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PHYSICAL ACTIVITY, HEALTH AND EXERCISE

Psychological responses to HIIT and MICT over a 2-week progressive randomized trial among individuals at risk of type 2 diabetes

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ABSTRACT

The purpose of this secondary analysis study was to examine the affective and social cognitive responses to low-volume high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT) over a progressive two-week supervised intervention for individuals at risk of type 2 diabetes. Ninety-nine adults that were low-active and overweight were randomized into one of two exercise conditions and had affective and social cognitive measures assessed before, during, and after intervention. Increases over time in post-exercise enjoyment, attitudes towards exercise, and intentions to exercise were noted for both HIIT and MICT conditions (ps <.05). The patterns of change in acute affective responses over the two-week intervention were consistent for both conditions, with participants in MICT reporting more positive in-task affect and affective attitudes throughout (ps <.001). Positive correlational relationships between affective and social cognitive responses were revealed throughout the intervention (ps <.05), highlighting the relationship between reflexive responses and reflective cognitions. Research is warranted to determine whether findings are a consequence of familiarization with exercise, whether such findings are translatable to real-world environments and non-progressive exercise protocols, and whether these reflexive responses and reflective cognitions are predictive of future exercise behaviour for individuals at risk of type 2 diabetes.

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By 2035, 592 million individuals worldwide are estimated to have type 2 diabetes (T2D) (Guariguata et al., 2014). T2D is a disease associated with numerous negative health outcomes including cardiovascular disease, neuropathy, and kidney failure (Papatheodorou et al., 2018). Given the potential personal and economic costs associated with the development of T2D, there is a need to identify individuals at high risk of T2D and mitigate their risk. Individuals not meeting current recommended physical activity guidelines (World Health Organization, 2010) are at greater risk of T2D (Walker et al., 2010), and lifestyle interventions including exercise have been shown to reduce the progression and risk of developing T2D (Knowler et al., 2002; Li et al., 2008; Lindstrom et al., 2003). There is evidence that high-intensity interval training (HIIT) may be a viable exercise option for individuals deemed to be at risk for T2D (Campbell et al., 2019; Jung et al., 2015; Locke et al., 2018). Although this initial evidence is promising, the use of HIIT for individuals not meeting physical activity guidelines remains hotly debated (Astorino & Thum, 2016; Biddle & Batterham, 2015; Del Vecchio et al., 2016; Hardcastle et al., 2014; Little et al., 2015; Stork et al., 2017; Oliveira et al., 2018). The current study is the first to examine psychological responses to HIIT for individuals participating in a diabetes risk reduction programme.

Psychological theories of behaviour change provide a framework to understand and predict exercise. Dual process and social cognitive theories are two broad classes of theories that have been used to explain HIIT engagement insofar as they explain the role of different types of cognitions that predict engagement. According to hedonic theory (e.g., dual-mode model; Ekkekakis, 2003), individuals are likely to experience more displeasure during HIIT (performed at intensities at/above ventilatory threshold [VT]) when compared to traditional moderate-intensity continuous training (MICT; performed at intensities below VT) due to greater activation of affective centres of the brain during exercise performed at/above VT. As such, individuals are thought to be more likely to experience negative affective responses during HIIT and less likely to subsequently engage in HIIT in the future. While hedonic theory emphasizes the role of *reflexive* affective valuations in exercise adherence, social cognitive theories underscore the role of *reflective* self-regulatory cognitions (Bandura, 1986). For example, attitudes are theorized to influence exercise behaviours by strengthening intentions (Ajzen, 1985). Dual-process theories such as dual-mode model and more recently, the Affective-Reflective Theory (Brand & Ekkekakis, 2018), also acknowledge the important role of social cognitions. Ultimately, a combination of both type 1 (reflexive) and type 2 (reflective) processes are thought to be involved in determining whether an individual decides to engage in exercise in the future.

In recent reviews of the psychological responses to interval exercise (Stork et al., 2017; Oliveira et al., 2018), in-task affect during acute exercise (i.e., type 1 processes) tended to be similar or more negative during interval exercise in comparison

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to continuous exercise. Despite this, post-exercise measures of enjoyment and preferences for HIIT-based exercise (i.e., type 2 processes) were equal or greater than for MICT (Crisp et al., 2012; Thum et al., 2017), and individuals were able to develop and maintain more positive social cognitions towards interval exercise following participation in such protocols (e.g., Jung et al., 2014). Further, there is mixed acute evidence regarding the psychological responses to HIIT and MICT, whereby in-task affective valence has been found to be significantly correlated with post-exercise enjoyment for both HIIT and MICT in some studies (e.g., Decker & Ekkekakis, 2017; Greene et al., 2018; Stork et al., 2018) but not others (e.g., Farias-Junior et al., 2019; Olney et al., 2018).

In a study by Astorino et al. (2016), twenty-three women with low baseline activity levels completed 12 weeks of supervised HIIT on a cycle ergometer three times per week. In-task affective responses to HIIT remained unchanged following the training intervention despite a progressive increase in exercise workload (6 to 10 work intervals at intensities ranging from 60 to 90% of maximal wattage). Similarly, another study (Vella et al., 2017) found that post-exercise enjoyment remained high and unchanged over the course of 8 weeks of HIIT (10 x 1 min bouts at ~75–80% heart rate reserve) or MICT (20 min at ~55–59% of heart rate reserve), with no differences between those in the HIIT and MICT conditions. In a study by (Heisz et al., 2016), a sample of men and women with low activity levels at baseline were randomly assigned to complete 6 weeks of HIIT (10 x 1 min at ~90–95% of maximum heart rate [HR_{max}]) or MICT (27.5 min at ~70–75% HR_{max}) group cycling three times per week on average. Post-exercise enjoyment was found to increase significantly over the course of the 6 weeks for those who completed HIIT, whereas enjoyment for MICT did not change. It should be noted however, that the exercise sessions were completed in a group setting and were not progressive in nature (i.e., the exercise protocol remained unchanged).

While the aforementioned studies provide an initial understanding of the affective and social cognitive responses to HIIT and MICT, these studies failed to examine all of the mentioned psychological responses together within the same study over multiple progressive exercise sessions. Evaluating in-task affect and exercise cognitions within the same study would allow for a more comprehensive evaluation of how these constructs are related, how people experience progressive HIIT and MICT, and what implications this may have for future behaviour. Additionally, assessing these measures over multiple training sessions as opposed to an acute session of HIIT and/or MICT permits the investigation of any reported potential changes in these constructs over the course of a progressive supervised exercise programme. Considering that current recommendations outline the necessity of progressive overload in exercise protocols for improvement (Slade et al., 2016), and the fact that some HIIT interventions (including ours) are using a progressive exercise format (i.e., starting with 4 intervals and progressing to 6 intervals; Astorino et al., 2016; Saanijoki et al., 2018), detecting potential changes in affective and social cognitive responses as workload increases over time could also have implications for future exercise behaviour.

Taken together, the purpose of this secondary analysis was to explore differential affective and social cognitive responses to low-volume HIIT and MICT over a progressive two-week supervised intervention among individuals undergoing a diabetes risk factor reduction programme. This was the first study to simultaneously assess affect, enjoyment, attitudes, and intentions in response to HIIT and MICT, and to evaluate potential changes to these constructs over the course of multiple progressive exercise sessions completed over time.

Considering previous evidence (Stork et al., 2017; Oliveira et al., 2018), we hypothesized that in-task affect would be less pleasurable during HIIT in comparison to MICT, but enjoyment of HIIT would be greater than MICT. Based on previous evidence of the changes in affective responses over the course of multiple training sessions (Astorino et al., 2016), it was hypothesized that in-task affective responses would remain unchanged across the 10 HIIT or MICT sessions. Consistent with existing evidence (Heisz et al., 2016; Vella et al., 2017), we also hypothesized that post-exercise enjoyment would remain unchanged or increase over time for both HIIT and MICT. Given that this exercise intervention incorporated an exercise counselling component (Bourne, Ivanova et al., 2019) designed to enhance social cognitions, and considering preliminary previous evidence (Stork & Martin Ginis, 2017), we hypothesized that participants' attitudes and intentions towards HIIT and MICT would increase over time. Finally, based on previous research, it was hypothesized that in-task affect would be significantly correlated to post-exercise enjoyment for each type of exercise (Decker & Ekkekakis, 2017; Greene et al., 2018; Stork et al., 2018) and that instrumental and affective attitudes would be positively correlated with intentions to exercise (Bandura, 1986).

Materials and methods

Inclusion criteria

Potential participants for this trial were recruited through paper and online ad postings in the community (e.g., posters in community centres, coffee shops, online advertisements). Of those who showed interest, eligible participants were between the ages of 30 and 65 years and were considered to be at increased risk of developing T2D because they were 1) insufficiently active (i.e., engaged in two or fewer bouts of moderate and/or vigorous aerobic exercise per week in the last 6 months; Rodgers & Gauvin, 1998) and were not meeting recommended physical activity guidelines (World Health Organization, 2010), and 2) had a body mass index (BMI) between 25 and 40 kg/m^2. Potential participants below 30 years of age and above 65 years of age were excluded from this trial as these age groups have different risk factors for the development of T2D and different physiological responses to exercise. Participants were cleared to engage in vigorous exercise using the Physical Activity Readiness Questionnaire-Plus (PAR-Q+; Warburton et al., 2011).

Study design

The protocol of this registered trial (ClinicalTrials.gov # NCT02164474) is published elsewhere (Bourne, Little et al., 2019). Since this is a secondary analysis paper of the main randomized trial, specific attention to the exercise training protocol is presented here along with an overview of the methods used to measure and analyse the psychological responses of interest. A two-arm parallel group randomized design was used for this study whereby participants not meeting physical activity guidelines and overweight were randomized to performing either low-volume HIIT or MICT for the duration of the *Small Steps for Big Changes* intervention. Briefly, *Small Steps for Big Changes* was a 2-week community-based diabetes prevention programme developed to be feasible to implement in community settings. Although landmark diabetes prevention programmes that are longer in duration (i.e., Knowler et al., 2002; Li et al., 2008; Lindstrom et al., 2003) have been shown to be efficacious in promoting behaviour change, the effectiveness of translating such programmes into community settings has proven difficult due to time and cost constraints. Thus, *Small Steps for Big Changes'* design allows for reduced researcher and participant burden, and evidence of its effectiveness is published elsewhere (Jung et al., 2020).

Randomization was computer-generated (SAS PROC PLAN) by a blinded external statistician with a 1:1 allocation ratio to each condition using permutated blocks of random size and stratified for sex. The intervention consisted of two phases: (a) a 2-week exercise training and counselling phase, and (b) a 12-month follow-up phase for assessments only. For the purpose of this paper, we focus on the psychological responses to exercise during the 2-week training phase. All work conducted as part of this trial received ethical approval from the institutional research ethics board to which the authors are affiliated.

Supervised exercise training

All participants were to engage in 10 exercise sessions over the training period: seven of the sessions were supervised in the laboratory (lasting approximately 30–60 minutes), and three sessions were to be conducted independently by participants at home to foster independence and self-management. Sessions were conducted Monday to Friday with Saturday and Sunday as rest days. Each supervised session consisted of an exercise component (i.e., low-volume HIIT or MICT) and 10 minutes of exercise counselling. To encourage autonomy, participants self-selected the exercise format in their given exercise modality for four of the supervised sessions (i.e., stationary cycling, treadmill walking, elliptical machine, or outside walking). During sessions when in-task outcome measures were being collected (sessions 1, 6, and 10), exercise modality was standardized to stationary indoor cycling. The exercise prescriptions for each condition were progressive in nature (see Figure 1) and matched for estimated external work based on heart rate responses to cycle ergometry seen in past work (Little

High Intensity Interval Training*	Training Day	Continuous Moderate Intensity Training+
4 intervals	Day 1$_a$	20 minutes
5 intervals	Day 2$_b$	29 minutes
6 intervals	Day 3$_c$	33 minutes
Home day 6 intervals prescribed	Day 4$_c$	Home day 33 minutes prescribed
7 intervals	Day 5$_c$	36 minutes
8 intervals	Day 6$_a$	40 minutes
Home day 8 intervals prescribed	Day 7$_c$	Home day 40 minutes prescribed
9 intervals	Day 8$_c$	43 minutes
Home day 9 intervals prescribed	Day 9$_c$	Home day 43 minutes prescribed
10 intervals	Day 10$_a$	50 minutes

Figure 1. Two-week intervention exercise prescription (Bourne, Little et al., 2019). Exercise format: $_a$ stationary bike; $_b$ outdoor walking (hills for HIIT, flat for MICT); $_c$ participant choice (includes stationary bike, treadmill, elliptical, outdoor walking). * One high-intensity interval consisted of 1 minute at ~77–95% of maximum heart rate followed by 1 minute at ~60% of maximum heart rate. + Moderate-intensity continuous exercise consisted of continuous exercise at ~64–76% of maximum heart rate.

		Supervised Exercise Training									
TIMEPOINTS	Baseline	Day 1	Day 2	Day 3	H	Day 5	Day 6	H	Day 8	H	Day 10
High intensity interval training											
Moderate intensity continuous training											
Demographics	X										
Exercise enjoyment		X									X
Affective & Instrumental Attitudes	X	X					X				X
In-Task Affect		X					X				X
In-Task RPE		X					X				X
Intention to exercise		X									X

Figure 2. Timeline for the Small Steps for Big Changes schedule of assessments throughout the 10-day structured exercised protocol. RPE = ratings of perceived exertion.

et al., 2011, 2014). Target heart rate zones were calculated for each participant based on maximum heart rates achieved during a maximum rate of oxygen consumption test (VO_{2max}), and participants were instructed to exercise at their target zones in accordance to their assigned group. For the three home-based exercise days, participants were instructed to measure exercise intensity as taught within the supervised training days, specifically, by the "talk-test" and/or rating of perceived exertion (RPE). The exercise protocols were pilot tested, and initial findings suggested that individuals not meeting physical activity guidelines and overweight or obese responded favourably to the training protocol (Jung et al., 2015; Locke et al., 2018).

High-intensity interval training protocol

The low-volume HIIT protocol involved sessions progressing from 4 to 10 1-min high-intensity intervals (cycling, treadmill walking, outdoor walking, or elliptical machine) at ~77–95% of HR_{max} interspersed with one-minute rest periods at ~60% of HR_{max}. A 3-min warm-up and 2-min cool-down at a self-selected light intensity was included with each HIIT session.

Moderate-intensity continuous training protocol

The MICT protocol involved sessions progressing from 20 to 50 min of continuous moderate-intensity exercise (cycling, treadmill walking, outdoor walking, or elliptical) at ~64–76% of HR_{max}. This prescription of MICT matches the progression of HIIT (% increase over time) and modelled the exercise programme that has been shown to prevent the progression of prediabetes to T2D (i.e., primarily walking; Knowler et al., 2002). An intensity of ~64–76% HR_{max} approximates brisk walking among individuals who are insufficiently active (Garber et al., 2011; Houmard et al., 2004), has been shown to improve cardiometabolic health in several large trials (Bajpeyi et al., 2009; Di Loreto et al., 2005), and aligns with the classification for moderate-intensity exercise by the American College of Sports Medicine (American College of Sports Medicine, 2018).

Brief exercise counselling

Behavioural counselling content was identical for each condition. A detailed description of the behaviour change techniques and the social cognitive mechanisms of change targeted in *Small Steps for Big Changes* are reported elsewhere (Bourne, Ivanova et al., 2019). Counselling sessions occurred after each of the supervised exercise sessions and had two primary goals. The first goal was to enhance individuals' confidence to perform their given exercise modality by providing opportunity to practice engaging in the exercise with feedback and helping participants identify physiological cues (e.g., heart rate responses, ability to talk) associated with the assigned exercise intensity. The second goal was to enhance participants' confidence to self-manage exercise by providing opportunities to practice exercise planning and self-monitoring, to work through exercise barriers, and to practice independent exercise (i.e., at-home exercise).

Measures

A visual depiction of the schedule of assessments for outcome measures can be found in Figure 2. Heart rate (HR), in-task affect, and ratings of perceived exertion (RPE) were measured during exercise on training days 1, 6, and 10. For both HIIT and MICT conditions, in-task measures were taken at times corresponding to 25, 50, 75 and 100% of exercise completion. For participants randomized to HIIT, this coincided with all intervals on day 1, intervals 2, 4, 6 and 8 on day 6, and intervals 2, 5, 8 and 10 on day 10. Measures were taken during the last 15 s of the given high-intensity interval, as recommended by previous work (Decker & Ekkekakis, 2017; Stork et al., 2017). Post-exercise enjoyment and intentions to exercise were measured 5 to 10 min post-exercise on the first and last days of supervised training, while instrumental and affective attitudes towards exercise were measured before the commencement of the intervention, and 5 to 10 min post-exercise on days 1, 6, and 10 of the supervised training.

Demographics

Age, anthropometrics, VO_{2peak}, sex, ethnicity, education level, marital status, occupation, and household annual income were collected at the baseline appointment.

Heart rate

HR information was collected during the supervised exercise sessions using a HR monitor (Polar H10). Second-by-second data were used to determine participants' HR at each of the specified data points.

Perceived exertion

RPE was assessed using Borg's CR-10 (Borg, 1998) which ranges from 0 (nothing at all) to 10 (absolute maximum). Participants were presented with a hardcopy of the scale and asked to rate their RPE immediately following their in-task affect rating.

In-task affective responses

In-task affect valence was assessed using the Feeling Scale (FS) (Hardy & Rejeski, 1989). Participants were asked, "please tell me how you feel at this current moment using the scale below" on an 11-point Likert scale ranging from −5 (very bad) to +5 (very good). Given the fluctuations in FS scores observed during HIIT protocols (e.g., Decker & Ekkekakis, 2017; Stork et al., 2018, 2015), the magnitude of the peak negative affect score was used as our main measure of in-task affect for this study. Peak negative affect was calculated by determining each participant's lowest FS score at any time point in-task for that specific day of training for both MICT and HIIT conditions. Separate analyses were also conducted using average FS scores and end-point FS scores, with findings being effectively the same as peak negative FS scores. Due to these similarities, and considering previous research (Stork et al., 2018), peak negative affect was deemed to be the most meaningful outcome to report.

Post-exercise enjoyment

The physical activity enjoyment scale (PACES; Kendzierski & De Carlo, 1991) was used to measure participants' enjoyment of their prescribed exercise. The PACES has 18 different word pairs (e.g., enjoy-hate, bored-interested) that were rated on a 7-point bipolar scale ranging from 1 to 7. Eleven negatively worded items were reverse scored, and all 18 items were summed to produce an overall score ranging from 18 to 126. The scale demonstrated strong reliability (αs > .95).

Affective and instrumental attitudes

Participants' affective and instrumental attitudes towards exercise were measured using a study-specific tool that was adapted from (Conner et al., 2011). Participants responded to 13 pairs of words on a seven-point scale ranging from 1 to 7. Word pairings varied depending on the subscale; for affective attitudes, word pairings related to the emotional perception of the consequences of exercise (e.g. not enjoyable-enjoyable). For instrumental attitudes, word pairings related to the perceived costs and benefits of engaging in exercise (e.g., useful-useless). The instrumental (αs > .90) and affective (αs > .72) subscales demonstrated acceptable reliability.

Intentions to exercise

Intentions to exercise was assessed using a one-item question developed for this study. Participants were asked, "How likely is it that you will perform HIIT/MICT (made condition specific) at least three times a week in the next 4 weeks?" Participants responded on a 9-point scale ranging from 1 (not likely at all) to 9 (very likely).

Statistical analyses

Shapiro Wilk's tests were used to assess normality, and Levene's tests were used to assess equality of variances for each outcome variable. Means and standard deviations were calculated separately by condition for baseline measures and each outcome variable. Separate Group x Time mixed-model repeated-measures ANOVAs were used to detect between- and within-group differences throughout the 2-week exercise intervention. For outcome variables that had an established relationship in prior literature (i.e., affective and instrumental attitudes [Kendzierski & De Carlo, 1991]), a two-condition (HIIT vs. MICT) repeated-measures multivariate analysis of variance (MANOVA) was used (Huberty & Morris, 1989) and significant *F* tests were followed by subsequent mixed-model ANOVAs. When significant main effects were detected, Bonferroni-corrected pairwise comparisons were used to detect between- and within-group differences. Two-tailed Pearson's correlation coefficients were calculated to determine potential relationships between outcome variables. An alpha level of .05 was set for all statistical analyses, and all analyses were conducted using SPSS (version 24).

Results

Participants

One hundred and ten individuals not meeting physical activity guidelines with overweight or obesity were recruited for this trial and randomly allocated to either low-volume HIIT (n = 55) or MICT (n = 55) prior to commencing any baseline testing. Of those who were randomized, 99 participants took part in the exercise intervention (HIIT = 47, MICT = 52). A total of 11 participants who were randomized did not receive their allocated intervention due to being found ineligible during baseline testing, injury prior to commencing training, and/or dropped out/did not show up for the training intervention. Of the 99 participants who took part in the intervention, 4 participants allocated to the HIIT group did not complete all sessions of the intervention, and 3 participants allocated to the MICT group did not complete all sessions of the intervention. Reported reasons for non-completion included knee injury unrelated to the study, myocardial infarction, and persistent cramps (please see Jung et al., 2020 for the study Consort diagram). Demographic information can be found in Table 1. Participants were, on average, 50.90 years of age (*SD* = 9.40), predominantly female, and 88.9% self-identified as Caucasian.

Descriptive statistics and assumption testing

Means and standard deviations for HIIT and MICT conditions were calculated for each outcome variable (Tables 2 and 3). Data were normally distributed (Shapiro Wilks $p > .05$). Levene's test for the equality of variances revealed significant differences for in-task affective responses and intentions to exercise ($p < .05$). Given the robustness of the analysis used, ANOVAs were still used for within- and between-group comparisons of these variables (Kirk, 2013). In cases where sphericity was violated, Greenhouse-Geisser values were used to interpret univariate test results.

Compliance to prescribed exercise intensity

Compliance to exercise intensity for those in the HIIT and MICT conditions for sessions 1, 6, and 10 was measured via percentage of HR_{max} (%HR_{max}) as well as RPE and can be found in Table 4. Overall, participants averaged 87.5 (*SD* = 6.12), 89.9 (*SD* = 4.50), and 87.5 (*SD* = 4.79) %HR_{max} during the HIIT intervals for training days 1, 6, and 10, respectively. Participants averaged 67.4 (*SD* = 3.84), 69.5 (*SD* = 5.02), and 68.4 (*SD* = 5.05) %HR_{max} during the bouts of exercise of the MICT training

Table 1. Baseline demographic information.

	HIIT (n = 47)	MICT (n = 52)
Age in years, mean (SD)	51.8 (8.80)	50.0 (9.90)
Height in cm, mean (SD)	168.2 (7.66)	168.4 (9.07)
Weight in kg, mean (SD)	89.4 (21.67)	89.3 (19.32)
BMI in kg/m^2, mean (SD)	31.4 (6.6)	31.4 (5.9)
Waist circumference in cm, mean (SD)	108.4 (15.67)	107.6 (14.72)
VO_{2max} in mL/kg/min, mean (SD)	22.7 (4.95)	23.0 (6.44)
MVPA10+ in weekly minutes, mean (SD)	31.33 (45.77)	40.61 (55.71)
Sex		
Female, n (%)	33 (71.7%)	36 (70.6%)
Male, n (%)	13 (28.3%)	15 (29.4%)
Ethnicity		
Caucasian, n (%)	41 (87.2%)	47 (90.4%)
Native American, n (%)	1 (2.1%)	1 (1.9%)
Asian, n (%)	2 (4.2%)	1 (1.9%)
Latin American, n (%)	1 (2.1%)	1 (1.9%)
Other, n (%)	1 (2.1%)	1 (1.9%)
Missing, n (%)	1 (2.1%)	1 (1.9%)
Highest Education		
High School, n (%)	8 (17%)	5 (9.6%)
College/university certificate, n (%)	31 (65.9%)	36 (69.3%)
Post-graduate degree, n (%)	6 (12.8%)	10 (19.2%)
Missing, n (%)	2 (4.3%)	1 (1.9%)
Marital Status		
Married, n (%)	37 (78.7%)	35 (67.3%)
Common-law, n (%)	1 (2.1%)	4 (7.7%)
Single, n (%)	8 (17.1%)	12 (23.1%)
Missing, n (%)	1 (2.1%)	1 (1.9%)
Occupation		
Full-time, n (%)	31 (66%)	32 (61.5%)
Part-time, n (%)	6 (12.8%)	8 (15.4%)
Unemployed/Student, n (%)	9 (19.1%)	11 (21.2%)
Missing, n (%)	1 (2.1%)	1 (1.9%)
Annual Income		
$0-$49,999, n (%)	5 (10.6%)	10 (19.2%)
$50,000-$99,999, n (%)	22 (46.8%)	16 (30.8%)
$100,000-$150,000, n (%)	14 (29.9%)	19 (36.6%)
$150,000+, n (%)	5 (10.6%)	6 (11.5%)
Missing, n (%)	1 (2.1%)	1 (1.9%)

Where applicable, data are shown as mean (SD) or n (%). BMI = body mass index; VO_{2max} = maximum rate of oxygen consumption; MVPA10+ = purposeful moderate-to-vigorous physical activity in bouts of 10 minutes or more; HIIT = high-intensity interval training; MICT = moderate-intensity continuous training.

sessions for training days 1, 6, and 10, respectively. In regard to RPE, participants who performed HIIT scored on average 5.28 (*SD* = 1.29), 5.69 (*SD* = 1.48), and 6.30 (*SD* = 1.29) for training days 1, 6 and 10, respectively, while participants who performed MICT scored on average 3.02 (*SD* = 1.18), 3.41 (*SD* = 1.02), and 3.65 (*SD* = 1.16).

Primary outcome analyses

Acute affective responses

Using a 2 × 3 mixed-model ANOVA, a significant main effect of time [$F(2, 192) = 5.45$, $p = .005$, $\eta^2 = .05$] and group [$F(1, 96) = 17.39$, $p < .001$, $\eta^2 = .15$] were observed, with participants in HIIT demonstrating significantly lower peak negative affective responses to their respective exercise protocol than participants in MICT across all 3 days. No interaction effect was noted ($p > .05$), suggesting a similar pattern of change for both conditions. Within-subject pairwise comparisons revealed that peak negative affective responses significantly decreased from day 6 of training to day 10 of training ($p = .003$), with no differences between day 1 and day 10 ($p > .05$) for both conditions (Figure 3(a)).

Post-exercise enjoyment

A 2 × 2 mixed-model ANOVA revealed a significant main effect of time [$F(1, 89) = 30.05$, $p = .001$, $\eta^2 = .25$] on post-exercise enjoyment, with scores similarly increasing from day 1 to day 10 for both conditions (Figure 3(b)). No between-group differences were found ($p > .05$).

Instrumental and affective attitudes

Given the well-established relationship between instrumental and affective attitudes (Conner et al., 2011), a 2 × 4 repeated measures MANOVA was conducted across these two measures. Results revealed a significant 3-way

Table 2. Correlations between in-task affect, post-exercise enjoyment, instrumental attitudes, affective attitudes, and intentions for HIIT (n = 47).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	M	SD
1. Day 1 Peak Negative Affect	–															0.85	2.2
2. Day 6 Peak Negative Affect	.543**	–														1.21	2.1
3. Day 10 Peak Negative Affect	.560**	.626**	–													0.65	2.6
4. Day 1 Enjoyment	.281	.186	.113	–												92.47	15.6
5. Day 10 Enjoyment	.179	.154	.354*	.543**	–											102.52	17.5
6. Pre-Training IA	.164	.124	−.210	.038	−.063	–										5.81	1.0
7. Day 1 IA	.122	.281	.083	.467**	.321*	.319*	–									6.46	0.8
8. Day 6 IA	−.117	.156	−.006	.337*	.487**	.256	.682**	–								6.72	0.6
9. Day 10 IA	−.149	.072	−.084	.254	.404**	.239	.648**	.888**	–							6.69	0.5
10. Pre-Training AA	.147	.314*	.101	−.078	.083	.478**	.223	.108	.114	–						4.70	1.2
11. Day 1 AA	.276	.364*	.252	.623**	.623**	.272	.689**	.626**	.582**	.261	–					5.29	1.0
12. Day 6 AA	.168	.456**	.291	.415**	.635**	.143	.477**	.592**	.579**	.304*	.690**	–				5.68	1.0
13. Day 10 AA	.037	.327*	.201	.408**	.655**	.079	.388**	.621**	.665**	.168	.689**	.866**	–			5.79	0.9
14. Pre-Training Intentions	−.032	−.039	−.090	.247	.191	.308*	.237	.327*	.209	.328*	.448**	.245	.153	–		6.41	2.9
15. Post-Training Intentions	−.088	−.227	−.075	.223	.180	−.093	.068	.098	.122	−.039	.204	.102	.074	.439**	–	8.57	0.8

Correlations are based on two-tailed Pearson's correlation coefficients. M = means; SD = standard deviations; IA = instrumental attitudes; AA = affective attitudes.
* $p < .05$.
** $p < .01$.

interaction between time, group, and measure [$F(6, 87) = 2.36$, $p = .037$, $\eta^2 = .14$]. Decomposition of this interaction was conducted via a 2 × 2 mixed-model ANOVA for each outcome.

Instrumental attitudes. A significant 2-way interaction between time and group was observed [$F(6, 87) = 2.356$, $p = .037$, $\eta^2 = .14$]. Within-group pairwise comparisons showed significant increases in instrumental attitudes for participants in HIIT at each time point ($p < .05$), with the exception of day 6 to day 10 (Figure 3(c)). A similar effect was also observed for participants in the MICT condition, with increases in instrumental attitudes observed as the intervention progressed, except from pre-training to day 1 and from day 6 to day 10 ($p > .05$). Between-group pairwise comparisons showed that instrumental attitudes for those in the MICT condition was significantly higher than for those in the HIIT condition at pre-intervention only ($p = .003$).

Affective attitudes. Significant main effects of time [$F(3, 276) = 24.93$, $p < .001$, $\eta^2 = .213$] and group [$F(1, 92) = 11.76$, $p = .001$, $\eta^2 = .113$] were observed, with participants in MICT reporting higher affective attitudes than those in HIIT throughout the intervention. Pairwise comparisons revealed that affective attitudes consistently increased for those in both conditions, with the exception of day 6 to day 10 ($p > .05$; Figure 3(d)).

Intentions to exercise

Using a 2 × 2 mixed-model ANOVA, a significant main effect of time was found [$F(1, 93) = 54.95$, $p < .001$, $\eta^2 = .371$], indicating that participants' intentions to exercise increased from pre- to post-intervention in both conditions (Figure 3 (e)). No interaction effect or between-group differences were found ($p > .05$).

Correlations

Relationships between outcome variables were explored using Pearson's correlation coefficients for the HIIT (Table 2) and MICT (Table 3) conditions. For participants randomized to HIIT, in-task affect on day 10 was positively correlated to post-exercise enjoyment on day 10 ($p < .05$), and in-task affect on day 6 was positively correlated to affective attitudes on day 6 of training ($p < .01$). Post-exercise enjoyment scores were positively correlated to both instrumental and affective attitudes at the beginning and conclusion of training, respectively ($ps < .01$), but were not correlated with intentions to exercise ($ps > .05$). Pre-training instrumental and affective attitudes were positively correlated with pre-training intentions to exercise ($ps < .05$), but attitudes and intentions were not correlated at the conclusion of the intervention ($ps > .05$).

For those randomized to the MICT condition, in-task effect responses were significantly positively correlated to post-exercise enjoyment ($ps < .01$) and affective attitudes ($ps < .05$) throughout the intervention, as well as instrumental attitudes on day 1 of training ($p < .05$). Post-exercise enjoyment was correlated with instrumental and affective attitudes at the beginning and conclusion of training, respectively ($ps < .01$). Day 10 post-exercise enjoyment was correlated with post-training intentions to exercise ($p < .01$). Further, instrumental and affective attitudes at the conclusion of training were correlated with post-training intentions ($ps < .01$). Finally, for participants in both groups, instrumental and affective attitudes were significantly positively correlated throughout the intervention ($ps < .01$).

Overall, in-task affect was more frequently correlated to social cognitions for those in the MICT condition compared to those in the HIIT condition. For participants in both HIIT and MICT conditions, there were significant positive correlations between post-exercise enjoyment and attitudes towards their respective exercise modality. Further, enjoyment of MICT was associated with more positive intentions to engage in MICT, but

Table 3. Correlations between in-task affect, post-exercise enjoyment, instrumental attitudes, affective attitudes, and intentions for MICT (n = 52).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	M	SD
1. Day 1 Peak Negative Affect	–															2.27	1.5
2. Day 6 Peak Negative Affect	.544**	–														2.60	1.3
3. Day 10 Peak Negative Affect	.515**	.616**	–													1.96	1.7
4. Day 1 Enjoyment	.675**	.419**	.358**	–												90.98	18.5
5. Day 10 Enjoyment	.662**	.499**	.513**	.568**	–											101.53	20.3
6. Pre-Training IA	.054	.083	.118	.002	.215	–										6.38	0.8
7. Day 1 IA	.281*	.289*	.318*	.402**	.477**	.225	–									6.31	0.8
8. Day 6 IA	.225	.216	.252	.320*	.541**	.223	.413**	–								6.67	0.6
9. Day 10 IA	.277	.370**	.274	.406**	.600**	.337*	.559**	.771**	–							6.69	0.6
10. Pre-Training AA	.214	.083	.082	.141	.321*	.673**	.288*	.049	.232	–						5.42	0.9
11. Day 1 AA	.341*	.190	.109	.497**	.346*	.015	.338*	.259	.442**	.101	–					5.84	1.2
12. Day 6 AA	.492**	.413**	.380**	.576**	.687**	.191	.563**	.693**	.683**	.321*	.404**	–				5.99	0.9
13. Day 10 AA	.481**	.439**	.330*	.674**	.656**	.140	.557**	.514**	.674**	.324*	.381**	.823**	–			6.02	0.9
14. Pre-Training Intentions	−.107	.015	.025	.034	.118	.173	.272	.177	.148	.316*	.212	.162	.119	–		6.90	2.5
15. Post-Training Intentions	.421**	.181	.155	.363**	.474**	.025	.329*	.561**	.560**	.080	.339*	.621**	.601**	.037	–	8.70	0.5

Correlations are based on two-tailed Pearson's correlation coefficients. M = means; SD = standard deviations; IA = instrumental attitudes; AA = affective attitudes.
* p <.05.
** p <.01.

Table 4. Compliance to exercise intensity for HIIT (n = 47) and MICT (n = 52) during 2 weeks of supervised exercise training.

	Rating of Perceived Exertion								Heart Rate							
	25% session		50% session		75% session		100% session		25% session		50% session		75% session		100% session	
	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range
Day 1																
HIIT	4.17 (1.3)	2–7	5.30 (1.5)	3–8			6.36 (1.6)	3–10	79.34 (9.1)	60.1–94.2	90.7 (6.1)	68.3–100			92.53 (5.9)	67.1–100
MICT	2.45 (1.3)	.5–6	3.21 (1.2)	.5–7			3.39 (1.4)	.5–7	65.79 (4.6)	56.4–80.9	67.86 (4.2)	61.4–79.2			68.69 (4.5)	61.2–80.3
Day 6																
HIIT	4.11 (1.5)	0–9	5.81 (1.6)	3–10	6.37 (1.7)	3–10	6.48 (1.8)	3–10	86.23 (6.4)	69.9–96.4	89.43 (4.5)	80.4–96.7	90.89 (4.7)	82.2–98.8	93.06 (4.8)	83.9–100
MICT	3.36 (1.3)	.5–7	3.49 (1.1)	.5–7	3.46 (1.0)	.5–7	3.34 (1.1)	.5–7	67.18 (6.3)	56–88.5	69.17 (5.7)	59.9–86.2	70.63 (5.9)	60.9–88.4	70.83 (5.9)	62.4–88.4
Day 10																
HIIT	4.55 (1.5)	3–9	6.64 (1.6)	3–10			7.70 (1.6)	3–10	83.41 (6.8)	66.9–94.3	88.1 (4.7)	75.3–98.2			90.95 (4.4)	80.1–100
MICT	3.61 (1.3)	.5–7	3.75 (1.3)	.5–8			3.59 (1.1)	.5–7	66.8 (4.4)	58.9–78.4	68.91 (5.2)	58.2–83.1			69.38 (6.5)	55.7–87.8

Rating of perceived exertion ranges from 0–10; heart rate data is given in percentage of maximum heart rate. Where applicable, data are shown as mean (SD). HIIT = high-intensity interval training; MICT = moderate-intensity continuous training.

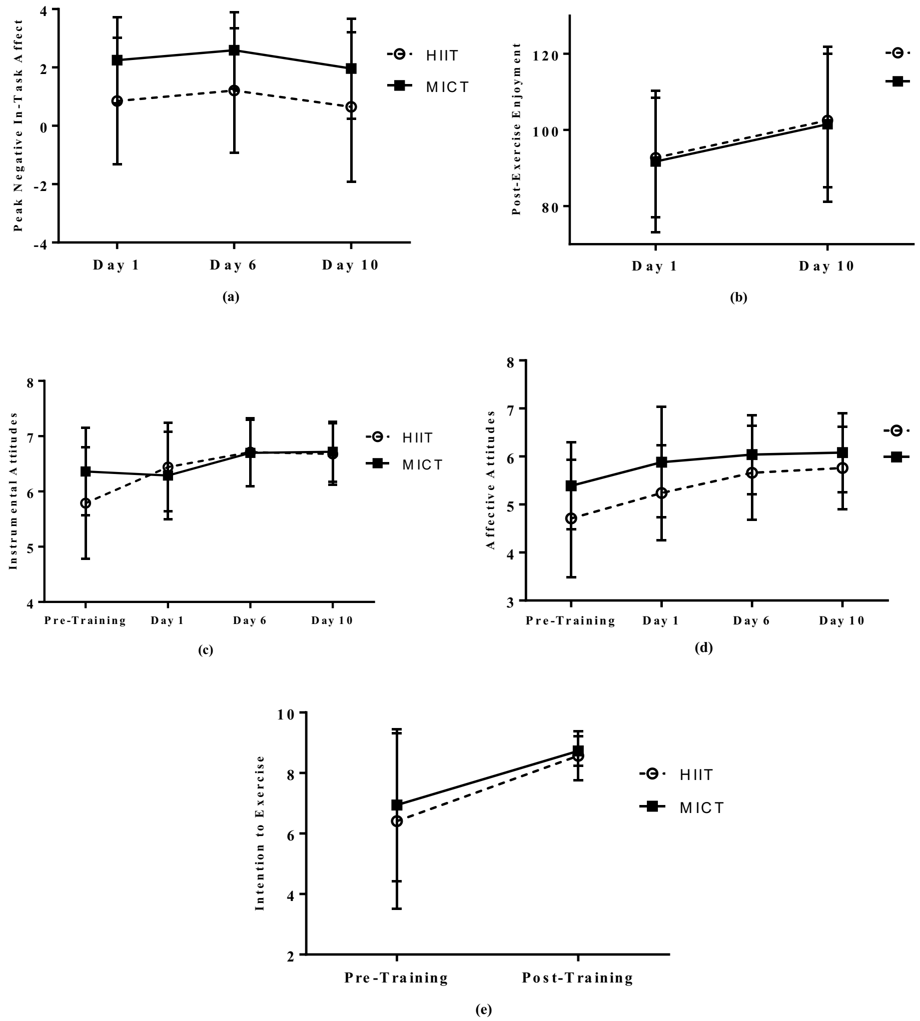

Figure 3. Means and standard deviations for participants in HIIT and MICT conditions throughout a 2-week progressive exercise intervention for (a) *Feeling Scale*, (b) *Post-Exercise Enjoyment*, (c) *Instrumental Attitudes*, (d) *Affective Attitudes*, and (e) *Intentions to Exercise*. HIIT = high-intensity interval training; MICT = moderate-intensity continuous training.

not for HIIT. Attitudes towards exercise were generally predictive of intentions to exercise for HIIT before the intervention, whereas attitudes were predictive of intentions to exercise for MICT after the intervention.

Discussion

The intensities and protocols associated with HIIT and MICT may differentially impact affective and social cognitive responses to short-term exercise. These responses to exercise are important to understand given their potential impact on exercise behaviour and the need for evidence to inform the ongoing debates in the field. While much of the literature examining acute responses to HIIT have examined responses to non-progressive protocols (e.g., single bouts of HIIT or MICT); this paper reports short-term changes that occurred over repeated sessions of supervised, progressive training in both exercise modalities.

The purpose of this study was to examine the affective and social cognitive responses to low-volume HIIT and MICT over a progressive 2-week supervised intervention. Our results indicate that, patterns of change in affective responses and social cognitions were similar over time for MICT and HIIT. Specifically, there were no significant changes in in-task affective responses from the first day of training to the last day of training within each of the two conditions, despite the progressive increase in exercise workload in both protocols. Exercise enjoyment, instrumental and affective attitudes, and intentions to exercise increased from baseline to day 10 with exposure to supervised training for both HIIT and MICT, with the exception of instrumental attitudes from baseline to day 1 of training and from day 6 to day 10 of training for MICT participants, where attitudes remained relatively stable.

Consistent with previous research and the study hypotheses, acute in-task affect was more pleasurable for those who engaged in MICT compared to HIIT (Jung et al., 2014; Kilpatrick et al., 2015; Martinez et al., 2015), with no significant changes in self-reported levels of pleasure experienced from their respective modality from day 1 to day 10 of the intervention. The finding that in-task affect scores did not become more negative from the start to end of the supervised training is also consistent with our hypotheses and in line with the only other study we are aware of that has examined changes in affect in HIIT as compared to MICT across multiple sessions (Astorino et al., 2016). A commonality in the current trial and Astorino and colleagues' (Astorino et al., 2016) is the progressive nature of the HIIT protocols. In the current study, HIIT progressed from four intervals on day 1 to 10 intervals on day 10, while the HIIT protocols in Astorino and colleague's study (Astorino et al., 2016) progressed from 6 intervals on week 1 to 10 intervals on week 12. Given the workload progressed each day of the intervention, these results suggest that individuals with low levels of baseline physical activity may not feel encumbered by continuously increasing volumes of prescribed exercise.

Consistent with our hypotheses, post-exercise enjoyment, instrumental and affective attitudes, and intentions to exercise significantly increased over the two-week training intervention for those in both conditions. It may be possible that repeated exposure to an exercise protocol in a supervised setting among individuals that are initially not meeting physical activity guidelines may promote increased enjoyment, attitudes towards exercise, and intentions to engage in future exercise. Indeed, some research has demonstrated this phenomenon (e.g., Vella et al., 2017). In addition to the supervised exercise, participants in this trial were exposed to brief (10 minutes per session) behaviour change exercise counselling (Bourne, Ivanova et al., 2019; Bourne, Little et al., 2019) that primarily targeted outcome expectations and self-efficacy. For example, participants were cued to pay attention to their physiological and affective states during exercise as a theoretically supported strategy (Bandura, 1986) to bolster their task self-efficacy to perform their prescribed exercise. Therefore, it is also plausible that exercise counselling alone, or in combination with exposure to exercise training, could have influenced attitudes and intentions. We are not aware of any current research that has explored this potential occurrence, and more research is needed to disentangle the effects of supervised progressive exercise training and behaviour change counselling on exercise-related enjoyment and social cognitions.

Mostly inconsistent with our hypothesis, but with some support from previous research (Decker & Ekkekakis, 2017; Greene et al., 2018; Stork et al., 2018), evidence of the relationship between in-task affect and post-exercise enjoyment was only present on day 10 for those randomized to the HIIT condition. In contrast, in-task affect and post-exercise enjoyment were far more correlated for those in the MICT condition throughout the intervention. Such results may indicate a stronger relationship between type 1 (reflexive) and type 2 (reflective) processes in MICT protocols compared to HIIT protocols. This may be due to the increased heterogeneity observed in affective responses to HIIT protocols, which is consistent with the notion that there is increased interindividual variability in affective responses during high-intensity exercise (i.e., within the zone of response variability [Ekkekakis, 2003]). Thus, it is possible that high variability in affective responses during HIIT subsequently reduced the likelihood of detecting relationships between type 1 and type 2 processes. Building off similar notions from Stork and colleagues (Stork et al., 2018), it is plausible that in-task affect during HIIT may be less predictive of other meaningful variables (e.g., social cognitions, future exercise behaviour) than in-task affect during MICT because of the unique fluctuations that occur during the work and rest periods of HIIT, as well as the increased variability in affective responses during high-intensity work bouts. In-task affect during MICT tends to decline predictably over time and be less variable (than what is observed during HIIT), which may explain why it tends to show stronger relationships with related variables. Extant research findings regarding the relationship between in-task affect and post-exercise enjoyment for HIIT and MICT protocols have been mixed (Decker & Ekkekakis, 2017; Farias-Junior et al., 2019; Greene et al., 2018; Stork et al., 2018; Olney et al., 2018), suggesting that even when individuals experience more negative reflexive responses (e.g., in-task affect) to HIIT, it does not necessarily mean that they will report negative reflective responses (e.g., enjoyment).

Strengths and limitations

To our knowledge, this was the first study to concurrently examine affect, enjoyment, attitudes, and intentions in response to HIIT and MICT, and to assess changes to such measures across multiple exercise sessions completed over time. By measuring both affective and social cognitive responses to HIIT and MICT in a controlled setting, it was possible to discern how these constructs are related and whether patterns of change differed over progressive training as participants became familiarized with their training modality. The prospective nature of the current study design also permitted a more comprehensive understanding of the psychological responses to these exercise modalities than studies examining a single bout of HIIT and MICT. Prospective examinations provide new insight into how such modalities can be effectively translated from a controlled laboratory environment into real-world community settings. Likewise, this study encouraged the translatability of the exercise programme into the real world by asking participants to complete three of their exercise sessions at home over the two-week intervention. Although not tracked in this study, future programmes should measure the completion rate of such home-based sessions to explore physical activity behaviour completed outside of the supervised setting and discern whether completion/non-completion has any impact on observed findings. Similarly, we were not able to record affective responses to exercise when participants exercised independently. As such, we were unable to discern what their affective experiences were like when exercising on their own, and whether such experiences influenced psychological responses during the standardized assessment days.

In attempts to minimize potential confounding factors of measurement, equipment and protocol variability, the in-task exercise measurements for days 1, 6, and 10 were taken within a controlled laboratory environment, increasing this study's internal validity. However, we acknowledge that having such a controlled environment diminishes external validity and its applicability to real-world, unsupervised exercise environments. The exercise protocols participants performed under the supervision of research staff may very well elicit different affective and social cognitive responses than exercise participants engaged in on their own. A limitation to the internal control of this study was participants' ability to self-select the exercise modality (e.g., treadmill, cycling) and environment (inside vs. outside) on four of the seven supervised days. This design feature fostered autonomy, which was necessary to help participants transition to self-managing exercise in free-living conditions following the structured training. However, it diminished our control over the setting that participants were performing their exercise and may have impacted their affective and social cognitive responses on subsequent days in which these variables were measured (Lahart et al., 2019).

It should also be noted that analyses performed for in-task affect were conducted using peak negative affect, which did not necessarily capture all nuanced changes in affect that may have occurred during the exercise protocols. In particular, the intermittent nature of HIIT has been shown to elicit experiences of alternating affect during intervals and rest periods (e.g. Decker & Ekkekakis, 2017). Novel explorations of in-task affect that account for the variation in affective responses that occur in HIIT and MICT are warranted, as well as consideration of the whole session experience. It should also be noted that although we took a conservative approach by using Bonferroni-corrected pairwise comparisons, there is always potential for a type 1 error when conducting multiple analyses on numerous outcome measures. Lastly, the study provided brief exercise counselling designed to enhance task and self-regulatory social cognitions in addition to the progressive training protocol. While this makes it impossible to parse apart the relative contributions of the exercise counselling and the progressive nature of the training protocol to improvements in social cognitions, it should be noted that each condition received identical counselling.

Future research

Considering this study's limitations, future research should examine whether patterns of affective and social cognitive responses to exercise are similar to exercise that is performed in free-living settings, such as public fitness facilities or home gyms. Future research could directly compare differences between progressive and non-progressive exercise protocols to elucidate the exact benefit of gradual exercise protocols. Future studies should also examine which reflexive (e.g., in-task affect) and/or reflective (e.g. enjoyment, attitudes, intentions) psychological factors are most predictive of unsupervised, free-living exercise. Moving forward, it will be important to distinguish whether observed effects are due to the familiarization of exercise and/or behaviour change counselling. Finally, it will also be of value to evaluate how affective and social cognitions during the intervention translate to free-living physical activity behaviour over the subsequent year.

Implications

Overall, the findings suggest that a supervised progressive exercise protocol can positively enhance social cognitions towards low-volume HIIT and MICT, with no deleterious effects on acute affective responses. Fluctuations in affective responses during the work and rest periods of HIIT sessions may decrease the predictive utility of in-task affect towards social cognitions and future exercise behaviour. Taken together, it appears that both progressive low-volume HIIT and MICT protocols may be feasible modalities of exercise for individuals who are not meeting physical activity guidelines and overweight.

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Data availability

Data pertaining to this research study is available from the corresponding author upon reasonable request.

Disclosure statement

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