

Effects of five weeks of self-paced and prescribed high-intensity interval exercise on perceptual responses, body composition, aerobic capacity, blood glucose, and lipid profile in overweight-to-obese adults.

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Published online: March 31, 2023

(Accepted for publication March 15, 2023)

DOI:10.7752/jpes.2023.03079

Abstract

Background: Evidence has shown that when overweight/obese individuals are permitted to self-pace their exercise intensity during a continuous exercise, it tends to generate a greater positive affective response (pleasurable) compared to the prescribed-based exercise, but these have yet to be explored in the context of high-intensity interval exercise (HIIE) in overweight and obese adults. We examined the health parameters (body composition, aerobic capacity, blood glucose, total cholesterol, triglyceride, HDL, and LDL) and perceptual responses (affective, enjoyment and perceived exertion) during prescribed HIIE (P-HIIE) and self-paced HIIE (S-HIIE) across a 5-week exercise intervention in overweight and obese adults. **Methods:** Twenty inactive men and women (mean $\pm$ SD; aged 26.7 ± 4.9 years old; BMI = 27.5 ± 4.2 ; PA levels = 482 ± 333 MET-min/week) were randomized to 5 weeks of P-HIIE (n=10; 6-8 $\times$ 1-min work-intervals at 90% of maximal aerobic speed) or S-HIIE (n=10; 6-8 $\times$ 1-min work-intervals at self-paced intensity), both for three days in a week (15 sessions in total). Perceptual responses observed in session 1, session 8, and session 15 were analyzed. Whereas health parameters were measured before and after 5 weeks exercise intervention. **Results:** P-HIIE group elicited lower affective responses across all work interval compared to S-HIIE group in session 1 (all $P < 0.03$, all $ES > 0.66$). Both groups generated greater post-enjoyment in session 8 and session 15 compared to session 1 (all $P < 0.02$, all $ES > 0.60$). Also, both P-HIIE and S-HIIE groups produced an enhancement in aerobic capacity ($P < 0.01$, $ES > 0.71$), but no significant between-group differences in the change of the pre- and post-measures of health markers. **Conclusion:** S-HIIE and P-HIIE protocols produce a comparable effect of perceptual responses and aerobic capacity over a 5-week exercise intervention in the overweight and obese cohort, indicating the viability and adoption of this protocol for health promotion in overweight and obese adults.

Keywords: affect, enjoyment, exercise intervention, interval exercise, overweight, obese

Introduction

The prevalence of overweight and obesity has reached global epidemic levels in many developing countries including Malaysia. According to the National Health Morbidity Survey (NHMS, 2019), the prevalence of overweight or obese adults continues to incline from 2006 to 2019 (28.6%, 14.2% vs. 30.4%, 19.7%, respectively) among Malaysian populations. Available evidence demonstrates an inverse association between physical activity (PA) levels with the risks of overweight and/or obesity in adult (Church et al., 2011; Preiss et al., 2015). These observations, however, contradict with the findings from Malaysia adult-based studies which have shown an increased number of moderate intensity PA participation, despite increasing incidence of overweight and obesity (NHMS, 2019). This valuable finding may suggest that moderate intensity PA may not be sufficient to reduce the risk of overweight and obesity in adults. This is not surprising given the mechanism of body weight reduction, which requires a prolonged duration for low to moderate intensity activities. Consequently, there is a strong rationale to study alternative PA modalities in overweight and obese adults, with one strategy focusing on vigorous intensity PA.

One of the modalities that may be used to deliver vigorous intensity PA is high-intensity interval exercise (HIIE) (Gibala, 2007). HIIE involves with a brief repeated bursts of relatively intense or near maximal effort exercise interspersed by low-to moderate-intensity exercise (Buchheit & Laursen, 2013). This specific exercise modality has attracted a lot of attention from exercise researchers given its time advantage. Specifically, HIIE can be delivered in a much shorter duration to achieve similar benefits of low to moderate exercise of longer duration. Despite wealth of available evidence concerning the timesaving advantages (i.e., 2 to 10 weeks interventions) of HIIE for health-enhancing adaptations in overweight and obese adults (Batacan Jr. et al., 2017; Wewege et al., 2017), the application of HIIE as a public health strategy is controversial. This is mainly due to the high-intensity nature of HIIE protocol will generate negative affective responses (feelings of displeasure) and greater exertional stress, thus leading to poor behavioural maintenance and engagement in long-term basis (Biddle & Batterham, 2015). Consequently, the adoption of HIIE to improve the health and well-being of overweight and obese adults is unclear.

There is available evidence demonstrate the affective responses (i.e., feelings pleasure and displeasure) to HIIE in adults (Oliveira et al., 2018; Stork et al., 2017), but the observations are contradictory between studies. Some studies (Decker & Ekkekakis, 2016; Oliveira et al., 2013) have revealed that individuals may engage to HIIE because they will find it pleasant (positive affective response), while others (Jung et al., 2014; Martinez et al., 2015) find it unpleasant (negative affect response) and therefore be unlikely to repeat the exercise behaviour. The dissimilar findings observed across studies may be attributed to the different work intensity employed within each study (e.g., 70% to 100% of maximal exercise capacities), indicating that the prescription of inappropriate work intensity may hamper the preservation of pleasurable feelings during HIIE. Therefore, it is pertinent to elucidate the role of work intensity for facilitating the maintenance and adoption of HIIE while fostering health adaptations in overweight and obese adults.

An important consideration in the formation of behavioural maintenance and exercise adherence is autonomy and a useful framework in understanding autonomous regulation is Self-Determination Theory (Deci & Ryan, 1985). This theory postulates that autonomous behavior is likely to be achieved when individual engage in behavior for intrinsic reasons out of inherent pleasure and interest in the activity. Indeed, consideration of preserving or maintaining pleasurable feelings during HIIE is important because negative affective responses (unpleasant feelings) may reduce the likelihood that individuals will continue it in future (Rhodes & Kates, 2015; Williams, 2008). Following this logic, provision of a self-paced activity, instead of externally enforced pace, is likely to enhance intrinsic motivation, and consequently perception of pleasure and enjoyment. Indeed, prior studies have shown that when overweight or obese individuals are permitted to self-pace their exercise intensity during a continuous exercise, it tends to generate greater positive affect compared to the researchers' prescribed intensity (Ekkekakis, 2009). However, a single study has evaluated affective responses to self-paced cycling HIIE and prescribed HIIE in physically active men (Kellogg et al., 2018). The authors reported that self-selected cycling HIIE elicited lower affective responses compared to imposed cycling HIIE, indicating that that the degree of autonomy possessed during self-selected HIIE may lead to a greater pleasurable feeling compared to the imposed HIIE protocol, but these have yet to be explored in the context of other HIIE mode (e.g., running) in overweight and obese adults. Documenting this information will enable health practitioner or researchers to design HIIE accurately, effectively, and safely in overweight and obese populations. Therefore, the purpose of the current study is to investigate the effects of 5 weeks self-paced HIIE and prescribed HIIE on perceptual responses (i.e., affective, enjoyment and perceived of exertion) and health markers (i.e., cardiorespiratory fitness, blood pressure, blood glucose, lipid profile, and body composition) in overweight men and women.

Methods

Participants

Twenty overweight and obese adults (8 men and 12 women; 21-34 years old) volunteered to partake in this study. Participants were categorised as overweight-to obese ($BMI = 23-30 \text{ kg.m}^{-2}$) based on overweight-to-obese Asian populations classification (Mahase, 2022). Participants were excluded from the study if they had previously involved in any exercise program within the past 3 months or had contraindications to exercise according to the Physical Activity Readiness Questionnaire. All participants were physically inactive (Category 3, <600 MET-min/week) as assessed by the Malay language version of the International Physical Activity Questionnaire IPAQ-M (Shamsuddin et al., 2015). Written informed consent was acquired from all participants and the protocol was approved by the Human Research Ethics Committee (USM/JEPeM/19120848). Participants were recruited through E-mail announcements, media socials (e.g., WhatsApp and Facebook) and flyers.

Experimental overview

This study incorporated a repeated measure, within-subjects, parallel group design, whereby each participant was assigned into two different HIIE conditions: prescribed HIIE (P-HIIE) and self-paced HIIE (S-HIIE) across a 5-week exercise intervention. The randomization between these two groups were stratified by gender (4 men and 6 women for each group). The first visit (pre-test measurements and familiarization) was to measure anthropometric variables, metabolic outcomes (i.e., blood glucose and lipid profile), determine cardiorespiratory fitness and familiarization of experimental protocol. Subsequently participants completed a 5-week exercise intervention consisting of S-HIIE and P-HIIE, with three exercise sessions per week (total of 15 sessions) in the laboratory-based setting and separated by a minimum two-day rest period (48 hours) between sessions. Perceptual responses consisting of affective responses (feelings of pleasure and displeasure), enjoyment and perceived exertion were measured during each HIIE session. All exercise sessions were performed on motorized treadmill (h/p/cosmos, Nussdorf-Traun-stein, Germany) at the same time of the day between the hours of 08:00 to 13:00 in order to minimize the effects of diurnal biological variation. After the 5-week intervention period, all the measurements carried out in the first visit were repeated with ultimately no less than four days (96 hours) following the final exercise training session. The laboratory temperatures and humidity were set similar across conditions (temperatures = 25-26 °C and humidity 55-60%).

Anthropometric, physical activity measures, and energy expenditure

Body mass and stature were measured to the nearest 0.1 kg and 0.1 cm, respectively. Body mass index (BMI) was calculated as body mass (kg) divided by stature (m) squared. Participants' daily habitual physical activity was measured using validated IPAQ-M prior to the experimental visits (Shamsuddin et al., 2015).

Participants were required to self-report their dietary intake during the first, third, and last week of the exercise intervention period. Subsequently, dietary intake records were analysed by a member of the research team using nutritional software (Nutritics V 4.267 Academic Edition, Dublin, Ireland) to assess the type and amount of food consumption. Participants were encouraged to avoid deviation from their normal dietary practices for the duration of the study and to maintain normal lifestyle. Also, energy expenditure during HIIE session for both groups was calculated as according to the compendium of PA (2011).

Determination of cardiorespiratory fitness

Participants were habituated to the motorised treadmill before completing an incremental speed-based protocol to establish maximal oxygen uptake ($\dot{V}O_{2max}$) and the ventilatory threshold (VT). Participants began a warm-up at a speed of 4.0 km.h⁻¹ for 3 min, followed by running at the speed of 6.0 km.h⁻¹ with 0.5 km/h increments every 30 s until volitional exhaustion, before a 5 min cool down at 4.0 km.h⁻¹. Throughout the incremental test, the treadmill gradient was set at 1%. HR was measured continuously using a telemetry system (Polar Electro, Kempele, Finland) and the highest HR achieved during the incremental speed test was taken as HR_{max}. This protocol has been used previously for determining maximal aerobic speed (MAS) in physically active adults (Laurent et al., 2014).

Expired gas exchange and ventilation variables during the cardiorespiratory fitness test was measured using a calibrated metabolic cart (Cortex Metalyzer III B, Leipzig, Germany). HR responses were recorded continuously using a telemetry system (Polar Electro, Kempele, Finland). Both gas exchange and HR data were subsequently averaged over 10-s intervals. The VT was determined from the incremental test data using the ventilatory equivalents for carbon dioxide ($\dot{V}CO_2$) and $\dot{V}O_2$ production. $\dot{V}O_{2max}$ was determined as the highest 10-s average in $\dot{V}O_2$ elicited either during the incremental or supramaximal test. Both maximal HR and MAS (HR_{max}) were taken as the highest HR (in bpm) and speed (in km.h⁻¹) achieved during the incremental speed tests, respectively.

HIIE protocols

Participants completed a 5-week HIIE intervention consisting of a 3-min warm-up at 4.0 km.h⁻¹ followed by 7 - 9 x 1-min work-intervals performed at either 90% MAS determined from the incremental test (P-HIIE group) or self-paced intensity (S-HIIE group) interspersed with 75 s active recovery. The number of work intervals (repetitions), starting from 7, were progressively increased by 1 after every two weeks of training session in both groups. For the S-HIIE group, immediately after the warm-up, participants were asked to begin the session by setting the treadmill to the highest possible speed they felt they could maintain for 1 minute knowing they need to perform 7 to 9 repetitions. Participants also were informed that there was no right, or wrong speed rather just set the belt at the speed they feel is their highest effort given the testing situation. Participants were allowed to adjust their running speed every 10 s before the end of each work interval during S-HIIE. In both P-HIIE and S-HIIE groups, participants dismounted the treadmill during the active recovery periods and were encouraged to pace around the laboratory to avoid any venous pooling and feeling lightheaded. Heart Rate (HR) was recorded continuously during the HIIE conditions, but no expired gases exchanges (no facemask) were collected to enhance external validity. A threshold of $\geq 85\%$ HR_{max} was used as our criterion for satisfactory compliance to the HIIE protocol (Ito, 2019). The selected interval running protocol was based on commonly utilised low-volume protocol in HIIE-based studies in adults (Sultana et al., 2019).

Experimental Measures

Affective responses

Affective response (pleasure/displeasure) was measured using the feeling scale (FS; Hardy & Rejeski, 1989). Participants responded to how they felt on an 11-point bipolar scale ranging from "Very Good" (+5) to "Very Bad" (-5). FS exhibited correlations ranging from 0.41 to 0.59 (with the Affect Grid) indicative of convergent validity with similar established measures (van Landuyt et al., 2000). Δ FS represent the change in the affective response from work interval 1 to the end of work interval across all HIIE conditions. Participants responded to the FS 5 min before exercise and at 20 s before the end of each work and recovery intervals.

Enjoyment responses

The physical activity enjoyment scale (PACES), which was validated for use with adults (Kendierski & DeCarlo, 1991), was used to assess enjoyment 10 minutes after exercise. The PACES consists of 7 positively and 11 negatively worded items, each rated from 1 to 7 on a 7-point bipolar scale. Negative items were reverse scored, and all 18 items were summed to produce a total enjoyment score out of 126. The internal consistency was acceptable at each administration (Cronbach's $\alpha > 0.90$) in the present study.

Rating of perceived exertion

The rating of perceived exertion (RPE) was assessed using the 10-point category-Ratio 10 Scale (Borg, 1998). Participants were instructed to report perceptions of their exertion via a 0-10-point Likert item ranging from 0 (nothing at all) to 10 (absolute maximum). This scale has been established as a reliable and valid measure of physical exertion during exercise (Borg, 1998). Participants responded to the RPE at 20 s before the end of each work and recovery intervals.

Metabolic outcomes

Metabolic outcomes were measured before and after 5 weeks of exercise intervention. In the first visit (pre-test), following an overnight fast (10 to 12 hours) and under standardize conditions at ~08:00, resting HR was measured. Subsequently a 5 ml of venous blood sample were taken from the participants after cleaning the venepuncture site with 70% alcohol, 3 ml of the blood sample (whole blood) were dispensed into fluoride oxalate tube for the fasting plasma glucose test and 2 ml into a gel separator sample tube for lipid test. Blood samples were then centrifuged at room temperature stored at -80°C for later analysis. Blood samples were analyzed using standardized methods for glucose, total cholesterol and sub-fractions [i.e., low-density lipoprotein (LDL), high-density lipoprotein (HDL) and very low-density lipoprotein (VLDL)].

Statistical analyses

All statistical analyses were conducted using SPSS (SPSS 26.0; IBM Corporation, Armonk, NY, USA). Descriptive characteristics are presented as mean $\pm$ standard deviation (SD). Normal distribution of the data was checked by the Shapiro–Wilk normality test. A mixed model ANOVA design with the between factor ‘group’ (S-HIIE versus P-HIIE), repeated factor ‘interval’ (work interval 1, 8, and end work interval), and repeated ‘session’ (session 1, session 8, and session 15) were used to analyse training session variables (i.e., affective, enjoyment, and RPE responses, HR, MAS, and metabolic markers). Each of the exercise sessions for both groups consisted with a different end work interval (Session 1= 7 reps; session 2= 8 reps; session 15= 9 reps). Bonferroni post hoc test was carried out on significant interactions to examine the location of differences. Where the assumption of sphericity was violated, degrees of freedom were corrected with Greenhouse–Geisser epsilon. The magnitude of mean differences was interpreted using effect size (ES) calculated using Cohen’s d (Cohen, 1988).

Results

The participants’ descriptive characteristics are presented in Table 1. Based on WHO Asian-BMI classifications, the percentage of overweight (BMI = 23-24.9 $\text{kg}\cdot\text{m}^{-2}$) and obesity (BMI $\geq 25 \text{ kg}\cdot\text{m}^{-2}$) in the present study was 20.8% and 79.2%, respectively. The participants fitness levels were ranged from very poor to poor ($\dot{V}\text{O}_{2\text{max}}$: male 27.2 - 43.5 $\text{mL}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$; female 21.7 - 33.6 $\text{mL}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$) according to the cardiorespiratory fitness norms of American College of Sport Medicine (ACSM, 2018) for age 20-29 years old. Our participants were also characterised as a physically inactive individuals based on the IPAQ (P-HIIE= 518 $\pm$ 334 MET-min/week and S-HIIE= 446 $\pm$ 331 MET-min/week).

There were no statistically significant differences across all characteristics before and after exercise intervention between two groups (all $P>0.05$, $\text{ES}<0.36$). However, a significant main effect of time was present for $\dot{V}\text{O}_{2\text{max}}$, MAS, and maximal FS in both groups (pre vs. post; all $P<0.01$). Also, there was no significant main effect of group by time interaction for energy intake in both groups ($P = 0.42$; Pre vs Mid vs Post; P-HIIE = 1142 $\pm$ 493 kcal vs. 1234 $\pm$ 290 kcal vs. 1079 vs 358 kcal; S-HIIE = 943 $\pm$ 285 kcal vs. 995 $\pm$ 246 kcal vs. 1036 $\pm$ 308 kcal; all $\text{ES}<0.42$). Finally, both P-HIIE and S-HIIE groups elicited comparable estimated energy expenditure across 5-weeks exercise interventions ($P = 0.42$; P-HIIE = $\sim$ 828 $\pm$ 107 kcal/week vs. S-HIIE = $\sim$ 789 $\pm$ 101 kcal/week, $\text{ES} = 0.37$).

Table 1: Descriptive characteristics of the participants (N=20)

Groups	Variables	Pre-Test	Post-Test	P-Value	ES
P-HIIE	Age	26.7 $\pm$ 4.9	-	-	-
	Body mass (kg)	69.4 $\pm$ 9	67 $\pm$ 11	0.25	0.24
	Stature (m)	1.6 $\pm$ 0.1	-	-	-
	BMI ($\text{kg}\cdot\text{m}^{-2}$)	27.3 $\pm$ 1.3	26.1 $\pm$ 3	0.10	0.54
	Body fat (%)	34.6 $\pm$ 6.4	31.3 $\pm$ 8.5	0.09	0.44
	$\dot{V}\text{O}_{2\text{max}}$ ($\text{mL}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$)	27.4 $\pm$ 6.5	32.9 $\pm$ 7.6	<0.01	0.78
	HR _{max}	180.3 $\pm$ 10.9	180.7 $\pm$ 9.2	0.48	0.04
	MAS ($\text{km}\cdot\text{h}^{-1}$)	9.5 $\pm$ 2	11.4 $\pm$ 2	<0.01	0.95
S-HIIE	Age	26.6 $\pm$ 3.7	-	-	-
	Body mass (kg)	71 $\pm$ 8	68.1 $\pm$ 10	0.31	0.32
	Stature (m)	1.6 $\pm$ 0.1	-	-	-
	BMI ($\text{kg}\cdot\text{m}^{-2}$)	28.4 $\pm$ 1.1	27.3 $\pm$ 2.7	0.08	0.53
	Body fat (%)	35.3 $\pm$ 7	31.7 $\pm$ 6.6	0.06	0.53
	$\dot{V}\text{O}_{2\text{max}}$ ($\text{mL}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$)	26.2 $\pm$ 7	31.3 $\pm$ 7.4	<0.01	0.71
	HR _{max}	178 $\pm$ 12.5	179 $\pm$ 10.6	0.46	0.09
	MAS ($\text{km}\cdot\text{h}^{-1}$)	9.3 $\pm$ 1.1	11 $\pm$ 2	<0.01	1.05

Values are reported as mean $\pm$ standard deviation, probability (P), and effect size (ES). Abbreviations: $\dot{V}\text{O}_{2\text{max}}$, maximal oxygen uptake; HR_{max}, maximal heart rate. Significant differences are shown in bold.

Heart rate responses

The HR data from the exercise conditions across three sessions (session 1, 8 and 15) are presented in Figure 1 (a, b, and c). There was no main effect of group by interval by session interactions ($P < 0.07$), but there was a significant group by interval interaction for HR responses ($P < 0.001$). Specifically, P-HIIE group generated greater HR response at work interval 1 compared S-HIIE group in session 1 and 8 [all $P < 0.02$; session 1 = 145 ± 22 bpm (80% HR_{max}) vs. 131 ± 22 bpm (75% HR_{max}); session 8 = session 1 = 144 ± 21 bpm (80% HR_{max}) vs. 132 ± 20 bpm (75% HR_{max}), all $ES > 0.77$].

Running speed

The running speed ($km \cdot h^{-1}$) during P-HIIE and S-HIIE across all three sessions are presented in Figure 1 (d, e, and f). There was a significant main effect of group by interval interaction for the running speed ($P < 0.01$). P-HIIE generated greater running speed compared to S-HIIE at work interval 1 [$(8.9 \pm 1.8$ $km \cdot h^{-1}$ (90% MAS) vs. 5.4 ± 0.7 $km \cdot h^{-1}$ (59% MAS), respectively] and 4 [$(8.9 \pm 1.8$ $km \cdot h^{-1}$ (90% MAS) vs. 7.2 ± 1.2 $km \cdot h^{-1}$ (78% MAS), respectively] during session 1 (all $P < 0.03$, $ES > 0.98$). Whereas in session 8, P-HIIE generated greater running speed compared to S-HIIE at work interval 1 [$P < 0.05$; 8.9 ± 1.8 $km \cdot h^{-1}$ (90% MAS) vs. 7.0 ± 1.9 $km \cdot h^{-1}$ (77% MAS), respectively, $ES = 0.92$]. Also, there was a main effect of interval by session interaction for running speed in S-HIIE group ($P < 0.01$). S-HIIE group generated lower running speed at work interval 1, 4, and end work interval during session 1 compared to session 8 and 15 (all $P < 0.01$, all $ES > 0.63$).

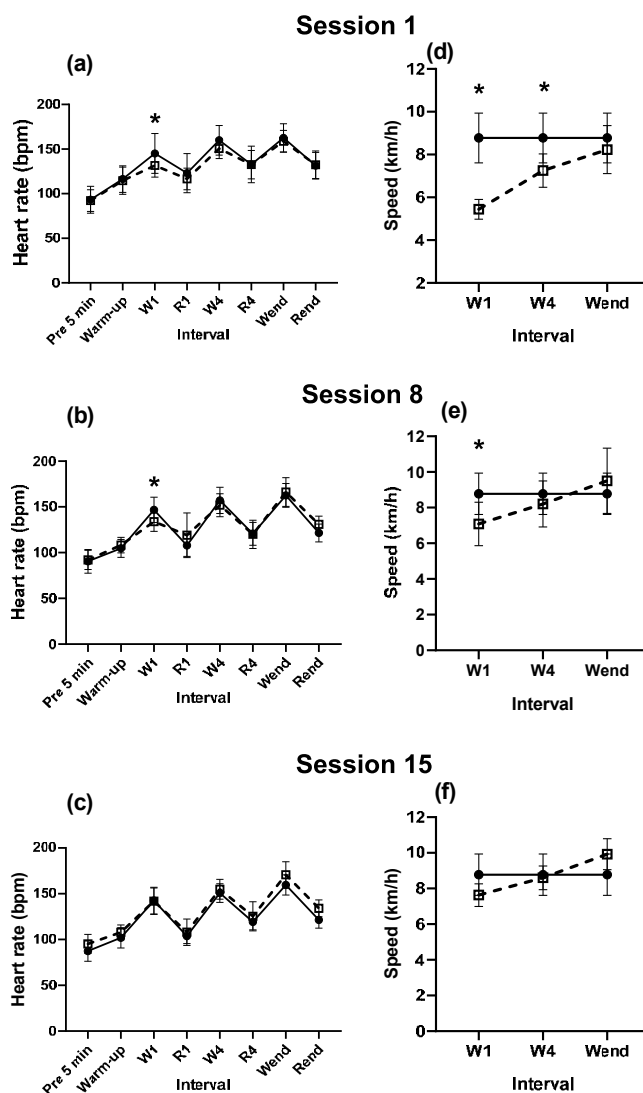


Figure 1 Heart rate responses (a, b, c) and running speed (d, e, f) across all three session of high-intensity interval exercise (HIIE) with prescribed HIIE (P-HIIE; ●) and self-paced HIIE (S-HIIE; □). Where, W= work interval and R= recovery interval. *Significant difference between P-HIIE and S-HIIE ($P < 0.01$). Error bars are presented as standard deviation. See text for details.

Metabolic outcomes

Changes in health marker for both group across pre- and post-exercise interventions are illustrated in Table 2. There was no main effect of time by group interactions across all health markers ($P=0.71$).

Table 2 Blood glucose and lipid profile P-HIIE and S-HIIE

Groups	Variables	Pre-Test	Post-Test	P-Value	ES
P-HIIE (n=10)	Blood Glucose (mmol/L)	4.1 ± 0.2	4.0 ± 0.3	>0.37	0.39
	Total Cholesterol (mmol/L)	5.2 ± 1.0	4.6 ± 1.6		0.45
	Triglycerides (mmol/L)	1.2 ± 0.7	1.1 ± 0.5		0.16
	HDL (mmol/L)	1.3 ± 0.4	1.4 ± 0.3		0.28
	LDL (mmol/L)	3.4 ± 0.5	3.4 ± 0.8		0.00
S-HIIE (n=10)	Blood Glucose (mmol/L)	4.2 ± 0.1	4.1 ± 0.2	>0.27	0.63
	Total Cholesterol (mmol/L)	5.2 ± 1.3	4.6 ± 2.2		0.33
	Triglycerides (mmol/L)	1.1 ± 0.8	1.1 ± 0.8		0.00
	HDL (mmol/L)	1.3 ± 0.3	1.4 ± 0.3		0.33
	LDL (mmol/L)	3.4 ± 1.1	3.2 ± 1.0		0.19

Values are reported as mean ± standard deviation, probability (P), and effect size (ES). Abbreviations: HDL, high-density lipoprotein; LDL, low-density lipoprotein.

Affective responses

Changes in affective responses measured by FS across three sessions (session 1, 8 and 15) in both HIIE groups are illustrated in Figure 2 (a, b, and c). There was a main effect of group by interval by session interactions ($P<0.05$). Specifically, P-HIIE group elicited lower FS at work interval 1, 4 and end work intervals compared to S-HIIE in session 1 (all $P<0.03$, all $ES>0.66$). Also, P-HIIE group elicited lower FS at the end of work interval during session 1 compared to session 8 and 15 ($P<0.05$, 1.0 ± 2.0 vs. 2.6 ± 2.1 vs. 2.6 ± 1.8 ; $ES>0.78$). There was also a significant main effect of interval interaction for the FS in both group ($P<0.01$).

Data indicated that FS significantly declined from 5-min pre across all work intervals during P-HIIE ($\Delta FS = -3$) and S-HIIE ($\Delta FS = -1.8$) for session 1 (all $P<0.001$, all $ES>0.55$), but not for other exercise session in both conditions (P-HIIE = all $P>0.37$, all $ES<0.20$, all $\Delta FS<-1$; S-HIIE = all $P>0.32$, all $ES<0.11$, all $\Delta FS<-0.8$). FS remained positive at the end of work interval during P-HIIE (above 0.8 on FS score) in more than 90% and in all participants (100%) during S-HIIE (above 2.1 on FS score) across all three sessions.

Post-enjoyment responses

There was a main effect of session for post-enjoyment ($P=0.01$). Specifically, P-HIIE group elicited lower post-enjoyment in session 1 compared to session 8 and 15 [all $P<0.02$, PACES score = 111 ± 9 (session 1) vs. 117 ± 6 (session 8) vs. 117 ± 7 (session 15); all $ES>0.74$]. Similarly, S-HIIE group elicited lower post-enjoyment in session 1 compared to session 8 and session 15 (all $P<0.02$, PACES score = 112 ± 12 vs. 116 ± 6 (session 8) vs. 120 ± 8 , $ES>0.60$).

Rating of perceived exertion

Changes in RPE across three exercise sessions (session 1, 8 and 15) in both HIIE conditions are illustrated in Figure 2 (d, e, and f). There was a main effect of group by interval interaction and interval by session interaction for RPE (all $P<0.05$). Specifically, RPE response was significantly greater during P-HIIE group compared to S-HIIE group at work-interval 1 and work interval 4 in session 1 (all $P<0.04$; P-HIIE = 2.7 ± 0.5 to 4.2 ± 0.6 vs. 2.0 ± 0.8 to 3.7 ± 0.9 ; all $ES>0.58$).

Also, P-HIIE group elicited greater RPE across all work intervals in session 1 compared to session 8 and 15 (all $P<0.01$, all $ES>2.13$). Whereas S-HIIE group elicited greater RPE at work interval 4 and end work interval during session 1 compared to session 8 and 15 ($P<0.01$, $ES>1.60$).

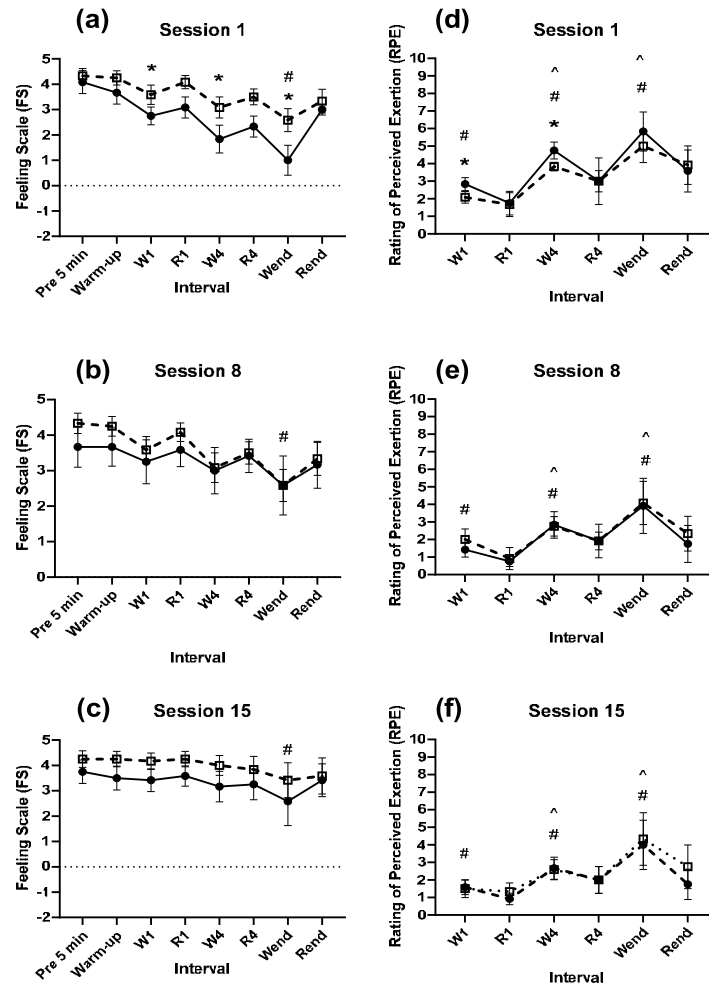


Figure 2 Feeling scale (a, b, c) and rating of perceived exertion (d, e, f) across all three session of high-intensity interval exercise (HIIE) with prescribed HIIE (P-HIIE; ●) and self-paced HIIE (S-HIIE; □). Where, W= work interval and R= recovery interval. *Significant difference between P-HIIE and S-HIIE ($P < 0.01$). #Significant difference across sessions for P-HIIE ($P < 0.01$). ^Significant difference across sessions for S-HIIE ($P < 0.01$). Error bars are presented as standard deviation. See text for details.

Discussion

This study presents data on perceptual responses (affective, enjoyment responses) and health markers (blood glucose and lipid profile) during P-HIIE and S-HIIE in overweight and obese adults. The major findings of this study were: 1) P-HIIE elicited lower affective responses (less pleasurable) across all work interval only in session 1; 2) P-HIIE and S-HIIE groups generated greater post-enjoyment in session 8 and session 15 compared to session 1; 3) P-HIIE group elicited greater RPE responses across all work intervals in session 1 compared to session 8 and 15. Whereas S-HIIE group elicited greater RPE responses at work interval 4 and end work interval in session 1 compared to session 8 and session 15; and 4) body fat percentage, aerobic capacity, and maximal aerobic speed were improved following a 5-week exercise training in both P-HIIE and S-HIIE groups. The HIIE protocol adopted in this study design was well tolerated by all participants in both groups and therefore may have practical implications for health strategies in overweight and obese cohort.

In the present study, we found that affective responses measured by FS scores during P-HIIE group generated lower affective responses (less pleasurable feelings) across all work intervals (interval 1, 4, and end work intervals) compared to S-HIIE in session 1 ($ES > 0.66$). A single study by (Kellogg et al., 2018) reported that self-selected cycling HIIE elicited lower affective responses compared to imposed cycling HIIE in adults which is line with our observation in the present study. The author (Kellogg et al., 2018) has proposed that the degree of autonomy possessed during self-selected HIIE may lead to a greater pleasurable feeling compared to the imposed HIIE protocol. This valuable study, however, is limited to the HIIE performed on the cycle ergometer among physically active men and women. Our findings extend this previous self-paced HIIE-based

study in adults by supporting the proposition that participants choice over their behaviour leads to greater perceptions of competence and feelings of autonomy, which in turn increase individual's positive affective responses (more pleasurable) particularly during HIIE-based protocol in overweight and obese adults. This viewpoint is posited by a self-determination theory (Deci & Ryan, 1985) framework which suggests that the degree of pleasure that an individual experiences when they act autonomously is probable to be greater than that experienced when behaviour is imposed or externally controlled. Our data reinforced this notion by showing that 'self-control' and 'self-choice' over the work intensity perceives by the participants during S-HIIE group contributed to the greater positive affective responses (more pleasurable feelings) compared to externally controlled work intensity during P-HIIE.

Previous HIIE-based studies have reported that affective responses during self-selected running HIIE are dependent on the intensity of the work-interval (Mohd-Liza et al., 2022). In the present study, it appears that the pacing strategies (i.e., selection of lower running speed at the initial work interval) adopted by the participants with overweight and obese may be attributed to the greater pleasurable feelings for the entire S-HIIE work intervals compared to P-HIIE in session 1. Moreover, we found a significantly greater decline in affective responses during P-HIIE ($\Delta FS = -3$) compared to S-HIIE ($\Delta FS = -1.8$). Nevertheless, these observations only occur during session 1 (acute effect of HIIE) and not for session 8 (week 3) and session 15 (week 5), indicating a similar affective response pattern after a few HIIE sessions regardless of HIIE conditions. One plausible explanation of this finding may be attributed to the accumulated exercise experience and familiarity to HIIE protocols which is consistent with previous HIIE study in adults (Frazao et al., 2016). This valuable finding may suggest that an individual's PA or exercise experience may play an important role when evaluating affect responses to HIIE. Indeed, a systematic review conducted by Rhodes & Kates (2015) reported that active individuals or experienced exercisers may be able to draw upon their overall PA experiences rather than relying solely on affective responses as an indicator of their capability and motivation to adhere or maintain future PA behaviour. Therefore, it seems plausible to suggest that the relationship between exercise intensity and affective responses may be negated following a few HIIE sessions in adults with overweight and obese in the context of the present study.

In the present study, a similar post-enjoyment was observed in both P-HIIE and S-HIIE groups across all HIIE sessions. This finding is in line with previous HIIE-based studies in adults that found similar post-exercise enjoyment responses to HIIE regardless of work intensity (Oliveira et al., 2018). Both P-HIIE and S-HIIE groups, however, generated greater post-exercise enjoyment in session 8 and session 15 compared to session 1, indicating an improvement in enjoyment responses following a few exercise sessions of HIIE regardless of HIIE groups. An explanation for this observation may be attributed to a 'rebound effect' from the previous feeling stimulated during intense exercise as suggested by Ekkekakis and colleagues (2005). In the present study, exercise challenge was increase in sessions 8 and 15 compared to session 1 due to the increasing number of HIIE work interval repetitions following every two weeks across a 5-week exercise intervention in both groups. Moreover, data from the present study shows an increase of running speed across all sessions at the end of work interval in S-HIIE work intervals (~88% to 106% of MAS). According to the attribution theory of achievement motivation (Weiner, 1985), individuals may attribute perceived of competence and success based on their greater effort or challenge toward the specific task and this achievement-related behaviour is linked to the enjoyment levels. We therefore reasons that an escalate in challenge posed during P-HIIE and S-HIIE groups across 5 weeks exercise intervention as indicated via the increased of work interval repetitions and running speed is likely to account for the greater post-exercise enjoyment responses in sessions 8 and 15 than session 1 for both HIIE groups.

We observed that 5 weeks exercise intervention of P-HIIE and S-HIIE protocols was not sufficient to enhance health markers (body compositions, blood glucose and lipid profile) measured in overweight and obese adults. In the present study, both HIIE conditions did not lead to any improvements in body compositions including individual's body mass, BMI, and body fat percentage. This finding, however, is corroborate with study in obese women conducted by (Kong and colleagues (2016). The authors have reported that no reductions of body mass, BMI and body fat percentage following a 5-week cycling HIIE (60 x 8 s work intervals separated by 12 s passive rest) intervention in obese women. One plausible explanation for the observations in the present study may be attributed to the caloric restriction or dietary intervention was not adopted across a 5-week exercise intervention as reported by Weweg et al., (2017). Moreover, Durstine and colleagues (2001) reported that a weekly minimum exercise energy expenditure of 1200 to 2200 kcal is required to produce any positive changes in body composition, blood glucose and blood lipids. This previous evident may suggest that the influence of any exercise including HIIE protocol on body composition, blood glucose and blood lipids may not be observable until certain activity thresholds are achieved. Consequently, given that less estimated weekly exercise caloric expenditure (P-HIIE = $\sim 828 \pm 107$ kcal/week vs. S-HIIE = $\sim 789 \pm 101$ kcal/week) in a short-term intervention (5-week intervention), it is not surprising that the present study did not observe any favourable changes in body composition, blood glucose and lipids profile in overweight and obese adults.

After a 5-week of HIIE intervention, aerobic capacity measured via individual's $\dot{V}O_{2max}$ increased from baseline (~ 5.1 mL $\cdot$ min $^{-1}$ $\cdot$ kg $^{-1}$) in both group in the present study. This observation indicates that HIIE protocol is a time-efficient means for enhancing cardiorespiratory fitness in overweight and obese adults. Our observation

is consistent with previous HIIE-based study in adults (Sultana et al., 2019), showing that HIIE interventions are effective for improving cardiorespiratory fitness despite utilising lower energy expenditure within short period of exercise intervention (e.g., 2-8 weeks). One plausible explanation for similar improvement pattern of aerobic capacity in both P-HIIE and S-HIIE may be attributed to the comparable exercise stimulus (i.e., running speed and energy expenditure) generated across exercise intervention in both groups.

There are several strengths and limitations that should be acknowledged in this thesis. On strength is that the participants involved in this present study were insufficiently active overweight-to-obese and had low cardiorespiratory fitness levels. This characterisation of our participants could augment the generalisability of data for exercise interventions that are substantially required in overweight and obese adult populations. This is important consideration to support the feasibility and effectiveness of HIIE protocol as a health strategy intervention for overweight and obese adults. The present study is limited to HIIE protocol performed in a laboratory, which may reduce ecological validity of the study or participant's real-world perceptual response to exercise. Nevertheless, this approach was taken to ensure accurate comparisons of perceptual (i.e., affect and enjoyment) and cardiorespiratory factors (i.e., HR and $\dot{V}O_2$) across the HIIE conditions. Specifically, in the present study, the research laboratory was setup in a similar manner each time for participants in both groups, and any communication with participants was standardised to ensure proper instructions were provided by a similar researcher as well as to providing a sterile environment (e.g., lack of auditory, visual, and social interaction).

Conclusion

The present study extends the application and implementation of the HIIE protocol by manipulating the prescription of either prescribed or self-paced HIIE protocol in overweight and obese adults. Our findings show that P-HIIE protocol elicited less pleasurable experienced and greater levels of exertional stress compared to S-HIIE during the first week of HIIE intervention, but these responses show improvements towards the end of exercise intervention in P-HIIE. Consequently, similar pattern of perceptual responses were observed in both HIIE groups, suggesting a comparable effect of perceptual responses within a 5-week exercise intervention in overweight and obese adults. Also, both HIIE groups produce significant enhancement in enjoyment responses, aerobic capacity and running speed over a 5-week intervention, indicating the viability and adoption of HIIE protocol for health promotion in overweight and obese adults.

Acknowledgments

We would like to thank the Universiti Sains Malaysia for funding this project under the short-term grant (304/PPSK/6315416). We would also like to acknowledge Exercise and Sport Science staff for their kindly assistance to this project and the participants who contributed to this study.

Conflict of interest

No conflict of interest to declare.

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