JOURNAL OF SPORTS SCIENCES
2021, VOL. 39, NO. 15, 1677–1686
https://doi.org/10.1080/02640414.2021.1892946

Routledge
Taylor & Francis Group

PHYSICAL ACTIVITY, HEALTH AND EXERCISE

Interval training causes the same exercise enjoyment as moderate-intensity training to improve cardiorespiratory fitness and body composition in young Chinese women with elevated BMI

Mingzhu Hu[a], Zhaowei Kong[a], Shengyan Sun[b], Liye Zou[c], Qingde Shi[d], Bik Chu Chow[e] and Jinlei Nie[d]

[a]Faculty of Education, University of Macau, Macao, China; [b]Institute of Physical Education, Huzhou University, Huzhou, Zhejiang, China; [c]Exercise and Mental Health Laboratory, School of Psychology, Shenzhen University, Shenzhen, China; [d]School of Health Sciences and Sports, Macao Polytechnic Institute, Macao, China; [e]Department of Sport, Physical Education and Health, Hong Kong Baptist University, Hong Kong, China

ABSTRACT
This study examined the effects of 12 weeks of sprint interval training (SIT), high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT) on cardiorespiratory fitness (peak oxygen uptake, VO_{2peak}), body composition and physical activity enjoyment in overweight young women. Sixty-six participants (age 21.2 ± 1.4 years, body mass index (BMI) 26.0 ± 3.0 kg·m^{-2}, body fat percentage 39.0 ± 2.8%) were randomly assigned to non-exercise control (CON), thrice-weekly SIT (80 × 6 s "all-out" cycling interspersed with 9 s rest), and HIIT (4 min cycling at 90% VO_{2peak} followed with 3 min recovery for ~ 60 min) or MICT (~ 65 min continuous cycling at 60% VO_{2peak}) with equivalent mechanical work (200/300 KJ). Compared to the CON group, all three training groups had significant and similar improvements in VO_{2peak} (~ +20%, d = 2.5–3.4), fat mass (~ −10%, d = 1.3–2.1) and body fat percentage (~ −5%, d = 1.0–1.1) after a 12-week intervention. Similar high levels of enjoyment were observed among groups for most (~70%) of the training sessions. The findings suggest that the three training regimes are equally enjoyable and could result in similar improvements in cardiorespiratory fitness and body composition in overweight/obese young women, but SIT is a more time-efficient strategy.

ARTICLE HISTORY
Accepted 16 February 2021

KEYWORDS
Obesity; intermittent exercise; repeated sprint training; high-intensity interval training; psychological responses

Introduction

It is commonly acknowledged that overweight and obesity are potential threats to health, which could trigger numerous diseases, such as type 2 diabetes, cardiovascular diseases, and even some types of cancer (Calle & Thun, 2004; Dallongeville et al., 2008; Li et al., 2005; Phillips & Prins, 2008; Ul-Haq et al., 2014). Treatments for overweight and obesity often include participation in routine physical activity, since it has been shown not only to help control weight and modify body composition but also to enhance cardiovascular fitness and consequently lower the risk of all-cause mortality, especially cardiovascular-related diseases and premature death (Blair & Brodney, 1999; Fogelholm, 2010; Warburton et al., 2006). Moderate-intensity continuous training (MICT) is a well-known exercise recommendation for the general population. However, given that participating in MICT could be time-consuming (i.e., 40–60 min per session) and monotonous (Thum et al., 2017), regular participation in MICT appeared difficult to achieve for the majority of overweight individuals who perceived lack of time and interest as barriers to performing physical activity (Gillen & Gibala, 2018; Stork et al., 2017). Therefore, high-intensity interval training (HIIT), characterized by intermittent high-intensity bursts interspersed with active or inactive recovery, has been advocated as an alternative to MICT due to its similar or even greater beneficial effects on health status but better time-efficiency and variability (Conraads et al., 2015; Foster et al., 2015; Gillen & Gibala, 2018; Hwang et al., 2016). Nevertheless, despite the fact that the intermittent nature of HIIT may provide a changing stimulus and consequently lower the monotonicity compared with MICT, the time spent on performing common HIIT protocols (i.e., 4 min cycling at 90% VO_{2peak} followed with 3 min recovery) could still be lengthy (i.e., 25–40 min per session) with warm-up and cool-down sessions (Lunt et al., 2014; Schjerve et al., 2008; Sun et al., 2019; Tjønna et al., 2013; Zhang et al., 2017), thus it may not actually help to save time for the participants.

More recently, sprint interval training (SIT) as a low-volume mode of HIIT, which consists of shortened "all-out" intervals (i.e., ≤30 s) (Wen et al., 2019) has generated great popularity due to its superior time-saving character over conventional HIIT with longer interval duration (i.e., ≥ 3 min) (Townsend et al., 2016). Previous studies have shown that SIT with short interval duration could improve cardiovascular fitness effectively in overweight/obese population when compared with traditional HIIT and MICT (Hazell et al., 2010; Metcalfe et al., 2012; Sun et al., 2019; Wen et al., 2019; Yamagishi & Babraj, 2017). However, it is less clear about the long-term effects of SIT on reforming body composition compared to HIIT and MICT. Although a few studies involving SIT protocols with less than 10 s work duration have reported significant improvements in body composition

CONTACT Jinlei Nie jnie@ipm.edu.mo School of Health Sciences and Sports, Macao Polytechnic Institute, Macao, China

Abbreviations BMI: Body mass index; DXA: Dual energy X-ray absorptiometry; HIIT: High-intensity interval training; HR: Heart rate; ICT: Moderate-intensity continuous training; PACES: Physical activity enjoyment scale; RCT: Randomized controlled trial; RPE: Ratings of perceived exertion; SIT: Sprint interval training; VO_{2peak}: Peak oxygen consumption after 12–15 weeks of intervention (Heydari et al., 2012; Martins et al., 2016; Sun et al., 2019; Tong et al., 2018; Trapp et al., 2008), these studies mostly did not incorporate both HIIT and MICT as a comparison to SIT (Heydari et al., 2012; Martins et al., 2016; Tong et al., 2018; Trapp et al., 2008), or had defects such as not including a control group (Heydari et al., 2012; Martins et al., 2016; Sun et al., 2019), or failed to use the golden standard for body composition analysis (i.e., dual energy X-ray absorptiometry, DXA) (Sun et al., 2019). Therefore, it is still unknown whether long-term participation in SIT with extremely short work intervals could impact body composition differently compared to MICT and HIIT.

Despite experimental data suggesting significant cardiometabolic adaptions in response to SIT, long-term adherence to this extremely demanding type of exercise for overweight and obese individuals is still under examination (Biddle & Batterham, 2015; Hardcastle et al., 2014). Enjoyment, a psychological state directly related to an eliciting stimulus or the exercise experience, is a decisive indicator of exercise adherence (Aaltonen et al., 2012; Bauman et al., 2012). SIT protocols of maximal intensity may be too arduous for inactive individuals to accomplish and possibly produce low enjoyment, thus limit the practicality of this exercise regime for an overweight population with sedentary lifestyle (Hardcastle et al., 2014). Nevertheless, acute or short-term enjoyment responses to SIT appeared to be similar or even higher than MICT and HIIT in inactive adults according to previous studies (Astorino et al., 2019; Marques et al., 2020; Olney et al., 2018; Stork et al., 2018), suggesting that individuals with relatively low initial fitness levels may still enjoy and be willing to adhere to SIT protocols despite its "all-out" nature. Moreover, there has been a tendency to modify SIT with reduced interval durations (i.e., ≤10 s) to alleviate the distress of performing it, thus increasing the applicability in sedentary individuals (Astorino et al., 2019; McKie et al., 2018; Townsend et al., 2016). However, to the best of our knowledge, there is no available data comparing the effects of SIT or HIIT with those of MICT with regard to exercise enjoyment in a relatively long intervention duration (≥12 weeks). Long-term participation in physical activity is essential for overweight/obese individuals to achieve meaningful improvements in body composition and cardiorespiratory fitness as it could possibly generate greater effects than those of short-term interventions. Thus, it would be of interest to investigate whether SIT with higher intensity could be associated with more favourable perceptions of enjoyment in comparison to HIIT and MICT in overweight and obese individuals to predict long-term exercise adherence.

In this context, the purpose of the present study was to observe the effects of 12 weeks of SIT (i.e., 80 × 6 s cycling interspersed with 9 s rest periods), compared to HIIT (i.e., 4 min cycling at 90% VO_{2peak} followed with 3 min recovery until the work of 300 KJ was done) and MICT (i.e., continuous cycling at 60% VO_{2peak}, until the work of 300 KJ was done), on cardiorespiratory fitness and body composition in overweight young females. Moreover, the enjoyment responses to the three training protocols would be compared during the intervention. The first hypothesis was that all three training protocols would improve VO_{2peak} and body composition to a similar extent. The second hypothesis was that SIT would be as enjoyable as HIIT, while MICT would induce a lower enjoyment level in overweight young women.

Methods

Participants

The study was approved by the Research Ethics Panel of the University and all experimental procedures were in accordance with the declaration of Helsinki. Through local advertisements, participants were recruited according to the following criteria: (1) 18 – 25 years old; (2) Chinese women with elevated body mass index (BMI) ≥23 kg·m^{-2} (WHO, 2004) and percentage of body fat over 30% (measured by DXA), (3) body mass maintained relatively stable (variation within ± 2 kg) in the past 3 months; (4) sedentary lifestyle (not participated in regular physical activity or any structured exercise in the past 6 months); (5) non-smoker and not used to drinking alcohol; (6) no use of oral contraceptive pills and medicines known to affect body mass and metabolism.

A power analysis was performed by G*Power (Version 3.1) to justify the sample size. Based on the previous findings (Zhang et al., 2017) regarding the improvement of fat mass resulting from HIIT (a power of 0.8 at $\alpha = 0.05$ and an effect size of 0.45), a sample size of 12 participants for each group was necessary. Considering a dropout rate of ~20%, a total sample size of 60 would be expected. Consequently, 66 overweight/obese but healthy Chinese females (age: 21.1 ± 1.4 years, BMI: 26.0 ± 3.0 kg·m^{-2}) were recruited to participate in this study. After the acquisition of written informed consent from all eligible participants, they were randomly allocated to four groups: the no-exercise control group (CON, n = 17); the SIT intervention group (n = 16); the HIIT intervention group (n = 17); and the MICT intervention group (n = 16). The randomization was carried out using the PASW software (Release 22.0; IBM, New York, USA) by one of the investigators who was unaware of group intervention assignment. Due to discontinued intervention, conflicting schedules or personal reasons, six participants withdrew from the study. Eventually, 60 participants who completed the programme and all pre- and post-measurements were included in the final data analysis.

Experimental design and procedures

This study used a four-arm randomized controlled trial (RCT) with pre- and post-test design. The experimental procedure consisted of pre- and post-measures, and a 12-week intervention period. The baseline assessments of cardiorespiratory fitness and body composition were completed within 3–5 days prior to the intervention. During the 12-week intervention period, participants in the CON group maintained their habitual daily activity and daily dietary intakes, and were instructed not to take part in extra exercise. In contrast, participants in the SIT, HIIT and MICT groups performed their training protocols three times per week under the guidance of two experienced research assistants. If the participant missed a session, she would be asked to make it up within the same week so that the intervention could be completed in 12 weeks as planned. Perceptions of enjoyment were measured immediately after the completion of the first and the last training sessions of the fourth, eighth and twelfth week. The post-intervention measurements were carried out between 3 and 5 days following the last intervention day, in the same way as the pre-intervention measures. All pre- and post-intervention measures were scheduled at the same phase of each participant's individual menstrual cycle (i.e., either follicular phase or luteal phase), which was estimated according to the self-reported menstrual cycle survey obtained before participation (the flow chart of the study is shown in Figure 1).

Anthropometric assessments

Anthropometric assessments were taken before and 72 h after the last intervention day. Participants were instructed to arrive at the laboratory in the morning (7.30 a.m.) without breakfast. Standing height was assessed using a wall-mounted stadiometer without shoes and in light clothing. The values were recorded to the nearest 0.1 cm. Then participants underwent a whole-body DXA scan (Lunar Prodigy Advance, Madison, WI) to measure body composition variables, including fat-free mass, total fat mass, and regional fat distributions (i.e., head, arms and legs). The same trained technician, who was blinded to participants' group allocation, was responsible for the DXA scanning and analyses. The trunk measurement covered an area between the bottom of the neckline to the top of the pelvis, without the upper limbs. The intra-class correlation coefficient between two scans was > 0.98, and the output from the DXA scanner was expressed in grams.

Maximal incremental exercise test

The maximal incremental exercise tests were carried out before and 72–120 h after the last intervention day to assess cardiorespiratory fitness level. After warming-up at 25 W for 3 min, participants began to pedal on a computer-controlled cycle ergometer (Monark 839E, Sweden) with an initial workload of 50 W, and the cycling cadence of 60 ± 5 rpm was maintained throughout. The exercise workload would be increased by 25 W every 3 minutes until the participants reached their volitional

Figure 1. Flow chart of study. CON, no exercise training, MICT, moderate-intensity continuous training, HIIT, high-intensity interval training, SIT, sprint interval training.

exhaustion. Respiratory gases were assessed on a breath-by-breath basis using a Cosmed metabolic analyser (Quark PFT4 ergo, Cosmed, Rome, Italy). The VO_{2peak} was determined as the highest 15-second oxygen consumption value averaged over the last stage (Rossiter et al., 2006). After the graded exercise test, the workloads (in watts) corresponding to 60% and 90% of VO_{2peak} used in the MICT and HIIT groups were calculated accordingly.

Training intervention

Participants in the SIT, HIIT and MICT groups performed supervised training intervention at the lab with controlled room temperature (22 °C) and humidity (50–60%). The exercise training was conducted three sessions per week on non-consecutive days for 12 weeks. For each training session, two research assistants supervised the training process and recorded the training data. Music or visual entertainment was not allowed during training, but they would receive the same verbal encouragement from the two research assistants.

For the SIT group, participants accomplished repeated sprint cycling on a cycle ergometer (Monark, 894E, Varberg, Sweden). Each training session consisted of 80 repetitions of 6 s cycling sprints interspersed with 9 s passive recoveries (20 min/session). Participants were required to pedal as fast as they could during the 6 s sprint intervals and rested on the seat during the 9 s recovery intervals. The initial workload was 1 kg. If the cycling cadence of all exercise bouts was maintained above 100 rpm for two consecutive training sessions, the resistance would be increased by 0.5 kg until achieving a workload equivalent to 5% of the participant's individual body mass. Heart rate (HR, Polar F4M BLK, Finland) and the ratings of perceived exertion (RPE, Borg 6–20 scale) were recorded every 10 sprints.

The mechanical work done in the HIIT and MICT groups was designed to be equivalent, which was 200 KJ/session for the first 4 weeks and 300 KJ/session for the following 8 weeks. All training sessions of the two groups were performed on Monark cycle ergometers (839E, Sweden). The HIIT intervention consisted of 4 min cycling bouts at 90% VO_{2peak} and followed by 3 min passive recovery bouts until the targeted mechanical work was achieved. HR and RPE were recorded right before and immediately after the 4 min exercise bouts. Participants in the MICT group performed continuous cycling at a workload of 60% VO_{2peak} until the targeted mechanical work was fulfilled. HR and RPE were recorded every 10 minutes. As previously described (Thum et al., 2017), the individual exercise time needed for each training session in the HIIT and MICT groups was calculated, whereas the repetition number of the SIT group was determined. Training load and duration in HIIT and MICT were recalculated according to the results of VO_{2peak} test performed in the 4th and 8th weeks, whereas the SIT group continued to increase the workloads during the intervention. Training loads were reported by HR, RPE, and training impulse (TRIMP) (Table 1) as previously described (Fitz-Clarke et al., 1991).

Dietary assessments

Throughout the study period, participants were required to maintain their normal daily activities and not to change their dietary habits. Three-day diet logs (two weekdays and one weekend day) were provided by all participants for 4 weeks (i.e., 1 week before the intervention, and the 4th, 8th and 12th week during the intervention) to record their daily food and beverage intake. Detailed instructions and a handout regarding how to estimate food size and how to document food/beverage intakes were given to all participants in advance. Daily energy intake and macronutrient proportions were calculated using the nutrition analysis and management system (NRISM, Version 3.1, Beijing, China).

Assessment of exercise enjoyment

Enjoyment responses to the three different training protocols were evaluated using the Physical Activity Enjoyment Scale (PACES) (Kendzierski & DeCarlo, 1991), which is an 18-item scale (11 items are reversely scored). Participants had to rate "how you feel at the moment about the physical activity you have been doing". The responses range across a 7-point bipolar rating scale, with 1 point being considered "feel bored" and 7 points being "feel interested". The total scores of PACES are between 18 and 126, with higher scores indicating greater enjoyment. Participants in all three training groups were asked to fill the PACES questionnaires immediately after the completion of the first and the last training sessions of the 4th, 8th and 12th week.

Statistical analysis

Data analysis was conducted using the PASW software (Release 22.0; IBM, New York, USA) by the same investigator who performed blind group allocations. Before the main statistical analyses, the normal distribution of the outcome variables

Table 1. Training data during intervention.

	MICT			HIIT			SIT		
	Week 1–4	Week 5–8	Week 9–12	Week 1–4	Week 5–8	Week 9–12	Week 1–4	Week 5–8	Week 9–12
Exercise time per session (min)	64 ± 13 ‡	69 ± 9 ‡†	63 ± 5 ‡	29 ± 5 *	33 ± 3 *†	31 ± 3 *	8 ± 0 *‡	8 ± 0 *‡	8 ± 0 *‡
HRmean (bpm)	132 ± 8 ‡	128 ± 8 ‡†	130 ± 7 ‡	143 ± 11 *	139 ± 8 *†	139 ± 7 *†	164 ± 8 *‡	164 ± 6 *‡	164 ± 6 *‡
%HRmax	70 ± 5 ‡	68 ± 5 ‡†	69 ± 5 ‡	78 ± 6 *	76 ± 5 *	75 ± 5 *	92 ± 3 *‡	92 ± 3 *‡	92 ± 4 *‡
RPEmax	14 ± 1 ‡	14 ± 2 ‡	14 ± 2 ‡	16 ± 1 *	17 ± 1 *	17 ± 1 *	18 ± 1 *‡	18 ± 1 *‡	18 ± 1 *‡
RPEmean	11 ± 1 ‡	11 ± 1 ‡	11 ± 1 ‡	14 ± 1 *	14 ± 1 *	14 ± 1 *	15 ± 1 *‡	15 ± 1 *‡	15 ± 1 *‡
TRIMP (au)	155 ± 24 ‡	193† ± 29 ‡	166 ± 31 ‡†	48 ± 7 *	56 ± 9 *†	51 ± 7 *†	31 ± 2 *‡	32 ± 2 *‡	31 ± 2 *‡

MICT: moderate-intensity continuous training, HIIT: high-intensity interval training, SIT: sprint interval training, TRIMP: training impulse.
*Significantly different from MICT ($p < 0.05$). ‡ Significantly different from HIIT ($p < 0.05$). †Significantly different from week 1–4 ($p < 0.05$). □Significantly different from week 5–8 ($p < 0.05$).

was checked by the Kolmogorov–Smirnov test. One-way analysis of variance (ANOVA) test was performed to detect the differences in the demographic data at baseline. Using the baseline values as covariate, analysis of covariance (ANCOVA) was performed to test the group differences on the outcome variables of body composition and cardiorespiratory fitness. A two-way ANOVA (group × time) was used to determine changes in training parameters, dietary energy intake, and exercise enjoyment. Significant interaction effects were subsequently analysed using the Tukey post hoc test. Paired-sample t-tests were used to examine within-group time effects. Regarding effect size (ES) measures of the main and interaction effects, partial η^2 was considered small if $\eta^2 < 0.01$ and large if $\eta^2 > 0.14$ (Kirk, 1996). Cohen's d values were used to access the effect sizes for the difference between the training and the control groups, and the scores of 0.2, 0.5 and >0.8 were classified as small, moderate and large, respectively (Cohen, 1992). All tests for statistical significance were standardized at an alpha level of $p < 0.05$, and all descriptive data were expressed as mean ± standard deviation.

Results

Training data and daily energy intake

Among the 66 enrolled participants, 60 completed the intervention and all measurements, representing a 9.1% of dropout rate. As the missed training sessions were required to be made up, the attendance rate of the 60 participants in the three training groups was 100%. In addition, no adverse events were reported during the study.

The duration time for each SIT, HIIT and MICT session was 20, ~60 and ~65 min, whereas the pure exercise time of each session was 8 ± 0, 31 ± 3 and 65 ± 6 min, respectively, which can be translated to the mechanical work of 150 KJ in the SIT group, and 200–300 KJ in the HIIT and MICT groups. During the intervention, participants in the SIT group had the highest HR level (~92% of HR_{max}), which was significantly higher than that of the HIIT group (~76% of HR_{max}, $p < 0.001$, $d = 3.87$) and the MICT group (~70% of HR_{max}, $p < 0.001$, $d = 6.06$). As reflected by RPE, SIT training (15 ± 1) was perceived to be harder than HIIT (14 ± 1, $p = 0.024$, $d = 0.93$) and MICT training (11 ± 1, $p < 0.001$, $d = 3.79$) (Table 1). For the training load, the mean TRIMP of SIT (31 ± 2 au) during the intervention was significantly lower than that of HIIT (52 ± 6 au, $p < 0.001$, $d = 7.32$) and MICT (171 ± 22 au, $p < 0.001$, $d = 8.86$).

There was no significant time or group difference in daily energy intake as measured at 1 week before, and the 4th, 8th and 12th week during the intervention ($p > 0.05$), indicating that the participants did not change their habitual diets across the 12-week study period (Table 2). In addition, the macronutrient proportions of carbohydrate, fat and protein roughly accounted for 50%, 35% and 15% of daily energy intake in all four groups.

Cardiorespiratory fitness and body composition

The cardiorespiratory fitness level was improved significantly in the three groups with training intervention ($p < 0.05$) but remained unchanged in the CON group. The SIT, HIIT and MICT groups improved VO_{2peak} by 21.5%, 20.5% and 19.4%, respectively, which was significantly higher than that of the CON group ($p < 0.001$, $\eta^2 = 0.616$, Table 3).

After intervention, the SIT, HIIT and MICT groups reduced body mass by 1.9 kg, 3.3 kg and 3.4 kg, respectively ($p < 0.001$, $\eta^2 = 0.261$), equivalent to 0.7 kg·m^{-2}, 1.3 kg·m^{-2} and 1.2 kg·m^{-2} reductions in BMI ($p < 0.001$, $\eta^2 = 0.261$, Table 4). The decrements in body mass and BMI were significantly greater than that of the CON group (Table 3). Consistently, participants in all three training groups also experienced significant reductions in total fat mass ($p < 0.001$, $\eta^2 = 0.276$), and regional fat mass in arms ($p < 0.001$, $\eta^2 = 0.351$), trunk ($p < 0.05$, $\eta^2 = 0.171$) and legs ($p < 0.001$, $\eta^2 = 0.316$) as measured by DXA, and there were significant group differences compared to the CON group. In contrast, none of the groups changed the fat-free mass ($p > 0.05$, Table 3). These findings suggested that the three training methods were equally effective in reducing body mass, and the overall and regional fat mass, but had no influence on fat-free mass.

Table 2. Dietary energy intake during intervention.

	Pre		Week 4		Week 8		Week 12	
CON (kcal•day^{-1})	1412	± 315	1398	± 315	1351	± 333	1446	± 344
MICT (kcal•day^{-1})	1473	± 530	1449	± 519	1382	± 419	1371	± 510
HIIT (kcal•day^{-1})	1315	± 421	1228	± 436	1309	± 404	1307	± 425
SIT (kcal•day^{-1})	1212	± 347	1220	± 390	1167	± 322	1174	± 314

CON: no-exercise training, MICT: moderate-intensity continuous training, HIIT: high-intensity interval training, SIT: sprint interval training

Enjoyment responses to the intervention

Figure 2 shows the changes in enjoyment responses in the three training groups. There was no significant interaction effect ($p = 0.224$, $\eta^2 = 0.064$) or main group effect ($p = 0.450$, $\eta^2 = 0.037$) on PACES. A main time effect with medium ES was found in enjoyment responses measured at the four time points ($p = 0.006$, $\eta^2 = 0.108$). Further analysis indicated that week 4 had a significantly lower score compared to weeks 1, 8 and 12. The enjoyment responses to the SIT and HIIT training decreased markedly during the early stage of the intervention. Specifically, the PACES score decreased from week 1 to week 4 in both SIT ($p < 0.05$) and HIIT groups. Furthermore, the PACES score rose back to the average level at week 8 in the HIIT group ($p < 0.05$), while there were no significant changes in the SIT group between week 4 and week 8 or week 12. In contrast, the enjoyment response to the MICT intervention remained relatively stable throughout the study.

Discussion

In this study, we investigated the effects of three exercise modalities, namely MICT, HIIT and SIT on cardiorespiratory fitness, body composition and enjoyment responses. The first main finding was that all training groups resulted in similar improvements in VO_{2peak} and significant reductions in body mass, fat mass, and body fat percentage after a 12-week intervention. Secondly, across the 12-week intervention, comparable levels of enjoyment were observed in SIT compared with

Table 3. Outcome measures before and after 12 weeks of exercise training.

	CON (n = 15)		MICT (n = 15)		HIIT (n = 15)		SIT (n = 15)		Group effect	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	p	η^2
Age (y)	20.9 ± 1.1		20.9 ± 1.4		21.5 ± 1.7		21.4 ± 1.0			
Height (cm)	161.3 ± 6.5		162.8 ± 4.6		162.6 ± 4.6		162.0 ± 3.8			
Weight (kg)	67.5 ± 8.4	67.3 ± 8.2	68.5 ± 8.0	65.1 ± 7.7 *†	67.3 ± 6.1	64.0 ± 6.0 *†	67.3 ± 6.1	65.4 ± 6.1 *†	0.001	0.261
BMI ($kg \cdot m^{-2}$)	25.9 ± 2.4	25.9 ± 2.5	25.8 ± 2.6	24.6 ± 2.3 *†	25.5 ± 2.4	24.2 ± 2.4 *†	25.6 ± 2.3	24.9 ± 2.2 *†	<0.001	0.274
BF (%)	40.9 ± 2.7	40.4 ± 3.5	38.0 ± 2.1	35.6 ± 2.3 *†	38.1 ± 2.3	35.6 ± 2.0 *†	38.4 ± 2.4	36.3 ± 2.2 *†	0.002	0.236
FFM (kg)	39.8 ± 4.2	40.0 ± 4.4	42.5 ± 4.8	41.8 ± 4.1	41.6 ± 3.5	41.1 ± 3.4	41.4 ± 3.4	41.5 ± 3.1	0.315	0.062
FM (kg)	27.7 ± 4.8	27.3 ± 5.0	26.1 ± 3.7	23.3 ± 3.9 *†	25.7 ± 3.3	22.9 ± 2.2 *†	25.9 ± 3.4	23.8 ± 3.4 *†	<0.001	0.276
Head FM (kg)	1.1 ± 0.1	1.1 ± 0.1	1.2 ± 0.1	1.2 ± 0.1	1.1 ± 0.1	1.1 ± 0.1	1.1 ± 0.1	1.2 ± 0.1	0.685	0.026
Arm FM (kg)	3.2 ± 0.7	3.3 ± 0.8	3.3 ± 0.6	2.9 ± 0.6 *†	3.1 ± 0.6	2.7 ± 0.4 *†	3.2 ± 0.5	3.0 ± 0.5 *†	<0.001	0.351
Trunk FM (kg)	12.9 ± 2.1	12.3 ± 2.1	11.4 ± 2.1	10.1 ± 2.0 *†	11.7 ± 2.1	10.2 ± 2.1 *†	11.6 ± 2.3	10.4 ± 2.0 *†	0.016	0.171
Leg FM (kg)	11.4 ± 2.0	11.5 ± 2.2	10.2 ± 1.6	9.1 ±1.7 *†	9.8 ± 1.0	8.9 ± 1.0 *†	10.0 ± 1.5	9.3 ± 1.6 *†	<0.001	0.316
VO_{2peak} ($L \cdot min^{-1}$)	1.9 ± 0.2	1.9 ± 0.3	2.1 ± 0.3	2.5 ± 0.3 *†	2.1 ± 0.2	2.6 ± 0.3 *†	2.1 ± 0.2	2.5 ± 0.2 *†	<0.001	0.592
VO_{2peak} ($ml \cdot kg^{-1} \cdot min^{-1}$)	28.8 ± 3.6	27.6 ± 3.5	30.6 ± 3.5	38.3 ± 4.4 *†	31.6 ± 2.2	40.0 ± 4.5 *†	30.8 ± 3.7	38.5 ± 5.0 *†	<0.001	0.616

Observed values are expressed as means ± standard deviation. CON: no-exercise training, MICT: moderate-intensity continuous training, HIIT: high-intensity interval training, SIT: sprint interval training. BMI: body mass index, BF: percentage of body fat, FFM: fat free mass, FM: fat mass, VO_{2peak}: peak oxygen uptake. Significantly different from pre-training at * $p < 0.05$. Significantly different from CON at † $p < 0.05$.

the other two training protocols that required more time commitment. However, there was a significant decrease in enjoyment in SIT and HIIT at the 4th training week, which was not observed in MICT.

We observed similar improvements in VO_{2peak} by ~20% in all three training groups, indicating that the low-volume SIT regimen is a time-efficient approach to ameliorate cardiorespiratory fitness in overweight and obese young women. Interestingly, the findings were supported by several previous studies that reported equivalent advancement in interval groups in overweight/obese population (Sun et al., 2019; Trapp et al., 2008), but were partially inconsistent with some studies that revealed better improvements in interval groups (Milanović et al., 2015; Schjerve et al., 2008; Tong et al., 2018). The comparable effects in SIT with a lower training volume may be explained by the maintenance of maximum efforts at high percentage of VO_2 (≥ 90% VO_{2max}) during numerous short sprints (i.e., 6 s) while interspersed with relatively short rest periods (Shi et al., 2018), allowing participants to utilize their aerobic capacity repeatedly to achieve similar improvements on VO_{2max} as the other two trainings with a much greater exercise volume. As for the effects on body composition, there were significant reductions in total body mass, fat mass and, notably, retention of fat-free mass in all groups after a 12-week intervention. Consistent with the findings in the current study, long-term SIT interventions have been shown to effectuate fat reduction and improve body composition in either individuals with normal weight (Trapp et al., 2008) or excess weight (Heydari et al., 2012; Martins et al., 2016; Tong et al., 2018). With regard to the "all-out" nature of SIT, potentially greater muscle glycogen depletion, post-exercise oxygen consumption (Moniz et al., 2020), and higher rates of hormone-driven lipolysis (Pritzlaff et al., 2000; Trapp et al., 2007) might account for the similar outcomes on fat reduction between SIT and MICT or HIIT with a lower intensity. Possibly, SIT might have induced a decreased post-exercise appetite via lactate accumulation (Vanderheyden et al., 2020), and thus daily energy intake in SIT was less than MICT and CON (i.e., ~200-300 kcal less) despite no significant differences. Nonetheless, short-term SIT interventions (i.e., 2–5 weeks) failed to elicit significant changes in body composition in the literature (Kong et al., 2016; Skleryk et al., 2013), suggesting that a long adhering period to SIT (i.e., ≥ 12 weeks) may be a determining factor to produce meaningful fat reductions in overweight populations. Of note, our findings on body composition measured by DXA provided strong evidence of the effectiveness of SIT on reducing total and regional body fat mass when compared with MICT and HIIT (Heydari et al., 2012; Tong et al., 2018; Trapp et al., 2008).

Enjoyment to exercise is one of the primary factors related to future adherence to any exercise regime (Oliveira et al., 2018). In the present study, the PACES scores in SIT and HIIT were not lower than those in the MICT at any time point of enjoyment measurements throughout the intervention, indicating that the two interval training protocols were perceived as comparably enjoyable as the traditional MICT across the 12-week period. Comparable enjoyment between energy matched HIIT and MICT was also reported in a 8-week study targeting at overweight and obese adults (Vella et al., 2017), yet higher enjoyment in HIIT than MICT was observed in another 6-week study with

Table 4. Changes in outcomes after intervention.

	CON (n = 15)		MICT (n = 15)		HIIT (n = 15)		SIT (n = 15)		ES (*d*) MICT	ES (*d*) HIIT	ES (*d*) SIT
Δ Weight (kg)	−0.20	± 1.46	−3.37	± 2.88	−3.33	± 2.58	−1.94	± 1.98	1.39	1.49	1.00
Δ BMI ($kg{\bullet}m^{-2}$)	−0.06	± 0.60	−1.29	± 1.13	−1.26	± 0.95	−0.74	± 0.76	1.35	1.50	0.99
Δ BF (%)	−0.50	± 1.86	−2.33	± 1.67	−2.51	± 1.89	−2.10	± 1.32	1.04	1.07	0.99
Δ FFM (kg)	0.16	± 1.38	−0.63	± 1.51	−0.46	± 1.00	0.16	± 1.38	0.14	0.03	0.38
Δ FM (kg)	0.21	± 0.95	−2.74	± 1.90	−2.87	± 2.06	−2.09	± 1.25	1.97	1.92	2.07
Δ Head FM (kg)	0.03	± 0.07	−0.01	± 0.06	0.02	± 0.06	0.01	± 0.05	0.57	0.23	0.43
Δ Arm FM (kg)	0.16	± 0.26	−0.39	± 0.41	−0.42	± 0.42	−0.24	± 0.21	1.62	1.67	1.68
Δ Trunk FM (kg)	−0.56	± 1.20	−1.24	± 0.94	−1.57	± 1.15	−1.23	± 0.82	0.62	0.85	0.65
Δ Leg FM (kg)	0.08	± 0.64	−1.12	± 0.75	−0.89	± 0.69	−0.63	± 0.54	1.72	1.46	1.21
Δ VO_{2peak} ($L{\bullet}min^{-1}$)	−0.08	± 0.15	0.39	± 0.18	0.43	± 0.24	0.44	± 0.16	2.85	2.55	3.30
Δ VO_{2peak} ($ml{\bullet}kg^{-1}{\bullet}min^{-1}$)	−1.19	± 2.13	7.72	± 3.34	8.43	± 3.95	7.70	± 2.96	3.18	3.03	3.45

Observed values are expressed as means ± standard deviation. CON: no-exercise training, MICT: moderate-intensity continuous training, HIIT: high-intensity interval training, SIT: sprint interval training, BMI: body mass index, BF: percentage of body fat, FFM: fat free mass, FM: fat mass, VO_{2peak}: peak oxygen uptake.

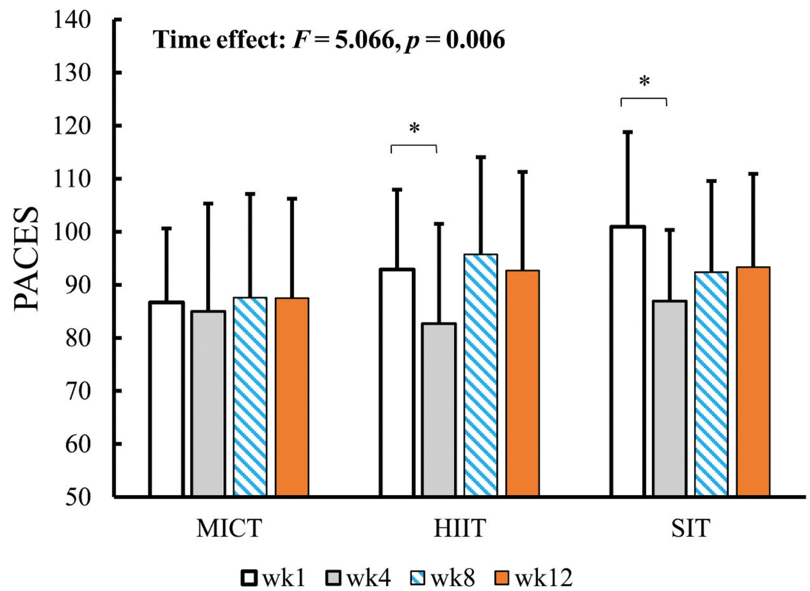

Figure 2. Scores of physical activity enjoyment scale (PACES) during the intervention *$p < 0.05$. MICT, moderate-intensity continuous training, HIIT, high-intensity interval training, SIT, sprint interval training.

young sedentary participants (Heisz et al., 2016). Our findings initially provided evidence that HIIT with 4-min intervals could be equally enjoyable as energy matched MICT during a 12-week intervention, since the aforementioned two studies both applied HIIT with shorter interval durations (i.e., 1-min). Contrary to the present work, we previously found that enjoyment scores in a similar SIT (i.e., 60 × 8 s sprint intervals interspersed with 12 s rest periods) were consistently higher than the scores in moderate to vigorous intensity continuous training (i.e., 60–80% VO_{2peak}, MVCT) during a 5-week intervention (Kong et al., 2016). The inconsistency might result from a higher intensity of MVCT in the previous study compared to the MICT protocol of this study, suggesting that the inverse relationship between enjoyment responses and exercise intensity would be clearer in continuous training mode than HIIT/SIT. Nevertheless, our findings further reinforce the notion that, due to the intermittent nature, interval training may differ from continuous training (i.e., MICT) for the negative relationship between exercise intensity and psychological perceptions (Jung et al., 2014). Greater exercise intensity and higher scores of RPE in HIIT/SIT might induce greater stimulations and feelings of accomplishment, which may also influence enjoyment responses (Stork et al., 2020). Collectively, the comparable enjoyment levels across protocols indicate that the participants actually "enjoyed" the exercise regardless of MICT, HIIT or SIT. Interestingly, enjoyment levels in MICT were relatively stable, which may contradict the assumption that MICT could be monotonous compared to interval trainings, suggesting "monotonicity" may be not the primary factor to determine the enjoyment responses to MICT. It is worth of mention that there was a large room for improvements of PACES in all the three training protocols in the current lab-based study with a between-subject design. Differences in the psychological perceptions (e.g., higher enjoyment responses) could not be excluded if within-subject design was additionally applied when each individual could have opportunities to experience all the three training protocols and choose their preferred protocol to participate in free-living settings. As such, a longitudinal study with a repeated measures cross-over design may be more helpful in manifesting the differences in individuals' perceptions to varying training protocols.

The present study added new evidence on long-term enjoyment responses to SIT compared with HIIT. Comparable enjoyment levels between SIT and HIIT suggested that the shortened sprint duration with more repetitions in SIT (i.e., 6 s sprints interspersed with 9 s rest periods) might lessen the strenuousness and mitigate the adverse feelings caused by seemingly formidable intensity. Indeed, previous short-term studies also provided evidence to support that SIT with shorter bouts was perceived equally or even more enjoyable compared to HIIT with prolonged bouts and higher training volume but relatively lower intensity (Marques et al., 2020; McKie et al., 2018; Olney et al., 2018).Collectively, despite that SIT can be categorized as a form of HIIT, the better time-efficiency and comparable enjoyment in SIT compared to HIIT could support the potential of implementing SIT in young women for improving body composition and physical fitness. However, both SIT and HIIT groups showed reductions in enjoyment levels at week 4 compared to week 1, while no further reductions in SIT and rather a significant increase in PACES scores in HIIT were generated. Decreased enjoyment levels resulting from interval training was previously found in an 8-week study targeted at untrained individuals (Foster et al., 2015), but a few studies reported contradictory findings, with enjoyment level consistently increasing (Heisz et al., 2016) or remaining at a high level in SIT (Kong et al., 2016) or HIIT (Vella et al., 2017) throughout 5–8 weeks of intervention. Specifically, this inconsistency might result from differences in characteristics of the participants, protocol designs (Stork et al., 2017), length of intervention, measurement timing, and psychological assessment (Robertson-Wilson et al., 2017). As such, employing more consistent exercise formats in targeted subjects could be of important to resolve the conflicts between interval training protocols, and more interdisciplinary approaches (i.e., exercise psychology and exercise physiology) and qualitative methods (i.e., interviews and diaries) are warranted to fairly evaluate enjoyment response to interval training modalities. Importantly, considering a potentially low adherence rate due to decreased enjoyment level during the early intervention stage, it seems reasonable to suggest that HIIT/SIT programmes designed for individuals with excess weight or low-fitness may need to provide enough encouragement and mental support to the participants in the early phase of the programme to assure long-term adherence.

The present study provides a valuable source of the long-term effects of the three most frequently adopted training protocols for improving cardiorespiratory fitness and body composition (i.e., MICT, HIIT and SIT) on enjoyment responses. To demonstrate the dynamic changes during the intervention, enjoyment responses were measured every 4 weeks across the intervention. Our study was strengthened by the RCT design with a non-exercise control group and the schedule of all training sessions between the period of three follicular stages of the participants in all training groups to avoid the impacts of the menstrual cycle on mood (Henderson & Whissell, 1997). However, this study also has some limitations. Firstly, despite the fact that we collected enjoyment responses every 4 weeks, estimations of enjoyment changes would be more precise if data were collected at more time points (i.e., every session or week). Secondly, although the participants were required to maintain their habitual daily activities throughout the study, no actual measurements were taken. Thirdly, unequal protocols adopted in the present study might unexpectedly influence changes in enjoyment responses. Specifically, in the HIIT and MICT groups, mechanical work output was set to a fixed value and workloads were adjusted according to VO_{2peak} tests conducted every 4 weeks. Therefore, participants in the HIIT and MICT groups might find it easier to perform the trainings as they gradually improved their cardiorespiratory fitness, which may positively influence enjoyment responses. In contrast, enjoyment responses might have been impacted differently in the SIT group with an increasing workload because the participants were always required to perform the interval training with “all out” effort. Additionally, given that all the training sessions were conducted under supervision in the laboratory, the present study may not be able to address the issue regarding enjoyment responses and adherence to HIIT/SIT in real-world settings. Despite that a few studies have addressed this issue and showed favourable enjoyment responses and preferences to acute (Marques et al., 2020) or short-term (Poon et al., 2020; Vella et al., 2017) HIIT/SIT in the real-world settings, more long-term studies on psychological responses are needed to underpin the applications of SIT in the overweight/obese population based on the fact that inactive populations are less familiar with engaging in interval training than MICT (Stork et al., 2020).

In conclusion, the current findings suggest that the time-efficient SIT, as a specific HIIT protocol with extremely short duration but more sprint numbers, could induce similar improvements in VO_{2peak} and body composition as well as comparable enjoyment when compared to HIIT and MICT in young women with excess weight. Therefore, SIT protocols with less time investment and mechanical work output could be worth considering by individuals who report lack of time as a major obstacle to adhering to physical activity.

Disclosure statement

The authors declare that they have no conflict of interest.

Funding

The study was supported by a research grant from University of Macau [MYRG2014-00116-FED]. The views expressed are those of the authors and not necessarily those of the UM.

ORCID

Zhaowei Kong http://orcid.org/0000-0002-9999-1312
Liye Zou http://orcid.org/0000-0001-6411-5710
Bik Chu Chow http://orcid.org/0000-0002-0282-3743
Jinlei Nie http://orcid.org/0000-0003-2326-3615

References

Aaltonen, S., Leskinen, T., Morris, T., Alen, M., Kaprio, J., Liukkonen, J., & Kujala, U. (2012). Motives for and barriers to physical activity in twin pairs discordant for leisure time physical activity for 30 years. *International Journal of Sports Medicine*, *33*(2), 157–163. https://doi.org/10.1055/s-0031-1287848

Astorino, T. A., Clark, A., De La Rosa, A., & De Revere, J. L. (2019). Enjoyment and affective responses to two regimes of high intensity interval training in inactive women with obesity. *European Journal of Sport Science*, *19* (10), 1377–1385. https://doi.org/10.1080/17461391.2019.1619840

Bauman, A. E., Reis, R. S., Sallis, J. F., Wells, J. C., Loos, R. J., Martin, B. W., & Lancet Physical Activity Series Working Group. (2012). Correlates of physical activity: Why are some people physically active and others not? The Lancet, 380(9838), 258–271. https://doi.org/10.1016/S0140–6736(12)60735–1

Biddle, S. J., & Batterham, A. M. (2015). High-intensity interval exercise training for public health: A big HIT or shall we HIT it on the head? *International Journal of Behavioral Nutrition and Physical Activity*, *12*(1), 1–8. https://doi.org/10.1186/s12966-015-0254-9

Blair, S. N., & Brodney, S. (1999). Effects of physical inactivity and obesity on morbidity and mortality: Current evidence and research issues. *Medicine and Science in Sports and Exercise*, *31*(11), S646. https://doi.org/10.1097/00005768-199911001-00025

Calle, E. E., & Thun, M. J. (2004). Obesity and cancer. *Oncogene*, *23*(38), 6365–6378. https://doi.org/10.1038/sj.onc.1207751

Cohen, J. (1992). A power primer. Quantitaitve methods in psychology. *Psychological Bulletin*, *112*(1), 155–159. https://doi.org/10.1037/0033-2909.112.1.155

Conraads, V. M., Pattyn, N., De Maeyer, C., Beckers, P. J., Coeckelberghs, E., Cornelissen, V. A., Denollet, J., Frederix, G., Goetschalckx, K., Hoymans, V. Y., Possemiers, N., Schepers, D., Shivalkar, B., Voigt, J.-U., Van Craenenbroeck, E. M., & Vanhees, L. (2015). Aerobic interval training and continuous training equally improve aerobic exercise capacity in patients with coronary artery disease: The SAINTEX-CAD study. *International Journal of Cardiology*, *179*, 203–210. https://doi.org/10.1016/j.ijcard.2014.10.155

Dallongeville, J., Bringer, J., Bruckert, E., Charbonnel, B., Dievart, F., Komajda, M., Pouchain, D., & Amouyel, P. (2008). Abdominal obesity is associated with ineffective control of cardiovascular risk factors in primary care in France. *Diabetes & Metabolism*, *34*(6), 606–611. https://doi.org/10.1016/j.diabet.2008.07.001

Fitz-Clarke, J. R., Morton, R. H., & Banister, E. W. (1991). Optimizing athletic performance by influence curves. *Journal of Applied Physiology*, *71*(3), 1151–1158. https://doi.org/10.1152/jappl.1991.71.3.1151

Fogelholm, M. (2010). Physical activity, fitness and fatness: Relations to mortality, morbidity and disease risk factors. A systematic review. *Obesity Reviews*, *11*(3), 202–221. https://doi.org/10.1111/j.1467-789X.2009.00653.x

Foster, C., Farland, C. V., Guidotti, F., Harbin, M., Roberts, B., Schuette, J., Tuuri, A., Doberstein, S. T., & Porcari, J. P. (2015). The effects of high intensity interval training vs steady state training on aerobic and anaerobic capacity. *Journal of Sports Science & Medicine*, *14*(4), 747–755.

Gillen, J. B., & Gibala, M. J. (2018). Interval training: A time-efficient exercise strategy to improve cardiometabolic health. *Applied Physiology, Nutrition, and Metabolism*, *43*(10), iii–iv. https://doi.org/10.1139/apnm-2018-0453

Hardcastle, S. J., Ray, H., Beale, L., & Hagger, M. S. (2014). Why sprint interval training is inappropriate for a largely sedentary population. *Frontiers in Psychology*, *5*, 1505. https://doi.org/10.3389/fpsyg.2014.01505

Hazell, T. J., MacPherson, R. E., Gravelle, B. M., & Lemon, P. W. (2010). 10 or 30-s sprint interval training bouts enhance both aerobic and anaerobic performance. *European Journal of Applied Physiology*, *110*(1), 153–160. https://doi.org/10.1007/s00421-010-1474-y

Heisz, J. J., Tejada, M. G. M., Paolucci, E. M., & Muir, C. (2016). Enjoyment for high-intensity interval exercise increases during the first six weeks of training: Implications for promoting exercise adherence in sedentary adults. *PloS One*, *11*(12), e0168534. https://doi.org/10.1371/journal.pone.0168534

Henderson, B. J., & Whissell, C. (1997). Changes in women's emotions as a function of emotion valence, self-determined category of premenstrual distress, and day in the menstrual cycle. *Psychological Reports*, *80* (3_suppl), 1272–1274. https://doi.org/10.2466/pr0.1997.80.3c.1272

Heydari, M., Freund, J., & Boutcher, S. H. (2012). The effect of high-intensity intermittent exercise on body composition of overweight young males. *Journal of Obesity*, *2012*, 1–8. https://doi.org/10.1155/2012/480467

Hwang, C.-L., Yoo, J.-K., Kim, H.-K., Hwang, M.-H., Handberg, E. M., Petersen, J. W., & Christou, D. D. (2016). Novel all-extremity high-intensity interval training improves aerobic fitness, cardiac function and insulin resistance in healthy older adults. *Experimental Gerontology*, *82*, 112–119. https://doi.org/10.1016/j.exger.2016.06.009

Jung, M. E., Bourne, J. E., & Little, J. P. (2014). Where does HIT fit? An examination of the affective response to high-intensity intervals in comparison to continuous moderate-and continuous vigorous-intensity exercise in the exercise intensity-affect continuum. *PloS One*, *9*(12), e114541. https://doi.org/10.1371/journal.pone.0114541

Kendzierski, D., & DeCarlo, K. J. (1991). Physical activity enjoyment scale: Two validation studies. *Journal of Sport & Exercise Psychology*, *13*(1), 50–64. https://doi.org/10.1123/jsep.13.1.50

Kirk, R. E. (1996). Practical significance: A concept whose time has come. *Educational and Psychological Measurement*, *56*(5), 746–759. https://doi.org/10.1177/0013164496056005002

Kong, Z., Fan, X., Sun, S., Song, L., Shi, Q., & Nie, J. (2016). Comparison of high-intensity interval training and moderate-to-vigorous continuous training for cardiometabolic health and exercise enjoyment in obese young women: A randomized controlled trial. *PloS One*, *11*(7), e0158589. https://doi.org/10.1371/journal.pone.0158589

Li, Z., Bowerman, S., & Heber, D. (2005). Health ramifications of the obesity epidemic. *Surgical Clinics*, *85*(4), 681–701. https://doi.org/10.1016/j.suc.2005.04.006

Lunt, H., Draper, N., Marshall, H. C., Logan, F. J., Hamlin, M. J., Shearman, J. P., Cotter, J. D., Kimber, N. E., Blackwell, G., & Frampton, C. M. A. (2014). High intensity interval training in a real world setting: A randomized controlled feasibility study in overweight inactive adults, measuring change in maximal oxygen uptake. *PloS One*, *9*(1), e83256. https://doi.org/10.1371/journal.pone.0083256

Marques, M., Alves, E., Henrique, N., & Franchini, E. (2020). Positive affective and enjoyment responses to four high-intensity interval exercise protocols. *Perceptual and Motor Skills*, *127*(4), 0031512520918748. https://doi.org/10.1177/0031512520918748

Martins, C., Kazakova, I., Ludviksen, M., Mehus, I., Wisloff, U., Kulseng, B., Morgan, L., & King, N. (2016). High-intensity interval training and isocaloric moderate-intensity continuous training result in similar improvements in body composition and fitness in obese individuals. *International Journal of Sport Nutrition and Exercise Metabolism*, *26*(3), 197–204. https://doi.org/10.1123/ijsnem.2015-0078

McKie, G. L., Islam, H., Townsend, L. K., Robertson-Wilson, J., Eys, M., & Hazell, T. J. (2018). Modified sprint interval training protocols: Physiological and psychological responses to 4 weeks of training. *Applied Physiology, Nutrition, and Metabolism*, *43*(6), 595–601. https://doi.org/10.1139/apnm-2017-0595

Metcalfe, R. S., Babraj, J. A., Fawkner, S. G., & Vollaard, N. B. (2012). Towards the minimal amount of exercise for improving metabolic health: Beneficial effects of reduced-exertion high-intensity interval training. *European Journal of Applied Physiology*, *112*(7), 2767–2775. https://doi.org/10.1007/s00421-011-2254-z

Milanović, Z., Sporiš, G., & Weston, M. (2015). Effectiveness of high-intensity interval training (HIT) and continuous endurance training for VO 2max improvements: A systematic review and meta-analysis of controlled trials. *Sports Medicine*, *45*(10), 1469–1481. https://doi.org/10.1007/s40279-015-0365-0

Moniz, S. C., Islam, H., & Hazell, T. J. (2020). Mechanistic and methodological perspectives on the impact of intense interval training on post-exercise metabolism. *Scandinavian Journal of Medicine & Science in Sports*, *30*(4), 638–651. https://doi.org/10.1111/sms.13610

Oliveira, B. R. R., Santos, T. M., Kilpatrick, M., Pires, F. O., & Deslandes, A. C. (2018). Affective and enjoyment responses in high intensity interval training and continuous training: A systematic review and meta-analysis. *PLoS One*, *13*(6), e0197124. https://doi.org/10.1371/journal.pone.0197124

Olney, N., Wertz, T., LaPorta, Z., Mora, A., Serbas, J., & Astorino, T. A. (2018). Comparison of acute physiological and psychological responses between moderate-intensity continuous exercise and three regimes of high-intensity interval training. *The Journal of Strength & Conditioning Research*, *32*(8), 2130–2138. https://doi.org/10.1519/JSC.0000000000002154

Phillips, L. K., & Prins, J. B. (2008). The link between abdominal obesity and the metabolic syndrome. *Current Hypertension Reports*, *10*(2), 156–164. https://doi.org/10.1007/s11906-008-0029-7

Poon, E. T., Little, J. P., Sit, C. H., & Wong, S. H. (2020). The effect of low-volume high-intensity interval training on cardiometabolic health and psychological responses in overweight/obese middle-aged men. *Journal of Sports Sciences*, 38(17): 1997–2004. https://doi.org/10.1080/02640414.2020.1766178

Pritzlaff, C. J., Wideman, L., Blumer, J., Jensen, M., Abbott, R. D., Gaesser, G. A., Veldhuis, J. D., & Weltman, A. (2000). Catecholamine release, growth hormone secretion, and energy expenditure during exercise vs. recovery in men. *Journal of Applied Physiology*, *89*(3), 937–946. https://doi.org/10.1152/jappl.2000.89.3.937

Robertson-Wilson, J., Eys, M., & Hazell, T. J. (2017). Commentary: Why sprint interval training is inappropriate for a largely sedentary population. *Frontiers in Psychology*, *8*, 1603. https://doi.org/10.3389/fpsyg.2017.01603

Rossiter, H., Kowalchuk, J., & Whipp, B. (2006). A test to establish maximum O2 uptake despite no plateau in the O2 uptake response to ramp incremental exercise. *Journal of Applied Physiology*, *100*(3), 764–770. https://doi.org/10.1152/japplphysiol.00932.2005

Schjerve, I. E., Tyldum, G. A., Tjønna, A. E., Stølen, T., Loennechen, J. P., Hansen, H. E., Haram, P., Heinrich, G., Bye, A., Najjar, S., Smith, G., Slørdahl, S., Kemi, O., & Wisløff, U. (2008). Both aerobic endurance and strength training programmes improve cardiovascular health in obese adults. *Clinical Science*, *115*(9), 283–293. https://doi.org/10.1042/CS20070332

Shi, Q., Tong, T. K., Sun, S., Kong, Z., Chan, C. K., Liu, W., & Nie, J. (2018). Influence of recovery duration during 6-s sprint interval exercise on time spent at high rates of oxygen uptake. *Journal of Exercise Science and Fitness*, *16*(1), 16–20. https://doi.org/10.1016/j.jesf.2018.01.001

Skleryk, J., Karagounis, L., Hawley, J., Sharman, M. J., Laursen, P. B., & Watson, G. (2013). Two weeks of reduced-volume sprint interval or traditional exercise training does not improve metabolic functioning in sedentary obese men. *Diabetes, Obesity & Metabolism*, *15*(12), 1146–1153. https://doi.org/10.1111/dom.12150

Stork, M. J., Banfield, L. E., Gibala, M. J., & Martin Ginis, K. A. (2017). A scoping review of the psychological responses to interval exercise: Is interval exercise a viable alternative to traditional exercise? *Health Psychology Review*, *11*(4), 324–344. https://doi.org/10.1080/17437199.2017.1326011

Stork, M. J., Gibala, M. J., & Martin Ginis, K. A. (2018). Psychological and behavioral responses to interval and continuous exercise. *Medicine & Science in Sports & Exercise*, *50*(10), 2110–2121. https://doi.org/10.1249/MSS.0000000000001671

Stork, M. J., Williams, T. L., & Martin Ginis, K. A. (2020). Unpacking the debate: A qualitative investigation of first-time experiences with interval exercise. *Psychology of Sport and Exercise*, *51*, 101788. https://doi.org/10.1016/j.psychsport.2020.101788

Sun, S., Zhang, H., Kong, Z., Shi, Q., Tong, T. K., & Nie, J. (2019). Twelve weeks of low volume sprint interval training improves cardio-metabolic health outcomes in overweight females. *Journal of Sports Sciences*, *37*(11), 1257–1264. https://doi.org/10.1080/02640414.2018.1554615

Thum, J. S., Parsons, G., Whittle, T., & Astorino, T. A. (2017). High-intensity interval training elicits higher enjoyment than moderate intensity continuous exercise. *PloS One*, *12*(1), e0166299. https://doi.org/10.1371/journal.pone.0166299

Tjønna, A. E., Leinan, I. M., Bartnes, A. T., Jenssen, B. M., Gibala, M. J., Winett, R. A., & Wisløff, U. (2013). Low- and high-volume of intensive endurance training significantly improves maximal oxygen uptake after 10-weeks of training in healthy men. *PloS One*, *8*(5), e65382. https://doi.org/10.1371/journal.pone.0065382

Tong, T. K., Zhang, H., Shi, H., Liu, Y., Ai, J., Nie, J., & Kong, Z. (2018). Comparing time efficiency of sprint vs. high-intensity interval training in reducing abdominal visceral fat in obese young women: A randomized, controlled trial. *Frontiers in Physiology*, *9*, 1048. https://doi.org/10.3389/fphys.2018.01048

Townsend, L. K., Islam, H., Dunn, E., Eys, M., Robertson-Wilson, J., & Hazell, T. J. (2016). Modified sprint interval training protocols. Part II. Psychological responses. *Applied Physiology, Nutrition, and Metabolism*, *42*(4), 347–353. https://doi.org/10.1139/apnm-2016-0479

Trapp, E. G., Chisholm, D. J., & Boutcher, S. H. (2007). Metabolic response of trained and untrained women during high-intensity intermittent cycle exercise. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, *293*(6), R2370–R2375. https://doi.org/10.1152/ajpregu.00780.2006

Trapp, E. G., Chisholm, D. J., Freund, J., & Boutcher, S. H. (2008). The effects of high-intensity intermittent exercise training on fat loss and fasting insulin levels of young women. *International Journal of Obesity*, *32*(4), 684–691. https://doi.org/10.1038/sj.ijo.0803781

Ul-Haq, Z., Mackay, D., Fenwick, E., & Pell, J. (2014). Association between body mass index and mental health among Scottish adult population: A cross-sectional study of 37272 participants. *Psychological Medicine*, *44*(10), 2231–2240. https://doi.org/10.1017/S0033291713002833

Vanderheyden, L. W., McKie, G. L., Howe, G. J., & Hazell, T. J. (2020). Greater lactate accumulation following an acute bout of high-intensity exercise in males suppresses acylated ghrelin and appetite postexercise. *Journal of Applied Physiology*, *128*(5), 1321–1328. https://doi.org/10.1152/japplphysiol.00081.2020

Vella, C. A., Taylor, K., & Drummer, D. (2017). High-intensity interval and moderate-intensity continuous training elicit similar enjoyment and adherence levels in overweight and obese adults. *European Journal of Sport Science*, *17*(9), 1203–1211. https://doi.org/10.1080/17461391.2017.1359679

Warburton, D. E., Nicol, C. W., & Bredin, S. S. (2006). Health benefits of physical activity: The evidence. *Cmaj*, *174*(6), 801–809. https://doi.org/10.1503/cmaj.051351

Wen, D., Utesch, T., Wu, J., Robertson, S., Liu, J., Hu, G., & Chen, H. (2019). Effects of different protocols of high intensity interval training for VO2max improvements in adults: A meta-analysis of randomised controlled trials. *Journal of Science and Medicine in Sport*, *22*(8), 941–947. https://doi.org/10.1016/j.jsams.2019.01.013

WHO expert consultation (2004). Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet (London, England)*, *363*(9403), 157–163. https://doi.org/10.1016/S0140-6736(03)15268-3

Yamagishi, T., & Babraj, J. (2017). Effects of reduced-volume of sprint interval training and the time course of physiological and performance adaptations. *Scandinavian Journal of Medicine & Science in Sports*, *27*(12), 1662–1672. https://doi.org/10.1111/sms.12831

Zhang, H., Tong, T. K., Qiu, W., Zhang, X., Zhou, S., Liu, Y., & He, Y. (2017). Comparable effects of high-intensity interval training and prolonged continuous exercise training on abdominal visceral fat reduction in obese young women. *Journal of Diabetes Research*, *2017*, 1–9. https://doi.org/10.1155/2017/5071740