Journal of Exercise Science & Fitness 20 (2022) 249–255

Contents lists available at ScienceDirect

Journal of Exercise Science & Fitness

journal homepage: www.elsevier.com/locate/jesf

High-intensity interval training elicits more enjoyment and positive affective valence than moderate-intensity training over a 12-week intervention in overweight young women

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ARTICLE INFO

Article history:
Received 29 September 2021
Received in revised form
1 May 2022
Accepted 2 May 2022
Available online 11 May 2022

Keywords:
Affective valence
Pleasure
Enjoyment
High-intensity interval training
Moderate-intensity continuous training
Repeated sprint interval training

ABSTRACT

Background/Objectives: The purpose of this study was to compare the differences in enjoyment and affect in response to four weight control intervention protocols over 12 weeks.
Methods: Sixty overweight young females were randomised into four intervention groups: repeated sprint training (RST, 6-sec all-out sprint interspersed with 9-sec rest), high-intensity interval training (HIIT) with short interval ($HIIT_{120}$, 1-min effort at 120% VO_{2peak}) and long interval ($HIIT_{90}$, 4-min effort at 90% VO_{2peak}), and moderate-intensity continuous training (MICT, 60% VO_{2peak}) by cycling over 12 weeks. The total workload in each training session in $HIIT_{120}$, $HIIT_{90}$, and MICT was confined to 200 kJ, while it was lower in RST with 57 ± 4 kJ. Enjoyment (Physical Activity Enjoyment Scale, PACES) and affective valence (Feeling Scale, FS) were measured throughout the intervention.
Results: The score of the PACES on average over 12 weeks showed a significant between-group effect that was lower in MICT (80.8 ± 11.8) compared with $HIIT_{120}$ (92.5 ± 11.4) and $HIIT_{90}$ (96.8 ± 13.9) ($p < 0.05$). In the 8th week, enjoyment was scored higher in two HIITs compared with MICT. In the 12th week, HIITs and RST were more enjoyable than MICT, where two HIITs were better than RST. The score of FS showed a significant between-group effect that was higher in $HIIT_{90}$ (1.5 ± 1.4) compared with $HIIT_{120}$ (0.2 ± 1.2) ($p < 0.05$), but a non-significant time or group-by-time interaction effect. A significant weight loss occurred in three interval training protocols ($p < 0.05$), but not in MICT. The VO_{2peak} significantly increased in four groups without between-group difference.
Conclusion: Interval training, especially the long-interval type, is an enjoyable and pleasant long-term exercise intervention for overweight young women. RST could be an alternative for weight control considering its time efficiency with comparable enjoyment and overall pleasure.

1. Introduction

Regular physical activity is recommended as an effective lifestyle strategy for weight management and health promotion. However, more than 40% of overweight adults have an insufficient amount of physical activity as recommended.[1] Lack of time is a frequently reported barrier contributing to the poor attendance and adherence to exercise.[2] To address this barrier, many studies have established high-intensity interval training (HIIT), which consists of short bursts of intense exercise interspersed with recovery phases,

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https://doi.org/10.1016/j.jesf.2022.05.001

as a time-efficient intervention for weight control and health maintenance.[3,4] Several interval training protocols manipulated with different intensities and durations in effort phases, either approximate or superior to maximal oxygen consumption (VO_{2max}), have been used in weight control.[5] HIIT can be a long-interval type with an effort phase of 85–100% VO_{2max} of 2–4 min and short interval with work phase superior (e.g., 120%) to VO_{2max} of less than 1 min. Both protocols maintain a high percentage of VO_{2max} for a certain duration during exercise which is crucial to improve cardiorespiratory fitness, especially with 120% VO_{2max} effort providing over 90% of intervals above VO_{2max}.[6] Interval training can also be repeated all-out effort within a few seconds called repeated sprint training (RST) with the greatest time efficiency.[5,7] The time-efficient interval training protocols has been proven to elicit favourable effects on fat loss and health improvement when compared to traditional moderate-intensity continuous training (MICT).[8–10] However, long-term adherence to HIIT or SIT may be too difficult for overweight population. The most tolerable and acceptable interval training protocol, if any, should be determined when intending to recommend such exercise as a lifestyle strategy among overweight adults.

Psychological responses of enjoyment and pleasure are important perceptions to exercise experience, which may lead to further adherence.[11,12] Enjoyment is emotionally and evolutionally based, involving significant cognition about the general feelings to experience and environmental context.[11,13] Affect is a direct valence response of pleasure or displeasure.[12,14] Enjoyment and affect have been shown to be determined by exercise intensity,[15,16] as there is less enjoyment when the exercise intensity increases, potentially leading to high dropout rates.[17,18] Referring to affect, dual-mode theory was developed under a traditional continuous exercise condition to suggest that intensity above the anaerobic threshold (i.e., above blood lactate concentration of 4 mmol L^{-1}) produced more negative responses.[15] The intensity of effort phase in HIIT was rather vigorous compared with MICT, but the experiences of successive accomplishment and constantly changing stimuli enabled by interspersed recovery periods[19] might strengthen enjoyment and affective response.[20]

Most studies have focused on the acute responses of enjoyment and affect after one single session of HIIT and MICT. A meta-analytical study showed similar beneficial effects of HIIT (mostly long-interval type) with MICT on enjoyment evaluated by the Physical Activity Enjoyment Scale (PACES) and affective valence measured by the Feeling Scale (FS) after acute exercise.[13] A more recent review included more comprehensive modes of exercise to obtain greater enjoyment following interval training (including HIITs and RST), with mixed results of affective responses.[21] The higher the intensity of effort, but the harder it is to achieve and persist. Given the differences in the anaerobic/aerobic contribution and the levels of the neuromuscular fatigue generated during exercise,[22] interval training protocols with the higher intensity may be less enjoyable than those with lower intensity. For example, performing the "aerobic interval training" protocol (i.e. long-interval HIIT with 90% VO_{2max}) may result in more positive affective and enjoyable responses than doing the short interval HIIT with 120% VO_{2max}, which mainly relies on anaerobic glycolytic energy. However, other variables, i.e., effort duration, recovery, and ratio of effort and recovery composing different interval training protocols may impact the psychological responses towards exercise.[20,21,23] In addition, the psychological responses towards exercise could be changed over time along with achievement of successful weight loss, improved fitness and physical activity status.[18,24,25] It was evidenced that enjoyment progressively increased following HIIT with repeated measurements over a period of 4–8 weeks.[24,26–29] However, few studies have analysed the long-term effects of HIIT (i.e., ≥12 weeks) on enjoyment and pleasure. To the best of our knowledge, only one study (Hu et al., 2021) examined the effects of 12-week interval protocols and found that interval training caused the same exercise enjoyment as MICT in overweight young women.[23] Of note, women may have different psychological responses than men, especially pain sensitivity and tolerance,[21,30] suggesting that the gender difference plays a role in exercise-induced enjoyment.

Therefore, the purpose of this study was to observe the differences in enjoyment and affect in response to four weight control intervention protocols (RST, short- and long-interval HIIT, and MICT, with descending exercise intensities) over 12 weeks to decide the most tolerable interventions for overweight young women, as well as potential impact factors (weight loss and VO_{2max}). It was hypothesised that: 1) interval training would provide higher enjoyment than continuous training, whereas the higher the training intensity the lower enjoyment responses among the three interval training protocols (i.e., long-interval HIIT > short-interval HIIT > RST); 2) the enjoyment and affective valence would fluctuate over 12-week period.

2. Materials and methods

2.1. Participants

Participants were recruited from a local university via fliers posted and distributed throughout the campus. Inclusion criteria were as follows: 1) female, age 18–23 years; 2) body mass index (BMI) > 23 kg m^{-2}, which was a cut-off point representing increased risk for public health recommended for the Asian population[31]; 3) constant body mass (±2 kg) during the past three months by self-report; 4) negative responses to all questions on the Physical Activity Readiness Questionnaire; 5) no regular physical activity (except compulsory 45-min physical education class twice per week); 6) no history of smoking; 7) no history of hormonal, orthopaedic, or cardiovascular diseases; no diabetes, hypertension, hyperlipidaemia, or polycystic ovary syndrome; and no use of prescribed medication (including contraceptive pill) in the past six months. The present study was performed in accordance with the Helsinki Declaration and approved by the Ethical Committee for the Use of Human and Animal Subjects in Research of the local university (no. 2019SC21). After fully informed about the purpose and constraint of this study, participants were provided with written informed consent.

Power analysis was conducted by G*power version 3.1.9.2 (Universitat Kiel, Germany) to estimate the target sample size. Using an ANOVA, repeated measures within-between interaction design, a sample size of 56 was required, with effect size of 0.25 for the primary outcome of enjoyment,[32] correlation of 0.6 between measures,[27] alpha of 0.05, and 80% power. Considering a dropout rate of approximately 20%, 64 participants were expected.

2.2. Study design and procedure

After initial screening, 60 eligible participants were randomised into four intervention groups, with 15 participants in each group. All participants subsequently completed two experimental sections—a procedure-experimental test and a 12-week intervention. During the experimental test, participants' height, body mass, and VO_{2peak} were measured before intervention (following familiarisation with the laboratory environment, equipment, rating scale, and questionnaire used in this study), every four weeks (24 h after the last training session in the 4th and 8th week), and after intervention. The exercise intensity (power output) in each training session (except the RST group) of the intervention was determined according to the individual VO_{2peak} and adjusted every four weeks. The 12-week intervention tallied to 44 training sessions in total, one training session per day, three days per week for the first four weeks, and then increased to four days per week until completion of the intervention. The compliance with the intervention was determined by the ratio of the training sessions missed and failed in achieving the optimising intensity and duration to the sessions completed meeting with the requirements. Enjoyment was investigated in the last training session of each week. Affective valence, heart rate, and perceived exertion were obtained in every training session of the 1st, 4th, 8th, and 12th week. Since an invasive test might influence the participants' mood, blood lactate was taken in two sessions only, which were the 3rd training session in the 1st week and the 42nd training session in the 12th week. All the experimental tests and training sessions took place in the afternoon with ambient conditions of 20 °C and 50% humidity. Participants were required to avoid strenuous exercise the day before the laboratory visit and refrained from caffeine 2 h before the visit. As we have reported previously, the averages of the estimated daily energy intake, and energy expenditure for physical activities apart from the sedentary activities and cycle ergometer training during the 3-week pre-intervention and 12-week intervention periods were recorded. Both the estimated values between the two periods, and across the four groups were not significantly different.[33]

VO_{2peak} The protocol of the graded exercise test on a cycle ergometer (Monark 839E, Sweden) has been described previously, initially 50 W with a pedal frequency of 60 rpm increased by 30 W every 3 min until volitional exhaustion.[33] Oxygen consumption during the exercise test was measured using a breath-by-breath metabolic analyser (Quark-PFT-ergo; Cosmed, Rome, Italy). VO_{2peak} was recorded as the highest value averaged every 30 s.

Intervention protocols All training sessions were conducted on a cycle ergometer, and the protocols have been described previously.[33] A standardised 10-min warm-up and 5-min cool-down were identical for the four intervention groups. During the effort phase, the pedal frequency was maintained at 60 rpm (except the RST group). During passive recovery, participants remained seated with their feet secured to the pedals by toe clips.

For the RST group, participants performed 40 bouts of 6-sec all-out sprint followed by 9-sec passive recovery on a Wingate cycle ergometer (Monark 894E, Sweden) in one training session. At the last 5 s of each recovery phase, the participant was supervised by countdown and then started to accelerate with minimum friction applied to the flywheel in the last 2 s. At the start of sprint, the pre-set load was applied instantaneously with an electromagnetic device. The load was begun at 0.5 to 1 kp and increased by 0.5 kp whenever the participant demonstrated adaptation until the completion without undue fatigue. For the HIIT with short interval ($HIIT_{120}$), participants repeated a 1-min effort at 120% VO_{2peak}, followed by a 1.5-min passive recovery. For the HIIT with long interval ($HIIT_{90}$), participants repeated a 4-min effort at 90% VO_{2peak}, followed by a 3-min passive recovery. For the MICT group, participants performed continuous cycling at 60% VO_{2peak}. In $HIIT_{120}$, $HIIT_{90}$, and MICT, participants accomplished a total workload of 200 kJ on an electronically braked cycle ergometer (Monark 839E, Sweden) in each training session. Exercise intensities (power outputs) that elicited approximately 120%, 90%, and 60% VO_{2peak} were estimated based on a linear relationship between steady-state oxygen consumption and power output. The corresponding training information, including work, exercise intensity (power output), and duration, is shown in Table 1.

2.3. Measurements

Enjoyment Enjoyment was assessed by the PACES, a questionnaire with 18 semantic-differential items using a 7-point Likert scale (1, I hate it; 7, enjoy it) including 11 reverse-coded items, with a total score of 126.[34] The PACES was completed by all participants immediately after the 5-min cool-down. The Cronbach's alpha value was 0.875 in the present study, indicating good internal consistency.

Affective valence Affective valence (pleasure/displeasure) was assessed by the FS, an 11-point single-item rating scale from −5 (very bad) to 0 (neutral) to +5 (very good).[35] The FS was reported by the participants and confirmed by the investigator in a neutral tone of voice. Considering that affect towards exercise changed over time during one training session,[16] FS scores were obtained at the end of the effort phase and administered at the following four percentages of bout duration: 25%, 50%, 75%, and 100% to completion of each training session. FS scores were averaged over each training session. The Cronbach's alpha value was 0.879 in the present study, representing good internal consistency.

Heart rate Heart rate was continuously recorded by telemetry (Polar, Lake Success, NY) and averaged over each training session.

Perceived exertion Perception of exertion was assessed by the validated Rating of Perceived Exertion (RPE), a 15-point scale from 6 (no exertion) to 20 (maximal exertion) by self-report.[36] The RPE was acquired similar to the FS at each measurement.

Blood lactate In each scheduled session, blood samples were taken twice, before and immediately after exercise. The concentration of blood lactate from the fingertip was assessed by a handheld analyser (h/p/cosmos Sirius, Germany), while the first drop of blood was discarded to avoid contamination.

2.4. Statistical analysis

Data were expressed as means ± standard deviation and analysed using SPSS 24.0 (Chicago, IL, USA). The Shapiro–Wilk test was used to assess normality. The scores of PACES and FS, as well as heart rate and RPE of every training session in the 1st, 4th, 8th, and 12th week were averaged and assessed by two-way (4 groups and 4 time points), mixed ANOVA with repeated measures. Two-way mixed ANOVA was also conducted for body mass, VO_{2peak} (4 groups and 2 time points, i.e., pre and post 12 weeks intervention) and blood lactate (4 groups and 2 time points, i.e., post 3rd and 42nd training session). When the sphericity assumption was violated, the Greenhouse–Geisser correction was used. Significant group-by-time interaction and main effects of group and time were followed by Bonferroni-corrected pairwise comparisons when appropriate. Significance was set as $p \leq 0.05$.

3. Results

Four participants (one in each group) dropped out due to personal reasons, including time conflict or sickness unrelated to this study. Finally, 56 participants remained in the data analysis. As shown in Table 1, there was no difference in age, height, body mass, and VO_{2peak} among the four groups before intervention. The compliance with training was 99.4 ± 1.5%, 93.8 ± 3.8%, 97.5 ± 2.8%, and 99.8 ± 0.7% for RST, $HIIT_{120}$, $HIIT_{90}$, and MICT, respectively. No adverse events were reported during the experimental test and intervention.

3.1. Difference in response to enjoyment and affect among four groups over 12 weeks

3.1.1. Enjoyment

The score of the PACES showed a significant between-group effect ($F = 9.63$, $p < 0.001$, $\eta^2 = 0.36$, power = 0.89) that was lower in MICT (80.8 ± 11.8) compared with $HIIT_{120}$ (92.5 ± 11.4) and

Table 1
Participant characteristics and training protocols.

		RST (n = 14)	$HIIT_{120}$ (n = 14)	$HIIT_{90}$ (n = 14)	MICT (n = 14)
Participant characteristics					
Age (years)	Before	20.7 ± 1.7	19.9 ± 1.7	19.7 ± 1.0	20.7 ± 2.2
Height (cm)	Before	161.8 ± 5.5	163.0 ± 2.9	160.5 ± 6.3	159.4 ± 6.2
Body mass (kg)[a]	Before	67.1 ± 6.8	70.6 ± 10.2	67.4 ± 8.0	64.2 ± 8.4
	After	63.5 ± 5.6 [c]	68.6 ± 9.8 [c]	63.6 ± 6.8 [c]	63.5 ± 8.4
	Reduction (%)	−5.2 ± 3.2	−2.8 ± 2.9	−5.4 ± 5.4	−1.0 ± 2.6
VO_{2peak} (ml.kg^{-1}.min^{-1})[b]	Before	27.5 ± 3.4	26.0 ± 4.1	28.1 ± 2.6	29.0 ± 2.9
	After	33.8 ± 3.1 [c]	35.2 ± 5.1 [c]	36.6 ± 4.0 [c]	34.2 ± 3.6 [c]
	Increase (%)	23.9 ± 13.0	36.8 ± 16.7	30.8 ± 13.6	18.4 ± 10.5
Training protocols					
Protocol	Effort	6 s	1 min	4 min	/
	Effort intensity	all out	120% VO_{2peak}	90% VO_{2peak}	60% VO_{2peak}
	Recovery	9 s	1.5 min	3 min	/
Work (kJ)	Week 1–4	49 ± 4	200	200	200
	Week 5–8	57 ± 4	200	200	200
	Week 9–12	65 ± 6	200	200	200
	Week 1–12	**57 ± 4**	**200**	**200**	**200**
Exercise intensity (power output) (W)	Week 1–4	203 ± 18	157 ± 17	118 ± 12	55 ± 9
	Week 5–8	239 ± 17	189 ± 18	133 ± 13	61 ± 8
	Week 9–12	270 ± 25	200 ± 24	145 ± 14	64 ± 9
	Week 1–12	**237 ± 18**	**182 ± 17**	**132 ± 12**	**60 ± 8**
Exercise duration (min)	Week 1–4	4	21 ± 2	29 ± 3	62 ± 11
	Week 5–8	4	18 ± 2	25 ± 3	56 ± 7
	Week 9–12	4	17 ± 2	23 ± 2	53 ± 7
	Week 1–12	**4**	**19 ± 2**	**26 ± 3**	**57 ± 8**

VO_{2peak}, maximal oxygen consumption.
RST, repeated sprint training, 6-s all-out sprints interspersed with 9-s rest; $HIIT_{120}$, high-intensity interval training with short interval, 1-min effort at 120% VO_{2peak} followed by 1.5-min rest; $HIIT_{90}$, high-intensity interval training with long interval, 4-min effort at 90% VO_{2peak} followed by a 3-min rest; MICT, moderate-intensity continuous training, continuous cycling at 60% VO_{2peak}.
[a] Effects of group, $p = 0.276$; time, $p < 0.001$; group × time, $p = 0.013$.
[b] Effects of group, $p = 0.473$; time, $p < 0.001$; group × time, $p = 0.006$.
[c] Significantly different from corresponding level before intervention, $p < 0.05$.

$HIIT_{90}$ (96.8 ± 13.9). As shown in Fig. 1(a), the score of the PACES showed a group-by-time interaction ($F = 2.95$, $p < 0.001$, $\eta^2 = 0.15$, power = 0.99). During the 12-week intervention, the score of the PACES was significantly increased in the 12th week in $HIIT_{90}$ compared with the 8th week. In the 8th week, enjoyment was scored higher in two HIITs compared with MICT. In the 12th week, HIITs and RST were more enjoyable than MICT, where two HIITs were better than RST.

3.1.2. Affective valence

The score of FS showed a significant between-group effect ($F = 4.47$, $p = 0.007$, $\eta^2 = 0.21$, power = 0.65) that was higher in $HIIT_{90}$ (1.5 ± 1.4) compared with $HIIT_{120}$ (0.2 ± 1.2). The FS showed a non-significant time or group-by-time interaction effect as shown in Fig. 1(b).

3.2. Potential impact factors on enjoyment and affect responses

3.2.1. Exercise intensity

The intensity of exercise was monitored by heart rate (Fig. 1(c)), RPE (Fig. 1(d)), and blood lactate (Table 2).

Heart rate revealed a between-group ($F = 89.95$, $p < 0.001$, $\eta^2 = 0.84$, power = 1.0) and time effect ($F = 27.64$, $p < 0.001$, $\eta^2 = 0.62$, power = 0.99), as well as group-by-time interaction ($F = 1.94$, $p = 0.05$, $\eta^2 = 0.10$, power = 0.99).

Regarding RPE, there were a significant between-group ($F = 127.86$, $p < 0.001$, $\eta^2 = 0.88$, power = 1.0) and time effect ($F = 5.23$, $p = 0.002$, $\eta^2 = 0.25$, power = 0.64), but no-significant interaction. Interval trainings attained a higher RPE than MICT (12.6 ± 1.0), where $HIIT_{120}$ (17.3 ± 1.2) was harder than RST (16.4 ± 1.2) and $HIIT_{90}$ (16.2 ± 1.2).

Post-exercise blood lactate revealed a between-group effect ($F = 27.07$, $p < 0.001$, $\eta^2 = 0.69$, power = 1.0). Blood lactate level in two HIITs and RST were above 9 mmol L^{-1}, which were significantly higher than MICT (~4 mmol L^{-1}).

3.2.2. Weight loss

Body mass showed a time effect ($F = 46.72$, $p < 0.001$, $\eta^2 = 0.47$, power = 0.99) and a group-by-time interaction ($F = 3.97$, $p = 0.013$, $\eta^2 = 0.19$, power = 0.99), which significantly decreased in three interval training protocols after 12-week intervention without between-group difference (Table 1). Detailed percentages of changes in body mass before and every four weeks during the intervention are shown in Fig. 1(e).

3.2.3. VO_{2peak}

VO_{2peak} also showed a time effect ($F = 281.23$, $p < 0.001$, $\eta^2 = 0.84$, power = 1.0) and a group-by-time interaction effect ($F = 4.69$, $p = 0.006$, $\eta^2 = 0.21$, power = 0.99), which significantly increased in the four groups after intervention without between-group difference (Table 1). Detailed percentages of changes before and every four weeks during the intervention are shown in Fig. 1(f).

4. Discussion

In the present study, our first hypothesis that interval training would result in better psychological responses than continuous training has been confirmed. Interval training, especially long-interval type (i.e., $HIIT_{90}$), was perceived more enjoyable and resulted in comparably positive feelings of pleasure towards exercise over 12 weeks, when compared with MICT. Further, we have not observed the associations between the lower intensity and the better psychological responses among the three interval training protocols. Referring to the second hypothesis, participation in long-interval HIIT group benefited more enjoyment from 12th week. In the 8th week, the two HIIT protocols were proved to be more

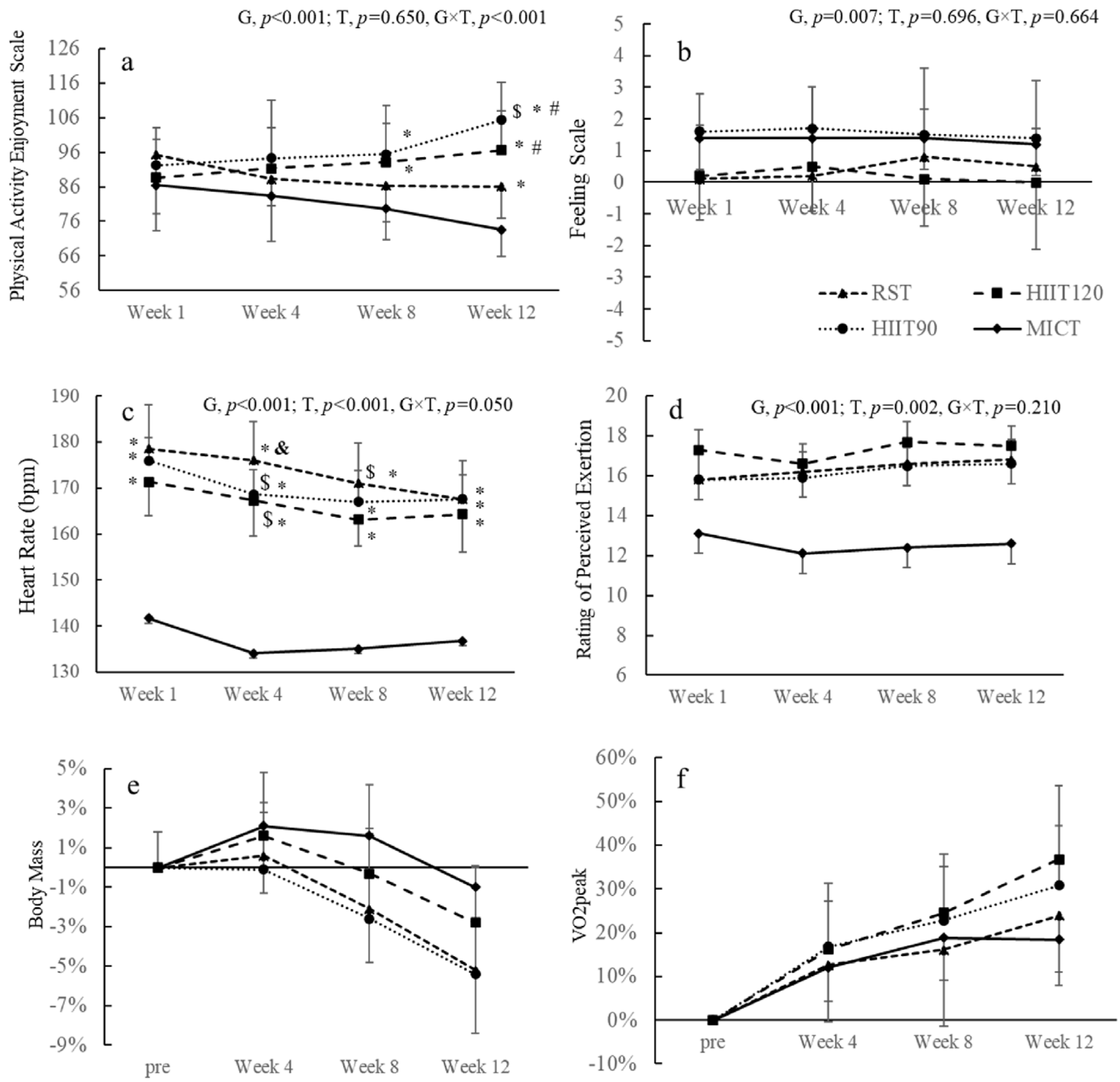

Fig. 1. Score of the Physical Activity Enjoyment Scale (a), Feeling Scale (b), heart rate (c), and Rating of Perceived Exertion (d) of 1st, 4th, 8th, and 12th week across four groups; percent of changes in body mass (e) and VO_{2peak} (f) every four weeks.
VO_{2peak}, maximal oxygen consumption ; RST, repeated sprint training, 6-s all-out sprints interspersed with 9-s rest; $HIIT_{120}$, high-intensity interval training with short interval, 1-min effort at 120% VO_{2peak} followed by 1.5-min rest; $HIIT_{90}$, high-intensity interval training with long interval, 4-min effort at 90% VO_{2peak} followed by a 3-min rest; MICT, moderate-intensity continuous training, continuous cycling at 60% VO_{2peak}. $^{\$}$, significantly different from corresponding levels of the previous time point, $p < 0.05$; *, significantly different from corresponding levels of MICT group, $p < 0.05$; $^{\#}$, significantly different from corresponding levels of RST group, $p < 0.05$; $^{\&}$, significantly different from corresponding levels of $HIIT_{120}$ group, $p < 0.05$.

Table 2
Concentration of serum blood lactate ($mmol.L^{-1}$) pre and post 3rd and 42nd training session.

		RST (n = 14)	$HIIT_{120}$ (n = 14)	$HIIT_{90}$ (n = 14)	MICT (n = 14)
3rd training session in week 1	pre	2.1 ± 0.4	2.0 ± 0.7	2.2 ± 1.0	1.9 ± 0.3
	post	13.1 ± 3.9	11.8 ± 3.5	9.6 ± 3.8	4.3 ± 2.3
42nd training session in week 12	pre	1.9 ± 0.3	2.1 ± 0.4	2.0 ± 0.4	1.7 ± 0.3
	post	11.2 ± 2.6	11.4 ± 3.4	9.2 ± 2.4	3.6 ± 1.5

RST, repeated sprint training, 6-s all-out sprints interspersed with 9-s rest; $HIIT_{120}$, high-intensity interval training with short interval, 1-min effort at 120% VO_{2peak} followed by 1.5-min rest; $HIIT_{90}$, high-intensity interval training with long interval, 4-min effort at 90% VO_{2peak} followed by a 3-min rest; MICT, moderate-intensity continuous training, continuous cycling at 60% VO_{2peak}.
Effects of group, $p < 0.001$; time, $p = 0.166$; group × time, $p = 0.814$.

enjoyable than MICT; whereas in the 12th week, the three interval training protocols attained more enjoyment than MICT, with the best of the two HIITs.

Our results showed better benefit of interval training upon enjoyment but mixed effect on pleasure when taking average to the score of PACES and FS across 12 weeks, which were consistent with majority of the previous studies analysing acute responses to interval training. A meta-analytical study conducted by Oliveira et al. (2018) showed six in 10 comparisons with small effect of benefits of HIIT on enjoyment compared to MICT.[13] For the FS, six of 12 comparisons presented positive but trivial effects with HIIT. Most of the HIIT protocols included were long-interval type (approximately 85–100% maximal work capacity, 2–4 min).[13] Another recent meta-analytical study also found greater enjoyment in HIIT due to recovery between effort phases, constantly changing stimuli, and time efficiency when compared with MICT.[21]

The inconsistence results of psychological responses among interval training protocols may be explained by the exercise modes with various intensities and interval durations. Nevertheless, in the current study, the HIITs and the RST had the similar HR (~160–170 bpm), RPE (~16–17) and blood lactate (~10–13 mmol L^{-1}), indicating comparable intensities among the three interval training protocols, while the $HIIT_{90}$ resulted in higher affective response when compared to the $HIIT_{120}$ despite comparable enjoyment. Thus, it is plausible that other factors (i.e., longer recovery periods in $HIIT_{90}$) could be more important in understanding the different responses to exercise protocols. Nevertheless, lower enjoyment and pleasure were observed in HIIT protocols with high intensity and long interval duration. However, some studies reported inconsistency of enjoyment and affect reported among various interval training protocols.[37,38] The different emphases of enjoyment (i.e., affective judgments involving cognitive processing) and core affect (i.e., immediate feelings of pleasure or unpleasure)[23] may interpret the discrepant findings regarding enjoyment and affect valences among the three interval training protocols.

Along with long-term physiological adaptations, responses of enjoyment and affect toward exercise might shift over time, as both related to exercise experiences to predict further exercise behaviours. Regarding enjoyment, our study found that interval training, especially HIITs, was perceived to be more enjoyable by overweight women during the 12-week weight control intervention. The effects of training-induced changes in enjoyment shifted from the 8th to the 12th week with long- and short-interval HIIT and the 12th week with RST. In Heisz et al.'s (2016) study, enjoyment of long-interval HIIT was increased with training especially in the 5th week in healthy sedentary adults.[24] In their study, the VO_{2max} increased from 31.8 to 35.8 ml $kg^{-1}.min^{-1}$ in HIIT, and 30.2–33.1 ml $kg^{-1}.min^{-1}$ in MICT. Vella et al. (2017) failed to observe training-induced changes in enjoyment (100.1 ± 4.3 and 100.3 ± 4.4 with HIIT and MICT, respectively) across 8 weeks in unsupervised HIIT (1-min effort). Exercise adherence was 93.4 ± 3.1 and 93.1 ± 3.7% for HIIT and MICT, respectively. VO_{2max} achieved better improvements in the HIIT group (2.6 ml $kg^{-1}.min^{-1}$) than MICT (0.4 ml $kg^{-1}.min^{-1}$).[27] In the study conducted by Kong et al. (2016), RST with 8-sec all-out effort and 12-sec passive rest with 60 repetitions was more enjoyable than MICT across 5-week training.[26]

Regarding affective responses, overall affective valence was positive in three interval training protocols in our study but without significant changes over 12 weeks. There were limited data on changes of affective valence over time in different types of interval trainings. Kong et al. (2020) demonstrated a similar score of the FS after exercise in RST (1.3–1.4) and MICT (1.5–1.6) without group and time effect across 6 weeks of intervention in overweight young women.[29] Astorino et al. (2019) found a reduction in FS score from the beginning to the end of exercise in two HIIT protocols with 1–2-min effort duration. The FS was 1.5–2.2 across 6 weeks in HIIT with low workload, which was 0.4–2.0 units higher than HIIT with high workload.[28] Thus, affective valence yielded an unstable trend across the whole intervention.

Fulfilled expectations of successful weight loss and better fitness might contribute to training-induced changes in enjoyment among overweight young women.[18] In our study, participants' self-efficacy and competency could be improved by achieving weight loss (from the 8th week) and/or increased aerobic capacity, evidenced with $HIIT_{90}$ yielding the highest weight loss and $HIIT_{120}$ having nearly a 40% increase in maximal exercise capacity. Specifically, participants could not be refrained from tracking their weight because it would be easily measurable by themselves. Those participants (i.e., in $HIIT_{90}$) having subsequently reduced body weight would have felt greater achievement (i.e., improved exercise self-efficacy) with training. Similarly, although our participants were blinded to the power output of the training load, along with the increased VO_{2peak}, they should have felt it easier to complete training sessions (i.e., improved exercise competency) in the later training period. Thus, besides the fact that exercise modes of HIITs enabled experiences of successive accomplishment and constantly changing stimuli, fulfilled expectation of weight control and fitness status could have impacts on the positive psychological responses associated with HIIT in a long-term manner.

A limitation of our study was that the intervention was conducted in lab-based settings. Enjoyment and affective valence were favourable in long-interval HIIT, but the changes of participants' exercise behaviour in real-life settings were not followed after the 12-week intervention. In this circumstance, we could only predict the adherence to exercise by the psychological responses without further confirmation. The dropout rate of 6.7% was equal in the four groups during training under supervision. The compliance with training sessions of intervention was 99.4 ± 1.5%, 93.8 ± 3.8%, 97.5 ± 2.8%, and 99.8 ± 0.7% for the RST, $HIIT_{120}$, $HIIT_{90}$, and MICT groups, respectively, suggesting it might be easier for overweight young participants in long-interval HIIT and MICT to complete training sessions. As the participants were recruited from a local teacher training university, the compliance and adherence were high compared with data commonly reported in the overweight of a 10–80% adherence rate.[18] Further studies should be conducted to observe the longitudinal exercise behaviour changes of overweight young women by follow-up in real life.

5. Conclusion

Interval training, especially the long-interval type with 4-min effort at 90% VO_{2peak}, is an enjoyable and pleasant long-term exercise intervention for overweight young women. RST with 6-sec all-out sprint followed by a 9-sec recovery could be an alternative for weight control considering its time efficiency with comparable enjoyment and overall pleasure.

Funding information

This research was funded by Hebei Social Science Foundation, China (grant no. HB20TY009).

Author statement

Conception and design of study: H. F. Zhang, Z. W. Kong, B. C. Chow, F. F. Li; acquisition of data: X. G. Zhu, D. D. Zhang; analysis and/or interpretation of data: F. F. Li, H. F. Zhang, Z. W. Kong, B. C. Chow;

Drafting the manuscript: F. F. Li, H. F. Zhang, Z. W. Kong; revising the manuscript critically for important intellectual content: B. C. Chow, W. Liang, B. R. Shang, Y. Liu.

Approval of the version of the manuscript to be published (the names of all authors must be listed):

Declaration of competing interest

No potential conflict of interest was reported by the authors.

Acknowledgments

All persons who have made substantial contributions to the work reported in the manuscript (e.g., technical help, writing and editing assistance, general support), but who do not meet the criteria for authorship, are named in the Acknowledgments and have given us their written permission to be named. If we have not included an Acknowledgments in our manuscript, then that indicates that we have not received substantial contributions from non-authors.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jesf.2022.05.001.

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