High-Intensity Interval or Continuous Moderate Exercise: A 24-Week Pilot Trial

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ABSTRACT

LOCKE, S. R., J. E. BOURNE, M. R. BEAUCHAMP, J. P. LITTLE, J. BARRY, J. SINGER, and M. E. JUNG. High-Intensity Interval or Continuous Moderate Exercise: A 24-Week Pilot Trial. *Med. Sci. Sports Exerc.*, Vol. 50, No. 10, pp. 2067–2075, 2018. **Purpose**: High-intensity interval training (HIIT) may lead to superior cardiometabolic improvements when compared with moderate-intensity continuous training (MICT). However, adherence to HIIT requires examination. The purpose of this pilot study was to examine moderate-to-vigorous physical activity (MVPA) adherence 24 wk after a brief counseling intervention combined with either HIIT or MICT. **Methods**: Individuals at high risk of type 2 diabetes (T2D) were randomized to HIIT (n = 15) or MICT (n = 17) and completed 10 exercise sessions accompanied by a brief 10-min counseling intervention over a 2-wk period. Objectively measured purposeful MVPA (accelerometry) and cardiorespiratory fitness ($\dot{V}O_{2peak}$) were assessed at baseline and 24 wk postintervention. Self-regulatory efficacy and task self-efficacy were examined at baseline, postintervention, and 24 wk postintervention. Using an intention-to-treat analysis, change scores were calculated for HIIT and MICT and compared between groups. **Results**: Individuals assigned to HIIT increased their MVPA by 53 min (Cohen's d = 1.52) at 24 wk compared with 19 min in MICT. Both HIIT and MICT increased relative $\dot{V}O_{2peak}$ by 2 and 1 $mL \cdot kg^{-1} \cdot min^{-1}$, respectively. Participants in both groups increased in their self-regulatory and task self-efficacy postintervention, but both groups demonstrated similar decline at 24 wk. **Conclusion**: This pilot intervention was successful in increasing, and maintaining, free-living MVPA over a 24-wk period in individuals at high risk of T2D. Speculation that HIIT is inappropriate or unattainable for overweight individuals at high risk of T2D may be unfounded. **Key Words:** DIABETES RISK REDUCTION, MODERATE-INTENSITY CONTINUOUS TRAINING, HIGH-INTENSITY INTERVAL TRAINING, SOCIAL COGNITION, EXERCISE ADHERENCE

By 2035, an estimated 592 million individuals worldwide will be diagnosed with type 2 diabetes (T2D [1]), a disease associated with numerous negative health outcomes, including cardiovascular disease, neuropathy, and kidney failure (2). Significant efforts are being made to identify individuals at high risk of T2D and mitigate their risk given the extensive costs associated with T2D. Lifestyle interventions incorporating physical activity have been shown to successfully reduce the progression of prediabetes to T2D (3,4) and have been demonstrated as more effective compared with pharmaceutical intervention (3). Physical activity guidelines for adults at high risk of T2D suggest that accumulating 75 weekly minutes of high-intensity exercise, even if done in brief bouts (≤10 min), reduces risk to a greater extent than longer durations of moderate-intensity exercise (5). Although regular physical activity has been shown to prevent or delay the onset of T2D, very few adults maintain enough regular physical activity in order to reduce the risk of developing T2D (6).

Enrolling individuals at high risk of developing T2D into supervised lifestyle programs, such as the Diabetes Prevention Program (3), is one effective means of increasing physical activity and lowering T2D risk. However, most individuals return to being physically inactive within 24 wk of completing supervised programs when left to self-manage their physical activity (7). Within the Diabetes Prevention Program, in particular, most participants returned to their baseline physical activity levels once they completed the supervised program (8). Thus, there is a need to develop programs that foster

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independent physical activity after supervised programs for individuals who are at high risk of T2D.

Recently, high-intensity interval training (HIIT) has been highlighted as an viable form of exercise through which positive cardiometabolic adaptations can be obtained, often with a lower time commitment when compared with traditional moderate-intensity continuous training (MICT [9]). HIIT is defined as repeated bouts of vigorous-intensity exercise separated by periods of active recovery at a low intensity. Unlike sprint-interval training, or SIT, HIIT is submaximal exercise that can be performed without specialized equipment and does not require extensive recovery between intervals, hence making home-based prescriptions simple to remember and administer (e.g., "1-min on, 1-min off" or "power walk to the lamp post, then walk casually to the next lamppost," etc.). In support of HIIT for diabetes prevention, a recent meta-analysis reported superior improvements in insulin resistance after HIIT when compared with MICT (10). Although HIIT is not without its critics (11,12), a recent scoping review synthesizing the evidence comparing HIIT and MICT has also concluded that HIIT is a viable exercise option to explore for both psychological and physiological outcomes (13).

To date, research examining the effect of HIIT on long-term objectively measured exercise adherence is limited. Louvaris et al. (14) recently reported significant improvements in accelerometer-assessed daily activity 12 wk after a pulmonary rehabilitation intervention that incorporated HIIT in patients with chronic obstructive pulmonary disease. Although these studies cast doubt on the criticisms of HIIT, additional research is needed to ascertain whether long-term adherence to HIIT is a viable exercise option for individuals at high risk of T2D and whether it will be independently maintained in free-living conditions postintervention.

Enhancing self-regulatory skills is a critical component for physical activity interventions aiming to reduce diabetes risk and to promote long-term independent adherence (The American Heart Association's scientific position statement (15); American Diabetes Association's scientific position statement [5]). Within this self-regulatory framework, self-regulatory efficacy is a belief that concerns the confidence to enact and carry out self-management behaviors. It is critical for the successful long-term engagement of behaviors such as physical activity. Self-efficacy has been identified as a significant predictor of the adoption and maintenance of physical activity behavior (16,17), a mediator of intervention effects on objectively measured physical activity in individuals with T2D (18), and has been identified as the most influential factor of behavior change within the physical activity literature (19).

Beliefs about personal efficacy also help to regulate motivation by shaping aspirations and outcomes that individuals expect to occur from their efforts (20). Outcome expectations are an important but underresearched component of social cognitive theory (21,22). Expected outcomes can influence whether individuals will choose to engage in a behavior. In this way, fostering strong beliefs about social, physical, and self-evaluative outcomes has the potential to influence individuals' motivation to exercise. To date, the authors know of no studies that have examined the effect of HIIT on the key constructs of social cognitive theory, namely, self-efficacy and outcome expectations. Bolstering self-efficacy and outcome expectation beliefs is an important outcome for behavior change interventions because of their effect on exercise adherence.

The primary purpose of this pilot investigation was to examine the 24-wk outcomes from the Small Steps for Big Changes intervention framework for lowering T2D risk factors. The utility of HIIT as compared with MICT for promoting physical activity adherence over 24 wk was examined using objectively measured physical activity. On the basis of our preliminary findings, which reflected adherence behaviors displayed 4 wk postintervention (23), it was hypothesized that exposure to HIIT would lead to greater exercise adherence 24 wk postintervention when compared with MICT. A secondary purpose of this study was to examine the differential effect of engaging in HIIT or MICT on self-efficacy, outcome expectations, and cardiorespiratory fitness. It was hypothesized that all three outcomes would increase after the intervention.

METHODS

Participants

Adults (30–60 yr old) were recruited through community posters, online forums, and word of mouth. Eligibility criteria included 1) engaging in two or fewer 30-min bouts of physical activity per week over the past 6 months and 2) having high risk of developing T2D based on meeting one of the following criteria: (a) physician diagnosed, (b) HbA1C values between 5.7% and 6.4% $mmol \cdot mol^{-1}$ (American Diabetes Association [24]) assessed using a clinically validated point-of-care monitor (HbA1C Now; Bayer Inc., Ontario, Canada), (c) a CanRISK questionnaire score of moderate/high (>21), and/or (d) fasting blood glucose of 5.6–6.9 $mmol \cdot mol^{-1}$. Exclusion criteria included diagnosed diabetes, taking glucose lowering medications, uncontrolled hypertension (blood pressure >160/90), history of heart disease, previous myocardial infarction or stroke, and any contraindications to exercise. All participants completed the CSEP Physical Activity Readiness Questionnaire-Plus (PAR-Q+ [25]) and were cleared for participation in vigorous activity by a CSEP Certified Exercise Physiologist® before entering the study. Participants (N = 32) meeting the eligibility criteria were enrolled in the study after providing written informed consent. See Figure 1 for participant flow diagram.

Procedures

The study was approved by the corresponding author's clinical research ethics board. A computerized random number generator was used to assign eligible participants to either the HIIT or the MICT condition. Each participant took part

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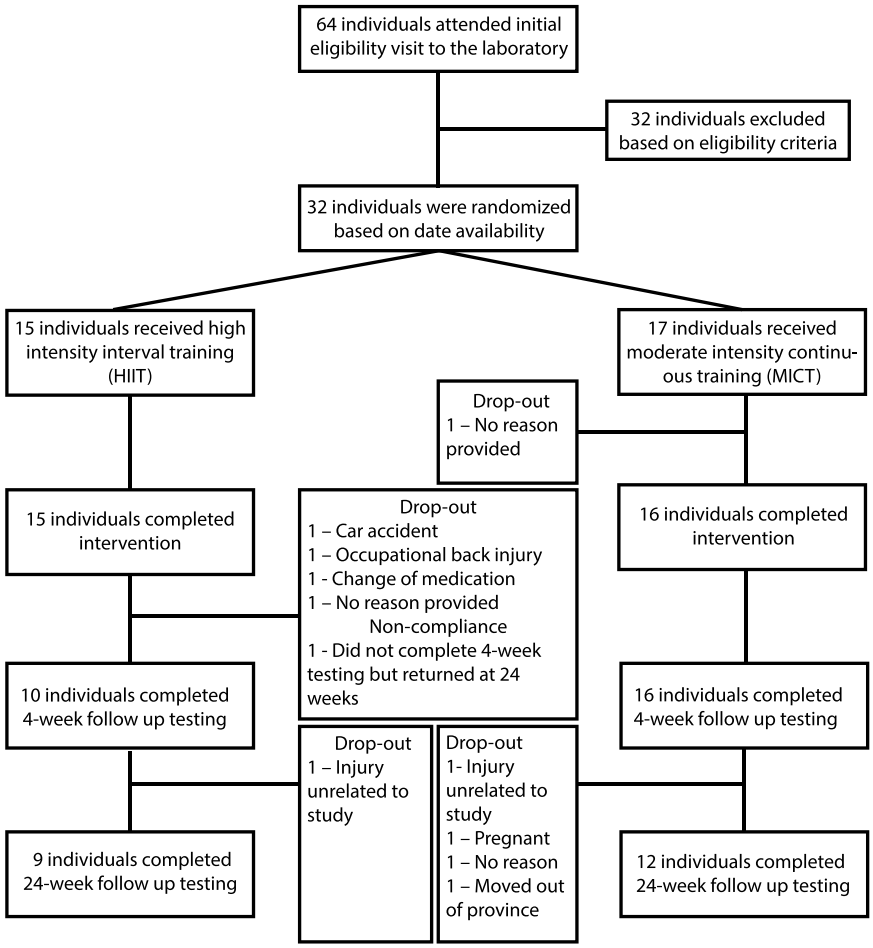


FIGURE 1—Flow of participants through the intervention.

in 10 sessions of exercise performed over a 12-d period (i.e., Monday–Friday over 2 wk with Saturday and Sunday as rest days). Seven of these sessions were supervised and three were self-managed at home to foster practice at becoming an independent exerciser. Participants self-selected the exercise modality (walking outdoors, elliptical machine, treadmill walking, or stationary cycling) for four of the supervised exercise sessions to encourage autonomy. The exercise prescriptions for each condition were progressive in nature and were matched for external work, with HIIT progressing from 4 × 1-min to 10 × 1-min intervals (with 1-min rest in between) and MICT progressing from 20 to 50 min over the 10 exercise sessions. The HIIT protocol was modeled after our previous work (23), whereby intensity at the participants' chosen modality was increased by the exercise counselor such that HR reached ~90% peak by the end of interval 3 and was maintained at this intensity for the remaining intervals. Intensity of recovery intervals was not specifically prescribed, but participants were instructed to reduce to an easy intensity for 1 min. A 3-min warm-up and 2-min cooldown at a self-selected intensity was included with each HIIT session. MICT participants were prescribed exercise at ~65% HR_{peak} on their chosen modality. After completion of the 10-session intervention, participants were instructed to independently maintain HIIT or MICT (day 10 exercise dose) 3 $d \cdot wk^{-1}$ for 24 wk. Thus, the HIIT group was prescribed vigorous exercise with a time commitment of 75 $min \cdot wk^{-1}$ (including warm-up and cooldown; ~85% HR_{peak}), whereas the MICT group was prescribed a total of 150 min of moderate activity per week (~65% HR_{peak}).

Cardiorespiratory fitness and accelerometer-measured moderate, vigorous, and purposeful moderate-to-vigorous physical activity (MVPA) were measured at baseline and the 24-wk follow-up. Self-efficacy and outcome expectations were measured at baseline, immediately postintervention, and 24 wk postintervention. The pilot intervention was run in four waves of seven to eight participants between July 2013 and August 2014.

Brief Physical Activity Counselling

All participants received brief counseling, tailored to HIIT or MICT, to promote physical activity engagement and self-management. Specifically, participants received seven supervised exercise training sessions paired with a 10-min brief counseling session (70 min total). On the three home-based training sessions, participants received tailored messages, in the form of handouts, emphasizing behavior change strategies

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that were tailored to condition (i.e., rewards, bolstering self-efficacy, and self-monitoring).

The broad purposes of the brief counseling were to 1) manage the physiological and affective expectations associated with exercise engagement, 2) enhance confidence and ability to perform the exercise (task self-efficacy), and 3) enhance confidence and ability to self-manage exercise (self-regulatory efficacy). The five key sources of self-efficacy information outlined by Bandura (20) were targeted to bolster self-efficacy.

Measures

MVPA. MVPA was measured objectively using the ActiGraph GT1M (ActiGraph^{TM}, LCC, Fort Walton Beach, FL). The GT1M is a dual-axis motion sensor, recording vertical and horizontal accelerations to determine physical activity intensity. Data were collected in 5-s epoch lengths. Epochs were summed to provide counts per minute. Valid wear time was ascertained using parameters set by Choi et al. (26). Participants were required to have at least five valid days of wear to be included in the analyses. The cut points of Freedson et al. (27) were used to identify time spent in moderate (≥1952 counts per minute), vigorous (≥5725 counts per minute), and MVPA (sum of moderate and vigorous) during wear time on valid days.

Purposeful exercise was operationalized as minutes spent in MVPA in bouts of at least 10 min (MVPA10+ [28]) based on physical activity guidelines (29), which specify bouts should be accumulated in bouts of 10 min or more. MVPA10+ is a more appropriate measure of purposeful exercise (30) and, therefore, allows a more direct objective assessment of exercise adherence. Time spent in moderate activity, vigorous activity, and MVPA10+ was calculated for each valid wear day independently. Time spent in the various intensities was averaged across valid wear days and multiplied by seven to provide a weekly estimate of physical activity at baseline and 24 wk postintervention.

Exercise task self-efficacy. Participants' confidence in their ability to perform either high-intensity intervals or continuous moderate-intensity exercise was assessed using a four-item measure. Each question included the stem, "How confident are you that you can…," with four items, "perform (4, 6, 8, or 10) high-intensity intervals" or "perform (20, 30, 40, or 50) minutes of continuous moderate exercise" (dependent on condition). Responses were scored on a scale of 0% (*not at all*) to 100% (*extremely confident*). The specificity of the four items was created following recommendations made by Bandura (20). The average of these four items was computed. This measure demonstrated good internal consistency across all three time points ($\alpha \geq 0.92$).

Self-regulatory efficacy. Participants' confidence in their ability to schedule exercise over the upcoming 4 wk was assessed using a 12-item measure. This measure was adapted from Shields and Brawley (29). This instrument assesses distinct aspects of self-regulatory efficacy, including participants' perceived confidence to monitor, schedule, and overcome exercise barriers. An example item included "How confident are you that you can resume regular exercise when it is interrupted and you miss a day or two?" Responses were scored on a scale of 0% (*not at all*) to 100% (*extremely confident*). The average of these 12 items was computed. This measure demonstrated strong internal consistency across all three time points ($\alpha \geq 0.97$).

Outcome expectations. The perceived likelihood and value of outcomes occurring as a result of engaging in exercise (i.e., social, physical, and self-evaluative) were assessed using a 23-item outcome expectations measure designed to assess outcomes of relevance to this study population. In line with expectancy and value operationalizations of outcome expectations, participants were asked, "How likely is it that each outcome in the list below will occur (and "How much do you value attaining each outcome") at least once in a typical week for the next 4 wk as a result of engaging in high-intensity interval training/moderate-intensity continuous exercise?" (dependent on condition). Participants were provided with a list of outcomes, including "socialize with friends," "lower risk of T2D," and "feel good about my physical appearance." Responses were scored on a 9-point scale from 1 (*very unlikely/little value to me*) to 9 (*very likely/very great value to me*). These outcomes were averaged to provide overall likelihood and value outcome expectation scores. The value and likelihood outcome expectation measures demonstrated sound internal consistency across all three time points ($\alpha \geq 0.91$).

Cardiorespiratory fitness. Participants performed a continuous incremental ramp maximal exercise test on an electronically braked cycle ergometer (Lode Excalibur, The Netherlands) to determine peak oxygen uptake ($\dot{V}O_{2peak}$) and peak power output. Expired gas was collected continuously by a metabolic cart (Parvomedics TrueOne 2400, Salt Lake City, UT) that was calibrated with gases of known concentration with a 3.0-L syringe before every test. The test started at 50 W and increased by 15 $W \cdot min^{-1}$. Verbal encouragement was provided to participants throughout the test, which was terminated upon volitional exhaustion or when revolutions fell below 50 min^{-1}. $\dot{V}O_{2peak}$ was defined as the highest 30-s average for $\dot{V}O_2$, and results were reported for relative $\dot{V}O_{2peak}$ ($mL \cdot kg^{-1} \cdot min^{-1}$). Criteria for achieving $\dot{V}O_{2peak}$ were: (i) respiratory exchange ratio >1.15, (ii) plateau in $\dot{V}O_2$, (iii) reaching age-predicted HR_{peak} (220 − age), and/or (iv) volitional exhaustion.

Analyses

Data were analyzed in SPSS (version 24) using an intention-to-treat analysis. Multiple imputation is a recommended analytic procedure for managing missing data from randomized trials (see review on missing data by Graham [31]). Five imputed data sets with 10 iterations were computed. Results from the five imputations were pooled. Auxiliary variables (e.g., baseline values and demographic factors) were used in the imputation model to aid missing value estimation.

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TABLE 1. Descriptive statistics for individuals that took part in the intervention.

Variables	All (N = 32)	HIIT (n = 15)	MICT (n = 17)
Age (yr)	50.84 ± 10	50.93 ± 10.57	51.06 ± 9.62
Gender, n (%)			
Male	5 (16.1)	1 (6.7)	4 (23.5)
Female	26 (83.9)	14 (93.3)	13 (76.5)
Body mass (kg)	90.84 ± 18.26	89.82 ± 22.96	91.21 ± 15.19
Body mass index (kg·m^{-2})	33.22 ± 6.15	33.10 ± 7.73	33.35 ± 4.46
Waist circumference (cm)	107.30 ± 13.74	105.16 ± 16.46	109.33 ± 10.38
CANrisk	32.13 ± 11.32	29.80 ± 11.49	34.00 ± 10.82
HbA1c (% mmol·mol^{-1})	5.77 ± 0.55	6.06 ± 0.60	5.53 ± 0.39
Ethnic origin, n (%)			
Caucasian	30 (96.8)	15 (100)	16 (94.1)
Latin American	1 (3.2)		1 (5.9)
Annual income, n (%)			
$0–$24,999	4 (12.5)		4 (23.5)
$25,000–$49,999	6 (18.8)	3 (20)	3 (17.6)
$50,000–$74,999	10 (31.3)	5 (33.3)	5 (29.4)
$75,000–$ 99,999	7 (21.9)	3 (20)	4 (23.5)
$100,000+	5 (15.7)	4 (26.7)	1 (5.9)

Values are presented as mean ± SD unless otherwise indicated.

Physical activity and cardiorespiratory fitness change between the preintervention and the 4-wk follow-up have been presented elsewhere (23). Change scores between the preintervention and the 24-wk follow-up were calculated for physical activity and cardiorespiratory fitness variables. Overall scale means were created for self-efficacy and outcome expectation measures at each time point. Change scores between examining social cognitive variables between 1) preintervention and postintervention and 2) preintervention and 24-wk follow-up were calculated for task self-efficacy, self-regulatory efficacy, and outcome expectations. The magnitude of difference in change between HIIT and MICT was examined using Cohen's d with the associated 95% confidence intervals (CI).

RESULTS

Study attrition. Thirty-two participants were initially randomized to HIIT (n = 15) or MICT (n = 17) conditions. See Figure 1 for participation flow through the study. To summarize, 31 participants completed the 10-d intervention (HIIT = 15, MICT = 16), 26 participants completed the 4-wk follow-up (HIIT = 10, MICT = 16; presented elsewhere [23]), and 21 participants completed the 24-wk follow-up (HIIT = 9, MICT = 12), which represented an overall dropout rate of 34.38%. Overall, 10.86% of the data were missing. There were 2.20% missing data across the study variables at baseline, 3.13% missing data immediately postintervention for social cognitive variables, and 31.16% missing data 24 wk postintervention across all outcome variables.

Preliminary analysis and descriptive statistics. The demographic characteristics at baseline are reported in Table 1. Mean ± SD accelerometer daily wear time was 855 ± 175 min at baseline and 804 ± 135.94 min at 24-wk follow-up. At least five valid wear days were acquired for all participants. Participants wore heart rate monitors during the supervised training phase to verify the relative exercise intensities. Average HR_{peak} during HIIT (including rest intervals, warm-up, and cooldown) was 82% ± 3% HR_{peak}, confirming that HIIT sessions were performed at a vigorous intensity. Average HR_{peak} during MICT was 67% ± 5%, confirming that MICT sessions were performed at a moderate intensity.

MVPA. See Table 2 for MVPA descriptive statistics. There was a 53-min large effect size increase in MVPA10+ from the preintervention to the 24-wk follow-up for those in HIIT (d = 1.52, CI = 0.70–2.32) and a small increase for those in MICT (d = 0.33, CI = −0.34 to 1.00). Those in HIIT increased their MVPA10+ by 34 more minutes than MICT, which represented a moderate-to-large effect (d = 0.68, CI = −0.02 to 1.4).

There was a 25-min small-to-moderate increase for HIIT (d = 0.29, CI = −0.43 to 1.00), and no change for those in MICT (d = 0.01, CI = −0.68 to 0.66) from the preintervention to the 24-wk follow-up. There was a 25-min small effect difference in 24-wk change scores between HIIT and MICT, in favor of HIIT (d = 0.22, CI = −0.47 to 0.91).

There was a 15-min large effect–sized increase in vigorous activity from the preintervention to the 24-wk follow-up for those in HIIT (d = 0.87, CI = 0.12–1.62). There was a small effect–sized increase from the preintervention to the 24-wk follow-up for those in MICT (d = 0.18, CI = −0.50 to 0.85). There was a large 14-min vigorous activity difference in 24-wk change scores between HIIT and MICT in favor of HIIT (d = 1.16, CI = 0.41–1.91).

TABLE 2. MVPA and fitness descriptive statistics between HIIT and MICT conditions at preintervention and 24 wk postintervention.

	Mean (SE)		Change (95% CI)	
Variable	Preintervention	24 wk	Within-Group Change	Difference Between Within-Group Change
MVPA10+				
HIIT	16.36 (6.14)	69.39 (11.72)	53.02 (37.47 to 68.58)	33.88 (−0.10 to 67.85)
MICT	33.85 (11.86)	53.00 (16.90)	19.15 (−10.88 to 49.18)	
Moderate activity				
HIIT	254.28 (23.25)	278.43 (21.93)	24.80 (−22.46 to 70.77)	25.34 (−56.03 to 106.71)
MICT	286.70 (30.96)	285.51 (25.12)	−1.18 (−65.52 to 63.15)	
Vigorous activity				
HIIT	9.26 (2.42)	23.95 (5.89)	14.68 (6.43 to 22.93)	13.54 (5.32 to 21.76)
MICT	8.99 (1.72)	10.13 (1.51)	1.14 (−1.80 to 4.07)	
Relative $\dot{V}O_{2peak}$				
HIIT	19.99 (0.93)	21.98 (0.97)	2.00 (0.41 to 3.59)	0.97 (−1.63 to 3.56)
MICT	20.44 (1.27)	21.47 (0.94)	1.03 (−0.98 to 3.05)	

HIIT, n = 15; MICT, n = 17.

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TABLE 3. Psychosocial descriptive statistics between HIIT and MICT conditions at preintervention, immediately postintervention, and 24 wk postintervention.

	Mean (SE)			Change (95% CI)		
Variable	Preintervention	Postintervention	24 wk	Within-Group Change (Pre–Post)	Within-Group Change (Pre–24 wk)	Difference Between Within-Group Change (Pre–24 wk)
Task self-efficacy						
HIIT	72.25 (7.31)	94.17 (1.99)	85.57 (3.57)	21.92 (−8.68 to 35.15)	13.31 (−4.54 to 31.17)	2.03 (−22.60 to 26.67)
MICT	63.31 (6.13)	95.09 (1.37)	74.59 (5.54)	31.78 (21.06 to 42.51)	11.28 (−5.67 to 28.25)	
Self-regulatory efficacy						
HIIT	80.94 (2.85)	89.33 (2.49)	74.59 (4.83)	8.39 (2.17 to 14.61)	−6.35 (−16.00 to 3.29)	2.40 (−14.25 to 19.06)
MICT	75.49 (4.82)	87.38 (1.81)	66.73 (4.73)	11.89 (4.66 to 19.13)	−8.75 (−21.87 to 4.36)	
OE—likelihood						
HIIT	7.11 (0.28)	7.45 (0.25)	7.04 (0.31)	0.34 (−0.11 to 0.79)	−0.06 (−0.63 to 0.50)	0.45 (−0.81 to 1.70)
MICT	7.08 (0.43)	7.61 (0.23)	6.57 (0.31)	0.54 (−0.36 to 1.43)	−0.51 (−1.58 to 0.55)	
OE—value						
HIIT	7.89 (0.21)	7.96 (0.18)	8.08 (0.15)	0.07 (−0.21 to 0.36)	0.18 (−0.13 to 0.50)	0.38 (−0.23 to 0.98
MICT	7.91 (0.17)	7.90 (0.23)	7.72 (0.26)	−0.01 (−0.48 to 0.47)	−0.19 (−0.68 to 0.30)	

Task self-efficacy and self-regulatory scales ranged from 0 to 100; OE scales ranged from 1 to 9.
OE, outcome expectations.

Social cognitions. See Table 3 for social cognitive descriptive statistics. Recall that self-efficacy scales ranged from 0 to 100. There was a 22-point increase in task self-efficacy from preintervention to postintervention for those in HIIT (d = 1.09, CI = 0.32–1.86), and a 32-point increase for those in MICT (d = 1.79, CI = 0.99–2.58). Both effects were large in magnitude. These increases declined slightly at the 24-wk follow-up. Between the preintervention and the 24-wk follow-up, there were increases in task self-efficacy for both HIIT (13-point increase, d = 0.62, CI = 0.11–1.35) and MICT (11-point increase, d = 0.48, CI = 0.20–1.16). Both these effects were medium in magnitude. There was no difference in task self-efficacy 24-wk change scores between HIIT and MICT (d = 0.06, CI = −0.64 to 0.75).

Self-regulatory efficacy increased from preintervention to postintervention for both HIIT (8-point increase, d = 0.84, CI = 0.09–1.59) and MICT (12-point increase, d = 0.81, CI = 0.11–1.51). Both these effects were large in magnitude. These declined at the 24-wk follow-up. Both HIIT (d = 0.51, CI = −0.02 to 1.24) and MICT (d = 0.46, CI = −0.22 to 1.13) experienced moderate effect–sized decreases between the preintervention and the 24-wk follow-up in self-regulatory efficacy. There was no difference in self-regulatory efficacy 24-wk change scores between HIIT and MICT (d = 0.10, CI = −0.59 to 0.80).

Outcome expectation scales ranged from 1 to 9. Those in HIIT (d = 0.34, CI = −0.38 to 1.06) and MICT (d = 0.39, CI = −0.28 to 1.07) experienced small increases in outcome expectation likelihood from preintervention to postintervention. These declined at the 24-wk follow-up. Between the preintervention and the 24-wk follow-up, there were no change for HIIT (d = 0.06, CI = −0.66 to 0.77) and a small effect size decrease MICT (d = 0.34, CI = −0.33 to 1.02). There was a small difference in outcome expectation likelihood 24-wk change scores between HIIT and MICT, in favor of HIIT (d = 0.25, CI = −0.44 to 0.95).

There were no differences in outcome expectation value from preintervention and postintervention for those in HIIT (d = 0.10, CI = −0.62 to 0.81) or MICT (d = 0.01, CI = −0.66 to 0.68). Between the preintervention and the 24-wk follow-up, there was a small increase for those in HIIT (d = 0.26, CI = −0.45 to 0.98) and a small decrease for those in MICT (d = 0.22, CI = −0.46 to 0.89). There was a small-to-moderate difference in outcome expectation value 24-wk change scores between HIIT and MICT, in favor of HIIT (d = 0.44, CI = −0.25 to 1.15).

Cardiorespiratory fitness. See Table 2 for cardiorespiratory fitness descriptive statistics. There was a moderate-sized increase in relative $\dot{V}O_{2peak}$ from the preintervention to the 24-wk follow-up for those in HIIT (d = 0.56, CI = −0.16 to 1.30) and a small size increase for those in MICT (d = 0.23, CI = −0.44 to 0.90). There was a small differences in relative $\dot{V}O_{2peak}$ 24-wk change scores between HIIT and MICT, in favor of HIIT (d = 0.26, CI = −0.43 to 0.96).

DISCUSSION

The purpose of this pilot intervention was to empirically evaluate whether individuals at high risk of developing T2D can adhere to HIIT in free-living conditions 24 wk after a brief supervised laboratory-based intervention. This pilot intervention study was not designed to be powered to detect statistically significant differences in small or moderate effects. Rather, it was designed to assess the magnitude of effect to lay the foundation for a fully powered efficacy trial. Although a larger sample is needed to increase statistical power, the direction and the magnitude of the effect sizes derived in this pilot study suggest potentially clinically meaningful changes. Large effects were observed for those in the HIIT condition, who increased the amount of time spent in purposeful MVPA by 53 min from preintervention to 24 wk postintervention, compared a 19-min increase for those in MICT. The adherence data demonstrate that individuals at high risk of T2D will engage in HIIT in free-living conditions over the longer term, up to 24 wk after supervised training has ended.

Initially high (at pretest) and sustained (at 24 wk postintervention) levels of moderate-intensity activity reflect the total time accrued throughout the day, which includes incidental activity. Although participants accrued in access of

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250 min of total moderate activity per week at preintervention and 24 wk postintervention, their amount of purposeful activity (MVPA10+) was considerably less. Interpretation of the number of total minutes of moderate physical activity should be viewed with caution given that purposeful exercise is the standard metric for major physical activity surveillance studies and scientific position statements (e.g., [5]). A small to moderate increase was observed for those in the HIIT condition, compared with no change for those in MICT.

Current physical activity guidelines suggest that accumulating 75 min of vigorous activity is equivalent to 150 min of moderate activity that is purposeful (32). In other words, vigorous exercise may elicit benefits over and above those accrued through moderate-intensity activity and in half the time. The National Health and Nutrition Examination Survey data suggest that engaging in greater amounts of vigorous-intensity physical activity can reduce the risk of metabolic syndrome, independent of total physical activity levels (33). At 24 wk, individuals who completed the HIIT program increased their vigorous physical activity by 15 min compared with no change by their MICT counterparts. The increased engagement in vigorous exercise corresponded with a 2-mL·kg^{-1}·min^{-1} increase in directly measured relative $\dot{V}O_{2peak}$ for those in HIIT. The moderate effect size increase for those in HIIT suggests that physiological improvements in cardiorespiratory fitness may occur 24 wk after the intervention.

Those in HIIT and MICT received the same brief counseling intervention to promote self-regulated exercise engagement. The only methodological difference between conditions was the mode of exercise—HIIT or MICT. Group differences in purposeful exercise at 24-wk are particularly striking when juxtaposed with long-term maintenance trends after structured physical activity interventions. Typically, participants in structured interventions increase their physical activity immediately after an intervention but return to baseline activity levels by 24 wk (7). The findings from the current pilot study counter early speculations about HIIT being inappropriate for overweight individuals or those at high T2D risk who would be unlikely to adhere to HIIT in the long term (e.g., [12]).

The brief counseling intervention was grounded in social cognitive theory and behavior change techniques known to be crucial for exercise adherence in this population (34). Self-efficacy to exercise (task efficacy) is important to develop when learning how to perform a new exercise behavior. Immediately after the 2-wk intervention, both HIIT and MICT participants were highly confident in their ability to perform the exercise that they were trained in, increasing their task self-efficacy by 22 and 32 points, respectively. Study participants were low-active and engaging in 16 to 34 min of weekly purposeful exercise when they entered the study. Concerns that such individuals will be unlikely to maintain HIIT because of their lack of confidence to perform the exercise modality appear unfounded. Indeed, the results of this 24-wk follow-up (postintervention) study provide preliminary evidence that addresses this concern. Although those randomized to HIIT and MICT experienced decreased task self-efficacy from postintervention to the 24-wk follow-up, they maintained increases of 11–13 points higher than baseline. There are two broad implications of these findings. First, brief evidence-based counseling interventions using behavior change strategies to enhance self-regulatory skills may be effective in enhancing sedentary individuals' confidence to engage in HIIT and MICT. Second, initially low-active individuals were able to maintain a high confidence to engage in HIIT across a 24-wk period.

Self-regulatory efficacy to manage exercise in free-living conditions is necessary for long-term adherence. An important intervention outcome was participants' confidence to manage their exercise upon completion of the 2-wk program. Participants in both exercise conditions increased their self-regulatory efficacy by about 10 points throughout the 2-wk structured intervention. At 24 wk, both HIIT and MICT declined in self-regulatory efficacy to levels below baseline. It is important to understand that these results from a theoretical perspective. Bandura (20) has suggested that initial self-efficacy beliefs may be overestimated for individuals without much direct experience in performing a behavior, such as exercise. Self-regulatory efficacy beliefs may have been overestimated after the 2-wk intervention where participants had a trainer to assist their exercise management. At the 24-wk follow-up, participants were required to self-manage exercise on their own in free-living conditions, which provided direct experience to form more accurate self-regulatory beliefs. This may help to explain the decreases in self-regulatory efficacy from immediately after the intervention to the 24-wk follow-up.

The value of expected outcomes was initially high for all study participants (~8 out of 9) and remained high throughout the 24-wk follow-up. The perceived likelihood of an expected outcome was initially high for all study participants (~7 out of 9). At the end of the 2-wk intervention, both groups increased their perceptions of outcome likelihood by 0.5 but returned to baseline levels at the 24-wk follow-up. In line with social cognitive theory, the increase in perceived likelihood of attaining expected outcomes may be related to improved social, physical, or self-evaluative outcomes seen by participants during the 2-wk intervention. The initial 2-wk improvements in self-efficacy may also account for the increase in outcome likelihood expectations. Overall, participants' expected value and perceived outcome likelihood remained high throughout the intervention to the 24-wk follow-up.

HIIT can lead to superior T2D risk reduction compared with MICT (e.g., reductions in insulin resistance [10]). HIIT is also time efficient and may be easier to self-manage in individuals' day-to-day lives than MICT. However, there is limited evidence examining adherence to HIIT in free-living conditions (13). In the current study, participants were more confident to perform and self-manage HIIT and were performing a greater volume of MVPA 24-wk after the intervention compared with those in MICT. Physical activity prescription alone is insufficient to promote long-term physical activity adherence (35). Theory-based behavior change counseling is a necessary

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component of interventions seeking to facilitate physical activity adherence after a structured intervention (34). Future HIIT research should leverage the high-quality behavior change techniques available (36) to optimize adherence for T2D risk reduction. One limitation of this pilot study was the 34% attrition rate, which can reduce statistical power. An intention-to-treat analysis using recommended multiple imputation procedures for handling missing data was conducted to account for the high attrition rate (see review by Graham [31]). Although intention-to-treat analyses tend to produce more conservative estimates of effects, robust increases in purposeful physical activity 24 wk after the intervention were observed for both HIIT and MICT participants. Handling of missing data using intention-to-treat analyses represents one study strength in accounting for attrition. Although both HIIT and MICT conditions were prescribed doses of exercise to meet physical activity guidelines for the 24 wk postintervention, neither group was meeting guidelines. Although both HIIT and MICT conditions were prescribed doses of exercise to meet physical activity guidelines for the 24 wk postintervention, neither group met the 150-min guidelines at 24 wk postintervention. Nevertheless, it is well established that individuals yield important health benefits from increasing activity to levels even if they do not reach 150 min of MVPA per week (37). There were several strengths of the current investigation. Interventions targeting lifestyle behaviors often take a theory-informed approach whereby theoretical constructs are measured but not systematically targeted and behavior change strategies are implemented but not linked to theoretical constructs (34). A second strength of the study was the purposeful implementation of behavior change strategies linked to the manipulation of Bandura's self-efficacy sources to promote physical activity (e.g., instruction on how to perform behavior and goal setting [20]). These strategies have been associated with meaningful long-term HbA1C reductions in individuals with T2D (38). Our findings suggest that strategies leading to health risk reduction for individuals who have developed T2D may also be useful for individuals at high risk of developing T2D.

Findings from this small-scale pilot intervention lay the groundwork for future research. The present study was limited by a small sample size. Examining the Small Steps for Big Changes intervention framework with a larger sample will strengthen the inferences that we are able to draw from the findings, expand the generalizability of the findings, and allow for the test of mediating mechanisms of change.

The intervention did not provide trainer contact between postintervention and 24-wk follow-ups. Although participants were engaging in physical activity 24 wk postintervention, meta-analytic findings suggest that follow-up contact or booster sessions can further enhance long-term intervention outcomes (e.g., physical activity adherence and HbA1C [7,38]). Future iterations of the program should include follow-up contact to bolster self-efficacy cognitions and promote adherence. Although results favored HIIT, both groups demonstrated 24-wk improvements from the Small Steps for Big Changes lifestyle program to lower T2D risk factors. Future research should recruit a larger sample with a longer follow-up period to conduct a fully powered trial to examine the efficacy of the Small Steps for Big Changes program for promoting long-term adherence to HIIT and MICT.

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