS were associated with greater preferences for HIIT and SIT, but not for MICT. Smaller declines in in-task FS were associated with more sessions of MICT completed over 4 weeks, but not with HIIT or SIT sessions. Greater enjoyment of HIIT and SIT were associated with greater preferences for HIIT and SIT, respectively, but enjoyment of MICT did not predict preferences for MICT. Exercise enjoyment did not predict exercise behavior for any of the three exercise types.

Discussion

The primary finding from the current study was that despite experiencing elevated RPE and HR as well as negative affective responses during HIIT and SIT, inactive individuals still reported similar levels of post-exercise enjoyment and preferences for MICT, HIIT, and SIT. A second key finding was that smaller declines in MICT in-task affect were associated with more MICT *behavior* over 4 weeks, but in-task affect and subsequent behavior were not correlated for HIIT or SIT. A third key finding was that smaller declines in in-task affect and greater post-exercise enjoyment were associated with greater *preferences* for HIIT and SIT, but not for MICT, respectively. To our knowledge, this is the first study to investigate psychological responses to MICT, HIIT, and a practical 3 x 20-s SIT protocol and whether these responses predict subsequent exercise behavior over a follow-up period.

Consistent with the hypotheses and previous research evidence (5), affective responses were more negative in-task for HIIT and SIT in comparison to MICT. Notably, peak negative affect during both HIIT (M=-1.47) and SIT (M=-0.80) dropped into negative valence, while MICT responses remained in positive valence (M=0.27). During MICT, participants experienced a gradual decline in affect over time (see Fig. 3). During HIIT and SIT, affect became more negative during the high-intensity work bouts and “rebounded” more positively during rest periods (relative to the work bouts; see Fig. 3). Although affect did “rebound” during the rest periods of HIIT and SIT, these “rebounds” tended to become less positive over repeated bouts. For instance, affective responses during rest periods 8 and 9 of HIIT both remained in the negative valence (see Fig. 3).

These acute changes in affect observed in-task support the predictions of the dual-mode theory (12), whereby affect is proposed to become more negative as exercise intensity increases. Further, a rebound to more positive affect was observed following all three exercise protocols (see Fig. 3), which also aligns with the dual-mode theory (12) and existing evidence (5).

There were no significant between-condition differences in affective responses pre, during, or 10- or 20-min following HIIT and SIT. These results provide the first evidence that, among inactive adults, affective responses to a 3 x 20-s SIT protocol are no more negative than affective responses to a 10 x 1-min HIIT protocol. It is possible that the brevity (20s) and frequency (3 bouts) of the "all-out" SIT intervals and the short total exercise duration (10 min) render this particular SIT protocol more tolerable than traditional forms of SIT (e.g., 4 x 30-s), despite the "all-out" work interval intensity. This interpretation aligns with exercise physiologists' rationale for developing 10-20s sprint protocols (instead of 30s sprint protocols) in order to "make the training sessions more time-efficient, less strenuous and more applicable to the largely sedentary general population" (7).

Consistent with our hypotheses, there were no significant differences in enjoyment between HIIT and MICT. However, contrary to hypotheses, enjoyment of SIT was equal to that of HIIT and MICT. Overall, these findings align with the majority of current evidence showing that exercise enjoyment is similar or greater following HIIT or SIT compared to MICT (5). One explanation for these findings may be that interval exercise is different from, and more challenging and stimulating than, traditional forms of exercise; challenge and stimulation are factors that may influence exercise enjoyment (14, 38). In addition, the brevity of the work intervals, the periods of rest between each interval, and the reduced total time commitment, may make interval exercise a less monotonous, and more appealing and enjoyable form of exercise than continuous exercise (e.g., 5, 22). These factors may, in part, explain why enjoyment of HIIT and SIT was not significantly different from MICT, despite participants reporting elevated RPE and negative affective responses during HIIT and SIT.

Contrary to the hypotheses, all three exercise protocols were preferred equally. This finding is consistent with results from two previous studies showing non-significant differences in preferences between HIIT and MICT (16, 22). Both studies were conducted among inactive male and female adults, but did not include comparison with a SIT protocol. To our knowledge, this is the first study to compare preferences between MICT, HIIT, and SIT among inactive adults. It has been suggested that the intermittent nature and relative intensities of the work bouts may make interval exercise more adaptable and tolerable than some people may believe (5), and this may explain why studies tend to report equal/greater enjoyment and preferences for HIIT and SIT in comparison to MICT. Interestingly, while in-task affective responses were most negative during HIIT in the current study, HIIT tended to be preferred (in lab) in comparison to MICT and SIT.

It should be noted that, although not statistically significant, participants' preferences to complete the exercise during their own free time tended to favor MICT over HIIT and SIT. This is also in line with the frequency of exercise behavior reported, whereby participants tended to complete more sessions of MICT than HIIT and SIT over the 4-week follow-up. These findings may be due to participants having previous experience with MICT (60% of participants reported that they had previously engaged in MICT prior to participating in the study), while no participants reporting previously engaging in HIIT or SIT. Extensive research shows that past physical activity behavior is the strongest predictor of future physical activity behavior (e.g., 39), which would suggest that participants were more likely to engage in MICT because they had engaged in it previously. In addition, because no participants had experience with the HIIT and SIT protocols, they may have felt less *capable* of completing HIIT or SIT on their own time because they were less comfortable with, and less aware of how to complete, HIIT or SIT outside of the lab. Further, the HIIT and SIT protocols were completed in the lab using specialized exercise equipment and with the direction from an experimenter, which are exercise *opportunities* they likely would not have on their own. According to Michie's COM-B system of behavior change (40), perceptions of personal capability, opportunity, and motivation are precursors to engaging in a particular behavior. Despite apparent *motivation* to engage in HIIT and SIT (as indicated by the preferences measures), study participants may have lacked the perceived capability and opportunity to engage in HIIT or SIT during their own free time. Inactive individuals may require continued supervised opportunities and experiences of completing HIIT or SIT before they feel capable and motivated to consistently engage in HIIT or SIT on their own. Nevertheless, it is encouraging that 79% of participants completed at least one session of HIIT and 54% completed at least one session of SIT on their own time.

Together, the exercise preferences and behavioural data from this study highlight the need for future research to a) investigate what role prior exercise experiences may play in determining people's current preferences for various forms of interval or continuous exercise and b) evaluate specific factors (e.g., perceived capability, barriers and facilitators) that impact people's ability to participate in interval exercise in real-world settings and over the long term (see also 5). Such research has the potential to guide the development of more effective real-world applications of interval exercise and further our understanding of how best to provide people with opportunities to engage in both continuous and interval exercise.

Consistent with the hypotheses and previous evidence (20), smaller declines in in-task affect were associated with greater post-exercise enjoyment for each type of exercise. Further, in-task affect during MICT predicted MICT behavior over the next 4 weeks, which also aligns with the hypotheses and previous research (21). However, contrary to the hypotheses, in-task affect during HIIT or SIT did not predict subsequent HIIT or SIT behavior (respectively) over the 4-

week follow-up. These results may suggest that affective responses to interval exercise protocols do not predict future interval exercise behavior. Alternatively, the fluctuations in affect during the bouts *and rest periods* of interval exercise may need to be accounted for when using affect to predict future interval exercise behavior. Given the lack of research testing the predictive relationship between affect and behavior for interval exercise, future research is encouraged to investigate if these findings hold true for various participant samples, forms of interval exercise, and durations of behavior measurement.

Study Strengths and Limitations

The current study has several strengths. Based on a scoping review of the psychological responses to interval exercise (5), the following steps were taken to minimize potential confounders: the gender of experimenters present during each exercise trial was controlled (1 male, 1 female); communication with participants was scripted for all visits; participants were familiarized with and reminded about the differences between the scale measures throughout the study; diurnal variation was controlled for; exercise trials were separated by 7 days; and the lab setup, procedures, and environment were carefully standardized. Further, both RPE and HR data were collected as manipulation checks to ensure participants were exercising at the desired exercise intensities and VO_2max was measured in order to supplement self-reported measures of physical activity. Finally, each exercise protocol administered in this study was carefully selected based on previous research showing similar physical benefits over several weeks of training.

Some potential limitations should be mentioned. Reports of MICT, HIIT, and SIT behavior were collected over the short-term (4 weeks) and may have been susceptible to self-report biases. Notwithstanding, this study was the first to investigate the affect-behavior relationship using HIIT and SIT, and future studies evaluating exercise behavior over the longer term and using objective measures (e.g., accelerometers) are encouraged. For the current study, total exercise duration was not controlled for between MICT, HIIT, and SIT. However, this decision was made in order to capture the trade-off between varying exercise intensity and duration and the potential time-saving appeal of HIIT and SIT in comparison to MICT (see also 5). Although the results from the current study provide new and important findings about MICT, HIIT, and SIT, such findings need to be replicated in future studies. Finally, this was an acute study of MICT, HIIT, and SIT, so we cannot infer how several weeks of training using these exercise protocols may impact participants' psychological responses and exercise preferences.

Conclusion

Although interval exercise protocols such as HIIT or SIT have been advocated as time-efficient alternatives to traditional endurance exercise (i.e., MICT), our current understanding of how inactive individuals psychologically respond to such protocols is limited (5). The present findings showed that, despite experiencing more negative affective responses during HIIT and SIT in comparison to MICT, inactive individuals still reported equal levels of post-exercise enjoyment and preferences for MICT, HIIT, and SIT. Importantly, this study shows that a SIT protocol consisting of 3 x 20-s "all-out" sprints can be completed, enjoyed, and even preferred over MICT or HIIT by some inactive individuals. Further, differences in the exercise affect-behavior relationship were detected for interval and continuous exercise, such that affect experienced during exercise predicted 4-week exercise behavior for MICT, but not for HIIT or SIT.

Overall, these findings provide us with a new-found understanding of inactive people's acute psychological responses to MICT, HIIT, and SIT, and what role such responses may play in predicting exercise preferences and future exercise behavior. While research has previously shown that HIIT and SIT can elicit similar physical benefits as MICT over several weeks of training, this study provides new evidence that a single session of HIIT and SIT can be equally as enjoyable and preferable as MICT among inactive individuals. Moreover, there may be differences – or at least important considerations – in the exercise affect-behavior relationship between interval and continuous exercise. This study prompts further consideration of how exercise is typically prescribed to the largely inactive population. For instance, it is possible that lab-based testing of people performing acute interval and continuous exercise protocols may be used to determine *individualized* exercise programs that are most conducive to exercise enjoyment and adherence. Similar to evidence that people have varied physiological responses to MICT versus SIT (41), this study suggests that people also have varied *psychological* responses to MICT, HIIT, and SIT. When it comes to exercise prescription, one size does not fit all; health care and exercise practitioners should provide people with opportunities to engage in and try different forms of continuous and interval exercise as a means of promoting physical activity and improving public health.

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Figure Captions

Figure 1: Individual power output data from one male participant for the MICT, HIIT, and SIT trials, graphed over time. Arrows represent the total exercise duration of each exercise trial.

Figure 2: Rating of Perceived Exertion responses (*M*±SE) during the MICT, HIIT, and SIT trials, plotted over time. W-Up, warm-up; CDown, cool-down; B1-B10, bouts 1-10; R1-R9, rest periods 1-9.

Figure 3: Feeling Scale responses (*M*±SE) before, during, and following the MICT, HIIT, and SIT trials, plotted over time. W-Up, warm-up; CDown, cool-down; B1-B10, bouts 1-10; R1-R9, rest periods 1-9; 0-Post, 0min post-exercise; 10-Post, 10min post-exercise; 20-Post, 20min post-exercise.

Figure 4: Felt Arousal Scale responses (*M*±SE) before, during, and following the MICT, HIIT, and SIT trials, plotted over time. W-Up, warm-up; CDown, cool-down; B1-B10, bouts 1-10; R1-R9, rest periods 1-9; 0-Post, 0min post-exercise; 10-Post, 10min post-exercise; 20-Post, 20min post-exercise.

Figure 1

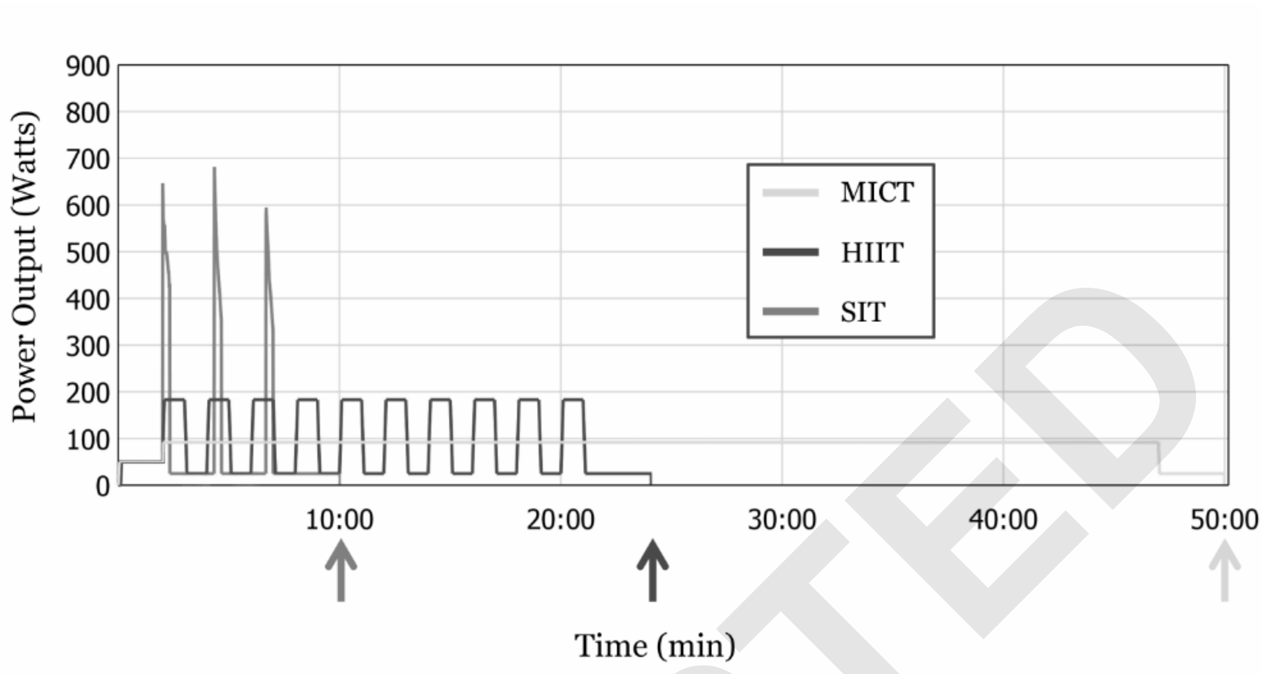
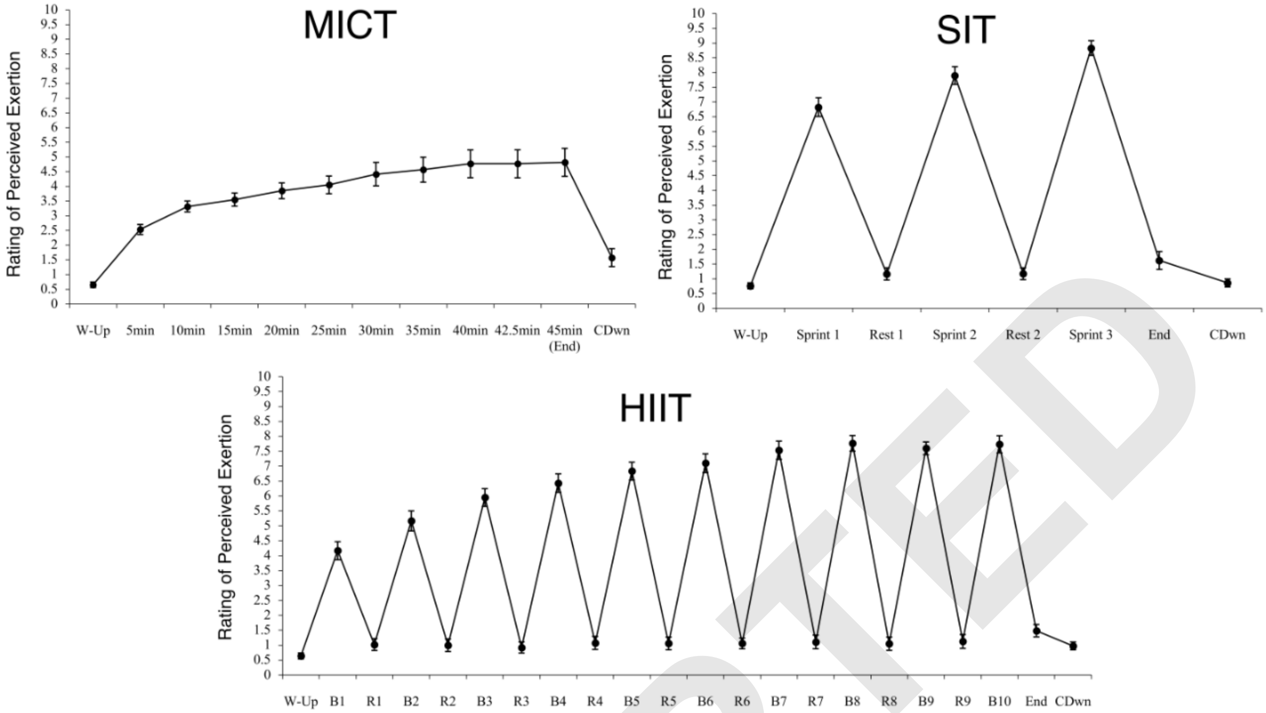

900
800
700
600
500
400
300
200
100
0
Power Output (Watts)
MICT
HIIT
SIT
10:00
20:00
30:00
40:00
50:00
Time (min)

Figure 2



MICT
Rating of Perceived Exertion
W-Up
5min
10min
15min
20min
25min
30min
35min
40min
42.5min
45min (End)
CDwn
SIT
Sprint 1
Rest 1
Sprint 2
Rest 2
Sprint 3
End
HIIT
B1
R1
B2
R2
B3
R3
B4
R4
B5
R5
B6
R6
B7
R7
B8
R8
B9
R9
B10

Figure 3

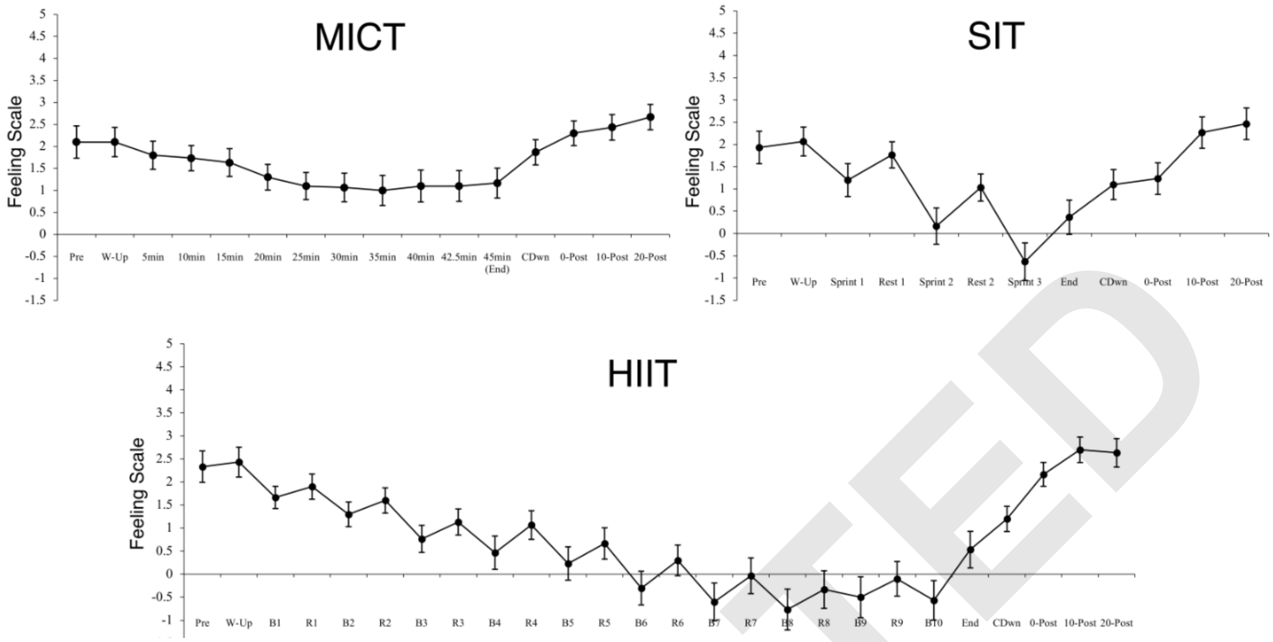

MICT
SIT
HIIT
Feeling Scale
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
Pre W-Up 5min 10min 15min 20min 25min 30min 35min 40min 42.5min 45min (End) CDwn 0-Post 10-Post 20-Post
Pre W-Up Sprint 1 Rest 1 Sprint 2 Rest 2 Sprint 3 End CDwn 0-Post 10-Post 20-Post
Pre W-Up B1 R1 B2 R2 B3 R3 B4 R4 B5 R5 B6 R6 B7 R7 B8 R8 B9 R9 B10 End CDwn 0-Post 10-Post 20-Post

Figure 4

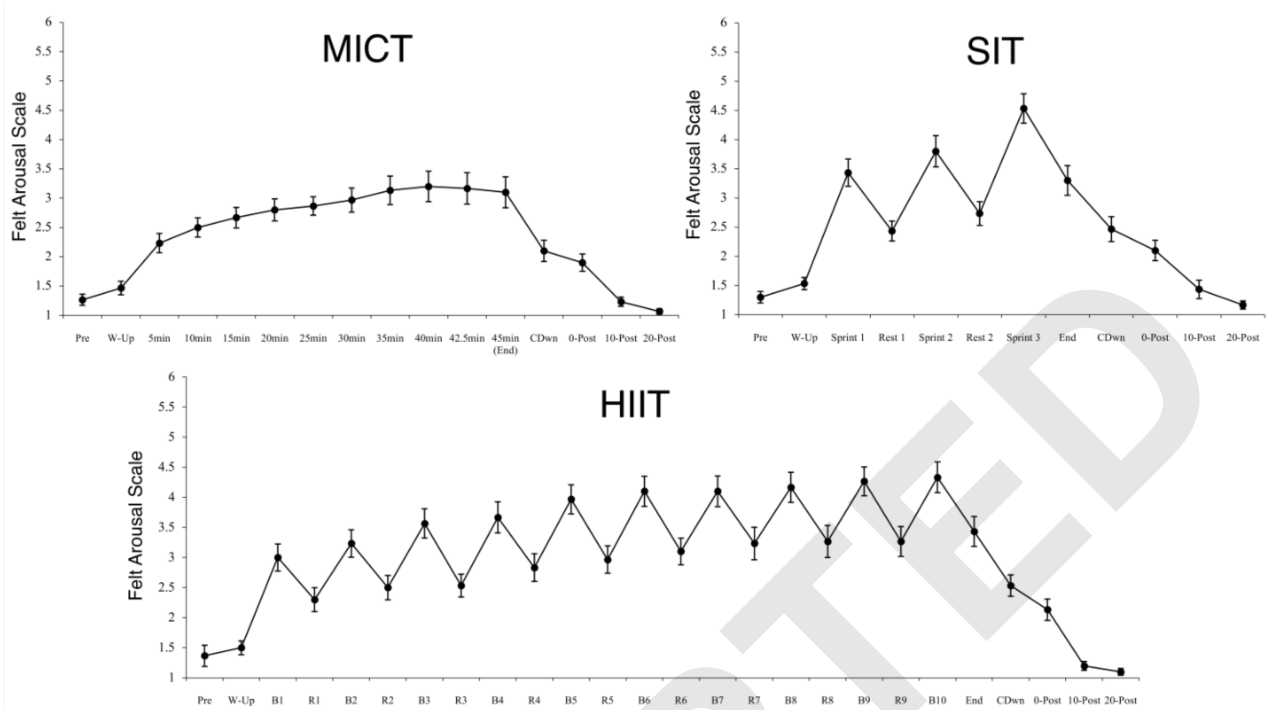

MICT
Felt Arousal Scale
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
Pre W-Up 5min 10min 15min 20min 25min 30min 35min 40min 42.5min 45min (End) CDwn 0-Post 10-Post 20-Post
SIT
Felt Arousal Scale
Pre W-Up Sprint 1 Rest 1 Sprint 2 Rest 2 Sprint 3 End CDwn 0-Post 10-Post 20-Post
HIIT
Felt Arousal Scale
Pre W-Up B1 R1 B2 R2 B3 R3 B4 R4 B5 R5 B6 R6 B7 R7 B8 R8 B9 R9 B10 End CDwn 0-Post 10-Post 20-Post

Table 1. Participant characteristics.

Variable	**Overall N=30**	**Females n = 18**	**Males n = 12**
Age (yr)	21.23 ± 3.81	21.06 ± 3.57	21.5 ± 4.30
Body mass (kg)	62.88 ± 11.20	57.85 ± 8.53	70.43 ± 10.71
Height (cm)	166.88 ± 7.54	161.94 ± 5.09	174.29 ± 3.19
BMI ($kg\text{-}m^{-2}$)	22.47 ± 3.02	22.04 ± 2.96	23.13 ± 3.10
HRmax (bpm)	183.90 ± 9.87	185.94 ± 7.70	180.83 ± 12.16
Wmax (watts)	195.70 ± 38.10	174.33 ± 20.46	227.75 ± 36.22
VO_2max ($mL\text{-}kg^{-1}\text{-}min^{-1}$)	31.3 ± 6.2	27.8 ± 3.3	36.5 ± 5.8

Note. Values are presented as mean ± SD.

Table 2. Effect sizes and 95% confidence intervals for comparisons between MICT, HIIT, and SIT conditions.

Measure Time Point	MICT – HIIT *d* [95% CI]	MICT – SIT *d* [95% CI]	HIIT – SIT *d* [95% CI]
RPE			
Work periods	1.64 [1.26, 2.01]**	2.28 [1.81, 2.74]**	0.80 [0.39, 1.21]**
%HRmax			
Work periods	2.32 [1.97, 2.67]**	1.10 [0.70, 1.49]**	1.06 [0.65, 1.46]**
FS			
Pre-task	0.12 [-0.14, 0.37]	0.08 [-0.16, 0.32]	0.20 [-0.08, 0.48]
Peak negative in-task	0.82 [0.43, 1.22]**	0.52 [0.07, 0.97]	0.29 [-0.07, 0.65]
Change score	0.77 [0.37, 1.16]**	0.39 [-0.02, 0.80]	0.38 [0.03, 0.74]
0-min post-exercise	0.09 [-0.34, 0.52]	0.59 [0.17, 1.01]*	0.53 [0.05, 1.01]
10-min post-exercise	0.17 [-0.19, 0.52]	0.09 [-0.23, 0.41]	0.24 [-0.10, 0.59]
20-min post-exercise	0.02 [-0.25, 0.29]	0.11 [-0.13, 0.35]	0.09 [-0.18, 0.36]
FAS			
Pre-task	0.13 [-0.29, 0.54]	0.06 [-0.22, 0.35]	0.08 [-0.34, 0.51]
Work periods	0.89 [0.47, 1.30]**	0.93 [0.46, 1.40]**	0.06 [-0.15, 0.28]
0-min post-exercise	0.25 [-0.21, 0.72]	0.22 [-0.11, 0.55]	0.03 [-0.37, 0.43]
10-min post-exercise	0.08 [-0.35, 0.50]	0.29 [-0.19, 0.76]	0.34 [-0.19, 0.86]
20-min post-exercise	0.12 [-0.42, 0.65]	0.30 [-0.15, 0.76]	0.19 [-0.20, 0.57]
PACES			
0-min post-exercise	0.04 [-0.39, 0.46]	0.11 [-0.26, 0.47]	0.15 [-0.30, 0.60]
Exercise Behavior			
4-week follow-up	0.56 [-0.01, 1.12]	1.34 [0.84, 1.84]**	0.60 [0.08, 1.11]

Note. Values are presented as *d* [95% CI]. *d* = Cohen's *d* effect size; 95% CI = 95% confidence interval of effect size; RPE = ratings of perceived exertion; %HRmax = percentage of heart rate maximum; FS = feeling scale; FAS = felt arousal scale; PACES = Physical Activity Enjoyment Scale. N=30 for all variables, except for exercise behavior (N=28) due to missing data. $^{*}p < 0.05$; $^{**}p < 0.01$.

Table 3. Correlations between affect, enjoyment, preferences, and behavior for MICT, HIIT and SIT.

MICT	1	2	3	4	5	*M*	*SD*
1. MICT most negative affect (FS)	-					0.27	1.76
2. MICT enjoyment (PACES)	0.47**	-				83.70	19.20
3. MICT preference (in lab)	0.00	-0.10	-			2.03	0.85
4. MICT preference (free time)	0.06	0.03	0.75**	-		1.73	0.83
5. MICT behavior (frequency)	0.40*	0.09	-0.15	-0.32	-	6.11	4.12

HIIT	1	2	3	4	5	*M*	*SD*
1. HIIT most negative affect (FS)	-					-1.47	2.30
2. HIIT enjoyment (PACES)	0.45**	-				84.43	18.47
3. HIIT preference (in lab)	-0.41*	-0.61**	-			1.93	0.91
4. HIIT preference (free time)	-0.25	-0.46**	0.68**	-		2.10	0.80
5. HIIT behavior (frequency)	0.13	0.12	0.05	0.22	-	3.54	4.23

SIT	1	2	3	4	5	*M*	*SD*
1. SIT most negative affect (FS)	-					-0.80	2.20
2. SIT enjoyment (PACES)	0.32*	-				81.63	18.78
3. SIT preference (in lab)	-0.47**	-0.50**	-			2.03	0.72
4. SIT preference (free time)	-0.38*	-0.34*	0.67**	-		2.17	0.79
5. SIT behavior (frequency)	0.15	0.17	-0.02	-0.18	-	1.39	1.85

Note. Correlations between variables 3 and 4 are based on one-tailed Spearman's correlation coefficients, while all other data are based on one-tailed Pearson's correlation coefficients. For exercise preferences, a lower ranking value represents a higher preference. N=30 for all correlations, except for those involving variable 5 (N=28) due to missing data. *$p < 0.05$; **$p < 0.01$.