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ORIGINAL ARTICLE

The Effects of High Intensity Interval Exercise (HIIE) On Cardiopulmonary and Perceptual Responses in Overweight and Normal Weight College Students

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KEYWORDS
Body Mass Index (BMI), Cardiopulmonary Responses, High Intensity Interval Training (HIIT), Overweight Adults, Perceptual Response.

ABSTRACT
Background. Cardiopulmonary and perceptual responses to prolonged continuous exercise are well documented, yet how these responses evolve during brief high-intensity interval exercise (HIIE) in college students across weight categories remains unclear. **Objectives.** The aim of this study is to quantify the effects of a 2-week, 8-session HIIE intervention on cardiorespiratory fitness and perceptual responses in overweight versus normal-weight college students. **Methods.** Thirty inactive participants (age 20.4 ± 1.6 y; baseline body-mass 66.6 ± 14.4 kg; BMI 25.3 ± 4.4 $kg \cdot m^{-2}$) were stratified into Normal-weight (n=13; BMI 23.99 ± 4.27 $kg \cdot m^{-2}$) and Overweight (n=17; BMI 26.39 ± 4.35 $kg \cdot m^{-2}$) groups. Each session comprised of 8–10 × 1-min work intervals at 90% maximal aerobic speed (MAS) with 75 s self-paced walking recovery. Cardiorespiratory fitness (20-m shuttle-run estimated VO_2max), body composition, heart rate (HR), Rating of Perceived Exertion (RPE), Feeling Scale (FS), and Physical Activity Enjoyment Scale (PACES) were assessed pre- and post-intervention. **Results.** Overweight participants reduced body-mass by 1.3 kg (95% CI –2.0, –0.6; ES=0.28), waist circumference by 2.7 cm (–4.1, –1.3; ES=0.39), and fat mass by 1.1% (–1.8, –0.4; ES=0.31) compared with negligible changes in the Normal-weight group (all between-group $P<0.05$). Estimated VO_2max rose 9.8% in the Overweight group (+3.3 $mL \cdot kg^{-1} \cdot min^{-1}$; P=0.00, ES=0.24) versus 4.7 % in the Normal-weight group (+1.5 $mL \cdot kg^{-1} \cdot min^{-1}$; P=0.00, ES=0.18). Mean HR during work intervals was 9–10 $b \cdot min^{-1}$ higher in the Overweight group across sessions ($P<0.001$, ES=0.51–0.53). FS scores improved by +1.2 ± 0.8 units in overweight and +0.6 ± 0.7 units in Normal-weight from session 1 to session 8 (time effect $P<0.01$). PACES enjoyment increased by 18% in overweight (+12 points, ES=0.41) and 10% in Normal-weight (+7 points, ES=0.22). No adverse events were reported, and compliance was 100%. **Conclusion.** In conclusion, this study found increased enjoyment and effectiveness over time in overweight students, suggesting a promising method to boost activity levels.

INTRODUCTION

Research has shown that college students are more prone to unhealthy behavior changes, such as increased sedentary behavior, simultaneously lowering the rate of physical activities (PA) (1).

According to the physical activity guidelines released by the US Department of Health and Human Services in 2008, the general adult should engage in at least 150 minutes of moderate intensity or 75 minutes of high-intensity physical activity per week (2). In addition, many scientific research results on exercise also suggest that a single exercise should be maintained at a moderate intensity for 20-30 minutes to have the expected benefits for individual physical and mental health (3). However, available data indicated that over 20% of adult males and females worldwide, including Malaysia, do not meet the above criteria (4). One of the main reasons for not exercising among people with insufficient physical activity/exercise is the lack of time/time constraints.

In this context, high-intensity interval exercise (HIIE) has become a rapidly popular physical exercise method in the fitness field in recent years due to its obvious short-term and efficient advantages (5). At the same time, this exercise method has also attracted much attention from exercise researchers. Specifically, HIIE can be delivered more briefly to achieve similar benefits to low to moderate exercise with aonger duration (6). Indeed, HIIE has been shown as a time-efficient strategy to improve cardiorespiratory fitness and health parameters (e.g., mental well-being and quality of life) for 2 to 12 weeks of exercise interventions in adults (7).

The application of HIIE as a public health strategy is controversial, as this protocol utilize work-intervals within the heavy or severe (i.e., exercise above the first ventilatory threshold [VT] up to the level of maximal exercise capacity) exercise intensity domains which may evoke negative affective responses (i.e., feelings of displeasure) and lead to poor exercise adherence (8). Available data demonstrates the affective responses to HIIE in adults, but the evidence is contradictory across studies, with some indicating that HIIE elicited pleasurable feelings during exercise, while others were less pleasurable. These inconsistencies across studies may be attributed to the different work intensity prescribed within each HIIE-based study in adults (8). Moreover, this observation is limited to an adult-based study involving HIIE performed in a laboratory rather than an outdoor-based setting, which limits the representations of a participant's real-world affective response to HIIE. Elucidating this information during interval-type exercise is important as affective responses during exercise may influence future attitudes towards PA behavior in adults (9).

HIIE typically involves alternating periods of high-intensity exercise with low-intensity recovery intervals (7, 8). The main appeal of HIIE is that this type of training can be completed quicker (compared to traditional continuous endurance training), and physical adaptations are comparable to those resulting from endurance training. Consequently, it has been proposed that HIIE can mitigate the most commonly cited barrier to physical activity, ' lack of time', particularly in adults (5). Although the fundamental concepts of HIIE are linked to sports training for endurance athletes, such protocols have recently been designed and adapted for both general and clinical populations (10). Recent investigations have suggested that HIIE, regardless of the protocol used, produces equal if not superior health benefits at considerably lower volumes of total work compared with continuous exercise at a lower intensity (7, 8). The multiple health benefits of HIIE in overweight/obese adults have recently been compiled in published reviews (6-8) showing that HIIE protocols are effective at improving cardiometabolic health markers (e.g., body composition, blood lipids, glucose, and insulin) and augmenting cardiorespiratory fitness in adults. These review papers also suggest that the average length of HIIE training intervention to generate multiple health benefits is between 2 and 12 weeks, supporting the time efficiency of this HIIE protocol. Collectively, the aforementioned review papers provide some support for HIIE as a potentially efficacious form of exercise for the improvement of health outcomes in adults. Despite these promises, short-term and unsustainable change has been an issue in PA and exercise intervention (10).

Despite the effectiveness of HIIE in promoting health benefits and well-being in overweight and obese adults, its high-intensity nature has limited its utility, especially among those who are not (11-13). Specifically, Biddle and others have argued that the intense work intervals performed during HIIE may evoke negative affect responses (feelings of displeasure) and a greater perception of exertion, leading to poor engagement and exercise adherence (8, 11). Research shows that optimizing affective responses (e.g., an increase in pleasant feelings) during exercise may be one solution to improving PA levels, as affect may be the first link in the exercise adherence chain (9, 12). Indeed, a positive affect response (i.e., feelings of pleasure), as opposed to a negative affect response (i.e., feelings of displeasure), has an impact upon an individual's motivation and behavior (10), which may influence any decisions made, regarding whether or not to re-engage in the behavior in the future (5, 6).

Although available data demonstrate the affective responses to HIIE, the evidence is contradictory across studies, with some indicating that HIIE elicited pleasurable feelings during exercise while others were less pleasurable (14, 15). These inconsistencies across studies may be attributed to the different work intensity prescribed within each HIIE-based study in adults (10, 11). Moreover, this observation is limited to an adult-based study involving HIIE performed in a laboratory rather than an outdoor setting, which limits the representations of a participant's real-world affective response to HIIE (14). Elucidating this information during interval-type exercise is important as affective responses during exercise may influence future attitudes towards PA behavior in adults (16).

So we conducted this study to determine whether: a) overweight participants display higher heart rate and RPE values across all HIIE sessions than normal-weight participants; b) after the 2-week intervention, the overweight group show greater improvements in estimated VO_2max and greater reductions in body mass, waist circumference, and body-fat percentage; and c) both groups will increase affective valence and enjoyment over the eight sessions, but the overweight group will report lower initial FS and PACES scores and a larger magnitude of improvement by session 8.

MATERIALS AND METHODS

Participants. Thirty college students from the School of Health Sciences, Universiti Sains Malaysia, were selected for the current study based on a sample size calculation conducted using G*Power version 3.1.9.2. This calculation is informed by related research, which reported effect sizes ranging from medium to large (d=0.3 to 0.6) for outcomes such as affective responses, enjoyment responses, and ratings of perceived exertion (RPE) during High-Intensity Interval Exercise (HIIE) (17).

For the current study, involving two conditions and three repeated measurement points (work interval 1, work interval 4, and end work interval), a sample of 15 participants is required to detect a moderate effect using a power of 0.8, an alpha of 0.05, and an effect size (F) of 0.30 (medium). To account for a potential 10% dropout rate (approximately 2 participants), 30 participants were recruited. The inclusion criteria for participant selection are as follows: (I) men and women aged between 18 to 25 years old; (II) body mass index (BMI) between 18.5 kg/m^2 and 24.9 kg/m^2 (normal to overweight individuals), and above 24.9 kg/m^2 (overweight individuals) according to the Asia-Pacific cutoff points; and (III) moderately active individuals (Category 2, <3000 MET-min/week, as determined via the International Physical Activity Questionnaire, IPAQ). The exclusion criteria include: (I) smoking; (II) hypertension; (III) dyslipidemia; (IV) impaired fasting glucose; (V) use of any medication or substance known to influence cardiorespiratory or metabolic responses to exercise; (VI) contraindications to exercise based on the Physical Activity Readiness Questionnaire; and (VII) participation in any exercise program. The study protocol was approved by the Human Research Ethics Committee of Universiti Sains Malaysia (USM/JEPeM/KK/23010030), and the research was conducted strictly following the Declaration of Helsinki. Participants were recruited via email announcements, WhatsApp messages, and the distribution of flyers.

Experimental Overview. The study used a repeated-measure, within-subjects, parallel group design, where each participant was randomly assigned to one of two groups: overweight or normal weight, using simple randomization (Random Allocation Software, 1.0.0) during their first visit. The groups were matched by gender. The first visit (pre-intervention) involved measuring anthropometric variables, assessing cardiorespiratory fitness, and familiarizing participants with the exercise protocols and measurement scales. Afterward, participants completed a 2-week High-Intensity Interval Exercise (HIIE) running program, with four sessions per week (a total of 8 sessions), conducted outdoors. Each session was separated by at least 24 hours of rest.

Participants continued their regular daily physical activity for the control group, recording it in a logbook throughout the 2 weeks. Perceptual responses, including feelings of pleasure/displeasure, enjoyment, and perceived exertion, were measured during each HIIE session. Participants received standardized verbal instructions on using the scales during the first visit and again before starting the exercise protocols (only in the first week). These instructions followed a standard format for each scale and were given by the same researcher. All exercise sessions occurred at the exact location (college field, outdoor setting) and at the same time of day to minimize environmental and diurnal variation effects. The protocol conducted in this study is simplified in the flowchart below (refer to Figure 1).

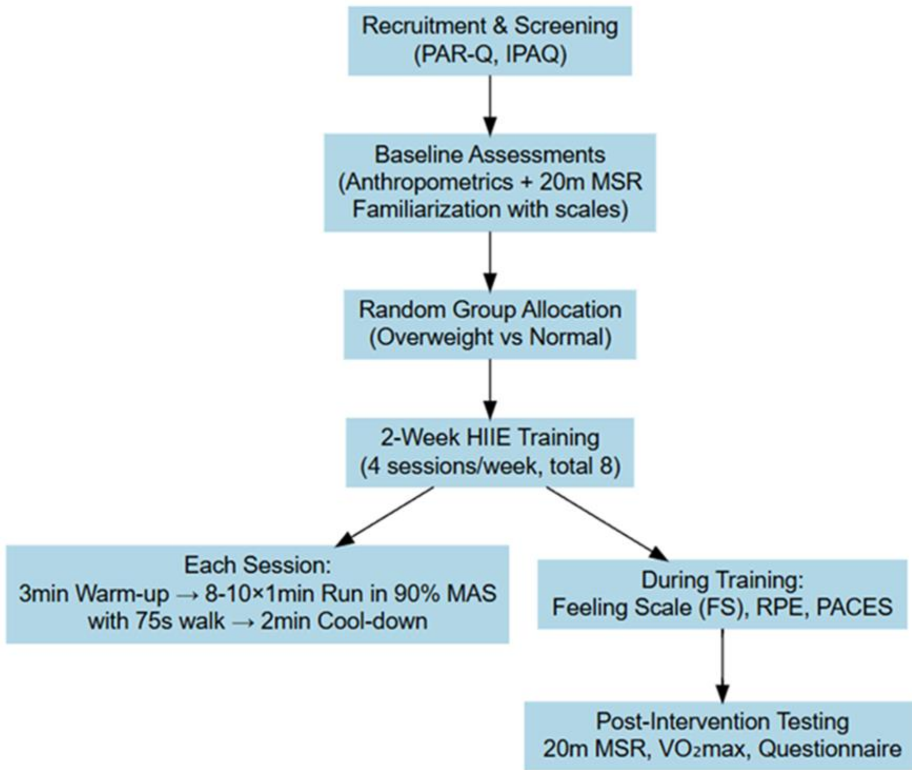

Figure 1. The flowchart depicts the outline of the study protocol.

Participants arrived at the indoor badminton hall of Universiti Sains Malaysia (ambient temperature 25°C, relative humidity 60%) between 08:00 and 09:30 h in a non-fasted state (light breakfast ≥2 h prior). Heart-rate data were collected continuously using a chest-strap telemetry monitor (Polar H10, on loan from the USM Exercise Physiology Laboratory). All tests were completed within 90 minutes per participant. Additional equipment included a calibrated digital stopwatch (Traceable® 60-Memory), a retractable steel tape (Lufkin W606PM, 0–200 cm), a calibrated digital scale (Tanita BC-543, 0.1 kg precision), a measuring tape for waist- and hip-circumference (Seca 201), a standard whistle for pacing cues, and ad libitum water to maintain hydration.

Anthropometric and Physical Activity Measurements. Body mass and height were measured to the nearest 0.1 kg and 0.1 cm, respectively, with participants barefoot and wearing light clothing. The waist-to-hip ratio (WHR) was calculated by dividing the waist circumference (cm) by the hip circumference (cm). Body mass index (BMI) was determined by dividing body mass (kg) by height squared (m^2). The Malay version of the International Physical Activity Questionnaire was used to assess participants' daily physical activity (PA) habits (18). The questionnaire consists of 12 items covering vigorous activity, moderate activity, walking, sitting, and sleeping. Its validity and reliability have been previously confirmed in the Malaysian adult population (19). IPAQ-M classifies physical activity into three levels: Category 1 (Inactive; <600 MET-min/week), Category 2 (Moderately active; <3000 MET-min/week), and Category 3 (Health-enhancing physical activity (HEPA); >3000 MET-min/week). Before starting the study, each participant completed a Physical Activity Readiness Questionnaire (PAR-Q) and a physical activity assessment (18, 19).

Cardiorespiratory Fitness. Participants completed the 20-m multi-stage run (20m MSR) to determine their maximal aerobic speed (MAS) and assess cardiorespiratory fitness, as indicated by predicted maximal oxygen consumption (VO_2max). This test would also familiarize participants with the field-based interval running protocol used in the 2-week exercise intervention. The 20m MSR involves running continuously between two lines set 20 meters apart, at a pace dictated by audio tones. The test begins at 8.5 km/h during the first minute and increases by 0.5 km/h every minute thereafter. Participants continued running until they voluntarily withdrew or failed to reach within 3 meters of the lines on two consecutive tones (following a second warning). Verbal encouragement was used to motivate participants to run for as long as possible. MAS was recorded as the highest speed achieved during the test, while VO_2max was predicted using equations established by Cooper et al. (20). For males, VO_2max was calculated as 2.75X + 28.8; for females, it was 2.85X + 25.1, where X represents the last half-stage of the test completed. After completing the 2-week exercise intervention, participants repeated the 20m MSR, with a minimum of 72 hours between the conclusion and the reassessment. This second test evaluated changes in MAS and cardiorespiratory fitness following the intervention.

Although direct CPET measurement of VO_2peak is considered the gold standard, this study adopted MAS-derived estimates due to feasibility and safety considerations for field-based testing. Previous studies have validated MAS as a practical and reliable method to approximate cardiorespiratory fitness in young adults.

Gas Exchange and Heart Rate. The heart beats faster to supply more oxygen to the tissue, and gas exchange strengthens, which are interrelated. The study uses heart rate to measure a person's cardiopulmonary response, with HR indicators specifically referring to the heart's number of beats per minute.

Affective Responses. The core affective dimension of affective valence (i.e., pleasure and displeasure) was assessed with the Feeling Scale (21) according to previous work in adults (22-24). The FS is an 11-point, single-item, bipolar rating scale commonly used to assess affective responses during exercise. The scale ranges from 5 to þ5. Anchors are provided at zero ("Neutral") and at all odd integers, ranging from "Very Good" (+5) to "Very Bad" (-5) (24). FS exhibited correlations ranging from 0.41 to 0.59 with the Affect Grid (25), indicative of convergent validity with similar established measures (24). Participants were asked to respond to the FS 5 minutes before exercise; at the end of the warm-up session; and at the end of each work interval (24).

Perceived Enjoyment. Participants' post-exercise enjoyment was assessed using a Physical Activity Enjoyment Scale, 10 minutes after HIIE sessions (26). The PACES consists of 18 semantic differential items, with the opposites separated by a 7-point scale (e.g., 1: "I enjoy it"; 7: "I hate it") (26). Participants were instructed to "rate how [they] feel at the moment about the HIIE [they] have been doing. Negative items were reverse-scored, and all 18 items were summed to produce a total enjoyment score out of 126 (26). PACES scores were recorded following 10 minutes of each exercise session on the first, fifteenth, and final days of training interventions (27). PACES has successfully been used in previous HIIE-based studies in Malaysian adults with a good internal consistency (Cronbach's αs >0.85) (27).

Rating of Perceived Exertion. RPE was assessed using the 10-point category-Ratio 10 Scale (28). 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 (28). The RPE data were collected during intervals and recovery time points similar to FS.

Training Protocol. Participants were assigned to a 2-week HIIE training intervention consisting of 8-10 repetitions of 1-minute work intervals at 90% of maximal aerobic speed (MAS) determined from the 20-meter SRT (HIIE 90%). The work intervals for both HIIE conditions were interspersed with 75 seconds of active recovery at self-paced walking. These interval exercises were preceded by a 3-minute warm-up and a 2-minute cool-down at self-paced running. Participants performed HIIE exercise sessions four times per week for 2 weeks (in total eight sessions). During the 1-minute running, participants continuously ran between two cones set apart to allow the speed to match participants' 90% MAS (i.e., the distance between the cones varied between participants) for each condition, respectively. The selected MAS for HIIE and MIIE are based on previous literature in adults (7). Participants performed the HIIE sessions on a short interval track. Participants were placed in a different lane according to their MAS, and they must cover the distance in 10 s back and forth with a total of 1-minute work interval (i.e., 6 times per minute). To pace individual speeds, at every 10 seconds, a sound cue from a whistle (i.e., 6 times per minute) was emitted to which participants should be at their individual cones. As it has been demonstrated that the maximal velocity reached at the end of 20 MST (MS) is significantly lower than MAS, we used a mathematical formula to convert MS ($km \cdot h^{-1}$) into MAS ($km \cdot h^{-1}$): MAS = 2.4 * MS - 14.7 (29). The number of work intervals (repetitions), starting from 5, was progressively increased by one after every two weeks of training sessions (Table 1). No audio and visual entertainment was provided during the exercise session.

Statistical Analysis. All statistical analyses were conducted using SPSS (SPSS 26.0; IBM Corporation, Armonk, NY, USA). Descriptive characteristics (mean ± standard deviation) were analyzed using independent samples t-tests. A mixed ANOVA design with the between factor' group' (overweight group vs normal group), repeated factor 'interval' (Work interval 1, 4, and end work intervals 8) was used to analyze training session variables (i.e., changes in affect and RPE responses, enjoyment, and HR responses). In the event of significant effects ($p<0.05$), a follow-up Bonferroni post hoc test was conducted to examine the location of mean differences. The magnitude of mean differences was interpreted using effect size (ES) calculated using Cohen's d (30), where an ES of 0.20 was considered a small change between means, and 0.50 and 0.80 were interpreted as a moderate and large change, respectively.

Table 1. A high-intensity interval exercise training intervention across two weeks with four sessions per week.

Training groups	Variables	Week 1				Week 2			
	Session	1	2	3	4	5	6	7	8
Overweight group or normal group (HIIE with 90% of MAS)	Repetition	8	8	9	9	9	10	10	10
	Duration (Work/Recovery)	60/75 s							
	Recovery intensity	Self-walking paced							

RESULTS

Participants' characteristics are presented in Table 1. There was no significant group-by-time interaction, but the findings showed a significant main-time effect across all variables ($P<0.01$), excluding height, IPAQ, and Age. Specifically, the Overweight group elicited greater improvement before and after the intervention in weight (kg), WHR, Fat, and Waist compared to the normal group (all $P<0.05$, all $ES>1.28$). Also, the overweight group elicited a greater estimated VO_2max after the exercise intervention than the normal group ($P=0.00$, all $ES=0.24$). In contrast, the normal group showed enhancement only in estimated VO_2max from pre- and post-exercise intervention ($P=0.00$, $ES=0.18$) and not for other health parameter variables (all $P>0.05$, all $ES<2.46$). Training compliance was 100% for both groups, and no adverse effects were reported.

Table 2 shows the descriptive anthropometric data at baseline and after the 2-week HIIE intervention. Despite similar mean body mass between groups at baseline (Normal: 66.97 ± 17.24 kg vs. Overweight: 66.31 ± 11.90 kg), the Overweight group began with a higher BMI (26.39 ± 4.35 $kg \cdot m^{-2}$) than the Normal group (23.99 ± 4.27 $kg \cdot m^{-2}$). After eight HIIE sessions, BMI remained essentially unchanged in both groups (Normal: 23.90 ± 4.09 $kg \cdot m^{-2}$; Overweight: 26.25 ± 4.09 $kg \cdot m^{-2}$), indicating that the short 2-week protocol was insufficient to elicit measurable BMI reduction.

Table 2. Baseline and post-intervention body-mass and bmi values by group.

Group (ID)	N	Pre-Weight Mean (kg)	Pre-Weight SD	Pre-BMI Mean (kg/m^2)	Pre-BMI SD	Post-BMI Mean (kg/m^2)	Post-BMI SD
Normal (1)	13	66.97	17.24	23.99	4.27	23.90	4.09
Overweight (2)	17	66.31	11.90	26.39	4.35	26.25	4.09

Heart Rate Responses. Figure 2 illustrates the heart rate (HR1-HR8) distribution of normal weight (N) and overweight (O) people in the 1st, fourth, and eighth stages of the exercise test through eight sets of box plots. The results show that, overall, the median heart rate of the overweight group (O) is generally higher than that of the normal weight group (N), especially in HR4, HR6, and HR8 dimensions. The median of the box plot of the O group has obviously moved up (for example, the median of the O group in the 8th stage of HR8 is close to 180), and the interquartile range is wide, indicating that its heart rate fluctuates more; as the test progresses (from the 1st to the 8th stage), the median of the O group in most heart rate dimensions (such as HR5, HR7) continues to rise, and the abnormal values (scattered values) are not obvious. The number of heart rate points increased significantly (e.g., multiple extremely high values close to 200 appeared in group O at the 8th stage of HR4), while the heart rate distribution of group N was relatively stable, with only slight fluctuations in the later stages of HR3 and HR6. It is worth noting that the inter-group differences in HR5 and HR8 were the most significant, with the median of group O being higher than that of group N in almost all stages (e.g., the median of group O at the 8th stage of HR5 was about 160, while that of group N was about 140). In addition, in the 8th stage of HR8, the high heart rate distribution of group O (the upper edge of the box was close to 200) was in sharp contrast to the concentrated distribution of group N (the box range was 140-160), reflecting the significant increase in cardiovascular load in overweight people in the later stages of exercise.

The results of the independent sample t-test of HR showed that the heart rates of the overweight group (O group) were significantly higher than those of the normal weight group (N group) in seven of the eight dimensions of heart rate (HR) (HR1, HR2, HR4-HR8), among which HR1 (Diff=-9.60, $p<0.001$), HR4 (Diff=-9.16, $p<0.001$) and HR5 (Diff=-9.61, $p<0.001$) had the most considerable inter-group differences and the effect size reached a medium level (Cohen's d≈0.51-0.53), suggesting that being overweight may significantly increase the cardiac load at rest or in a specific physiological state; HR6 (Diff=-6.43, $p<0.05$), HR7 (Diff=-6.07, $p<0.05$) and HR8 (Diff=-6.82, $p<0.01$) showed minor differences but were still statistically significant, while HR3 (Diff=-6.23, $p>0.05$) did not reach significance, which may be related to the considerable measurement variation (SE=3.54) or the high dispersion of the sample in this dimension. Although the results consistently showed that the overweight group had a higher heart rate (mean range of group N 161.15-164.69, group O 168.41-171.73), the cross-sectional design cannot rule out the influence of confounding variables (such as exercise habits, metabolic levels) or reverse causality. In the future, it is necessary to combine dynamic heart rate monitoring, physiological indicators (such as blood pressure, inflammatory markers), and longitudinal studies to verify the association mechanism between weight and cardiovascular function, and provide a basis for targeted health interventions for overweight people.

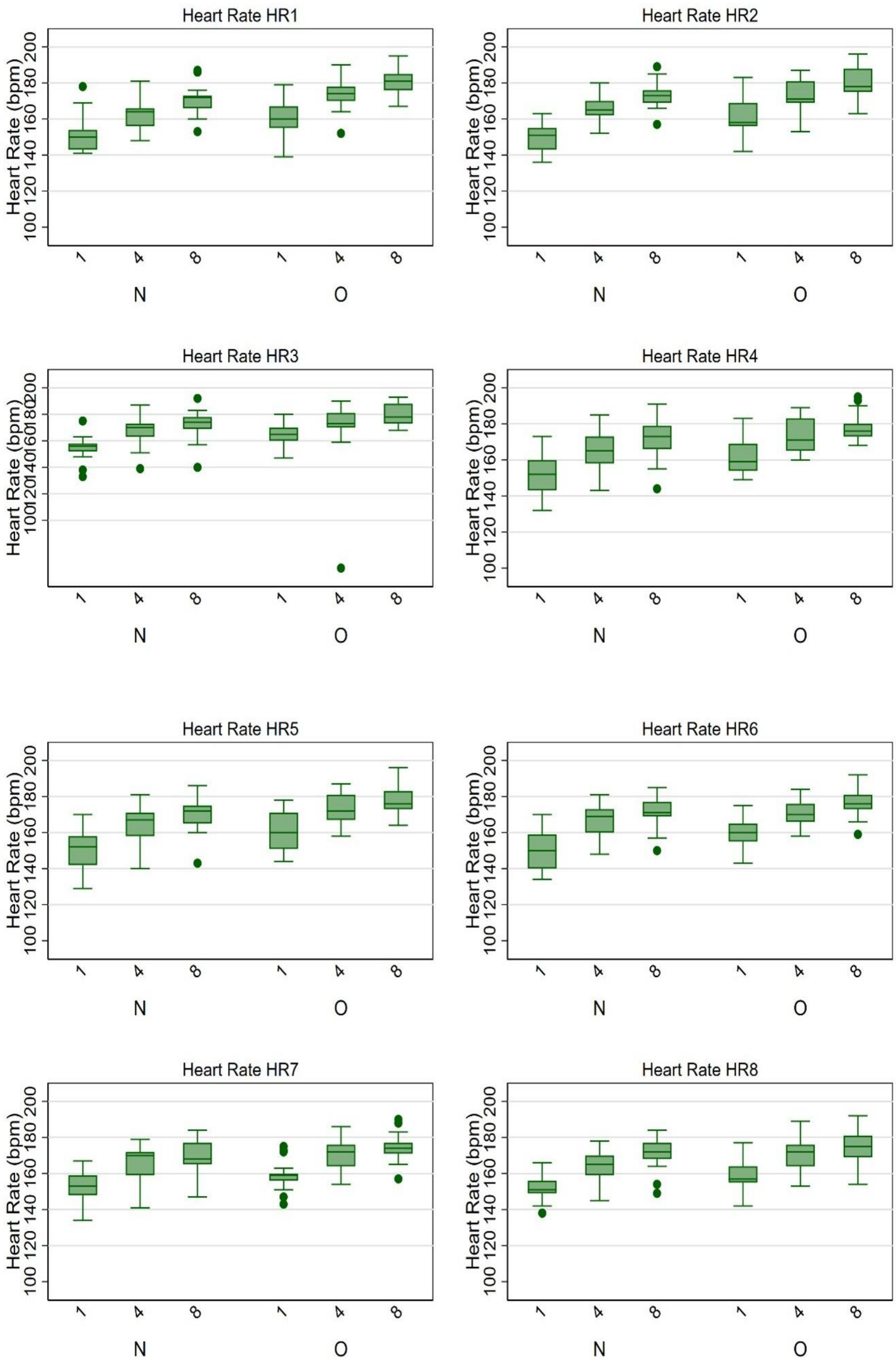

Figure 2. Between-group differences in heart rate across HIIE sessions (Sessions 1, 4, and 8). Values represent median and interquartile range (IQR). *: p<0.05 vs. Normal weight group.

Affective Responses. Figure 3 illustrates the score distribution of the eight dimensions (FS1-FS8) of the Feeling scale between normal weight and overweight groups in the 1st, fourth, and eighth stages of the exercise test through eight sets of box plots. The results show that the median score of the normal weight group (N) is generally higher than that of the overweight group (O), especially in FS1, FS3, FS5, and FS7 dimensions. The interquartile range of the N group is more concentrated and has a significant positive shift. In contrast, the box distribution of the O group in multiple stages (such as FS2, FS4, FS8) is broader and the median is close to or below zero, indicating that the emotional experience fluctuates more and tends to be negative; as the test stages progress (from the 1st to the 8th stage), the N group remains stable or slightly changes in most dimensions. The medians of group O in some dimensions (such as FS4 and FS6) showed a downward trend, and the number of outliers (black dots) increased significantly in the 8th stage of group O, indicating that overweight people may face greater emotional differentiation in the later stages of the test; it is worth noting that the score differences between the two groups were most significant in FS2 and FS8 dimensions. The medians of group O in almost all stages were lower than those of group N, and a negative extreme value (close to -5 points) appeared in the 8th stage of FS8, reflecting the persistent influence of weight on emotional response to exercise in a specific dimension.

However, the results of the independent sample t-test of FS showed that there was no statistically significant difference in the scores of the normal weight group (N) and the overweight group (O) in the eight dimensions of the Feeling Scale (FS1 to FS8) (all dimensions $p>0.05$). The sample size of each group was 90, and the total sample size of the two groups was 180. The test calculated the t value by comparing the mean difference (Diff) and standard error (SE) of the two groups, but the t value of all dimensions did not reach the significance threshold (such as FS1 difference 0.35, $t \approx 0.35/0.38=0.92$). Although the scores of the normal weight group in all dimensions were slightly higher than those of the overweight group (such as FS4 with a maximum difference of 0.48), the degree of difference was affected by the large standard error and did not show statistical significance. This result may indicate that weight status has a limited influence on the subjective feeling scores of each dimension of the Feeling Scale. Future studies may consider expanding the sample size to reduce random errors or further explore potential associations in combination with other physiological and psychological variables.

Rating of Perceived Exertion. Figure 4 illustrates the distribution of perceived exertion scores (RPE1-RPE8) of normal weights and overweight people in the 1st, fourth, and eighth stages of the exercise test through eight sets of box plots. The results show that, overall, the median scores of overweight people (O) are generally higher than those of normal weight people (N), especially in the dimensions of RPE5, RPE6, and RPE8. The interquartile range of the O group is wider. The median is significantly upward (e.g., the median of the O group in the 8th stage of RPE8 is close to 6 points, while that of the N group is about 4 points), indicating that their fatigue perception during exercise is stronger and the individual differences are greater; as the test stages progress (from the 1st to the 8th stage), the medians of the O group in most RPE dimensions (such as RPE5, RPE7, and RPE8) show an upward trend (e.g., RPE5 increases from the 8th stage to the 8th stage). The median of Group O was 4 points in the first stage and increased to 6 points in the eighth stage), and abnormal values (such as extremely high values of nearly 10 points in Group O in RPE5 and RPE8) increased significantly in the later stages, while the score distribution of Group N was relatively stable, with only slight fluctuations in the low to medium range (2-4 points). It is worth noting that the inter-group differences in RPE5 and RPE8 were the most significant, with the median of Group O being higher than that of Group N in almost all stages (such as the interquartile range of Group O in the eighth stage of RPE8 covered 4-8 points, while that of Group N was only 2-4 points), and in the eighth stage of RPE8, the score distribution of Group O (nearly 8 points at the upper edge of the box) was in sharp contrast to the concentrated distribution of Group N (box range 2-4 points), reflecting the intensified perception of fatigue and the cumulative effect of cardiovascular metabolic load in overweight people in the later stages of exercise.

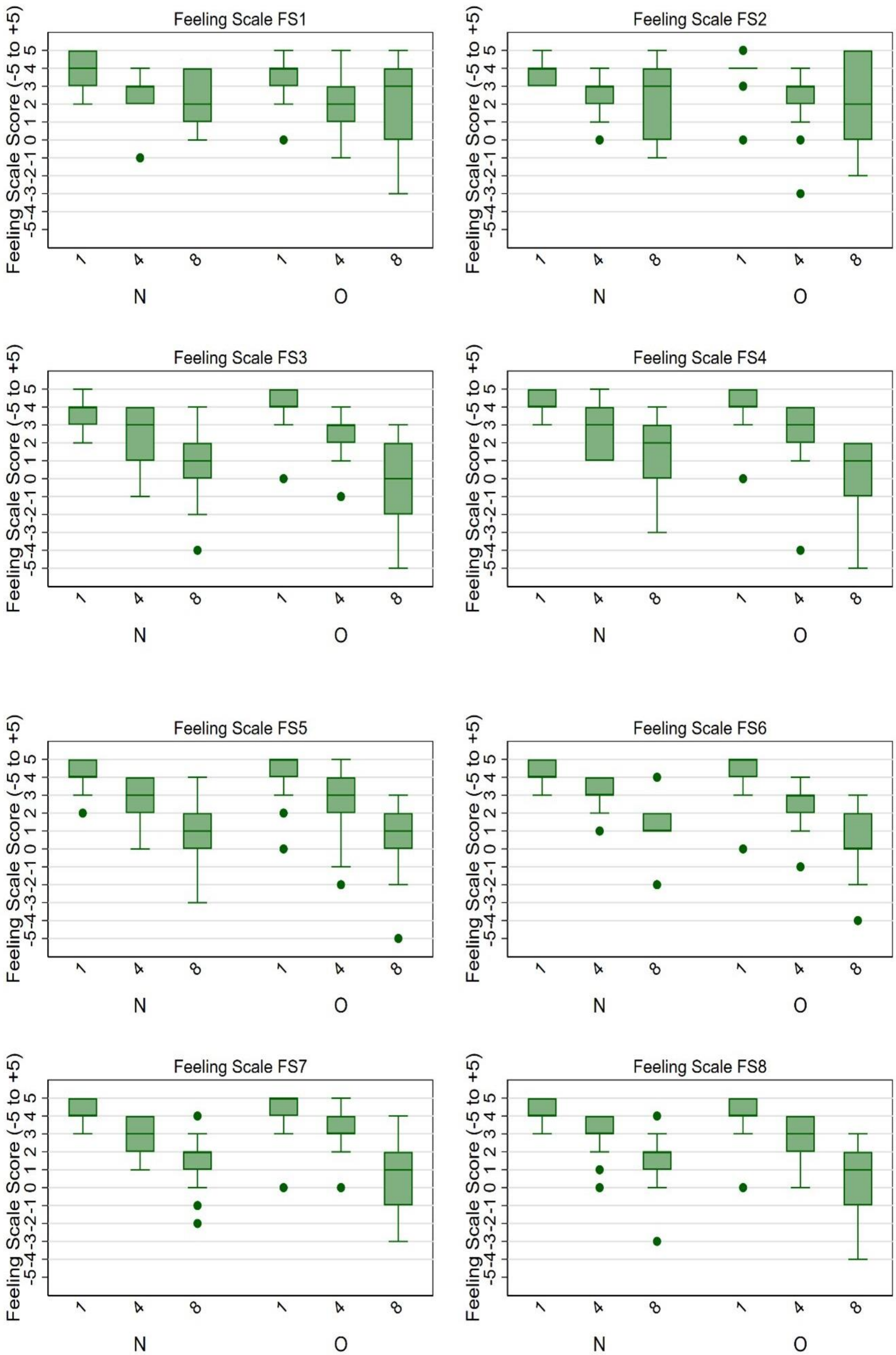

Figure 3. Feeling Scale responses during HIIE at Sessions 1, 4, and 8 for the Overweight and Normal weight groups. Scores are median ± IQR. *: p<0.05 vs. Normal weight group.

The independent sample t-test results of RPE showed that the scores of the O group on the eight dimensions of subjective fatigue (RPE) were slightly higher than those of the N group, but none of the differences reached statistical significance (p>0.05). Specifically, the RPE scores of the overweight group were the most different in the RPE4 (Diff=-0.51, N=2.85 vs. O=3.35) and RPE8 (Diff=-0.53, N=2.56 vs. O=3.10) dimensions, but the corresponding t values (-1.42 and -1.56) were both below the significance threshold (critical |t|≈1.97), and the effect size was in the small to medium range (Cohen's d≈0.21-0.23), suggesting that weight gain may slightly increase fatigue perception in specific situations.

However, the current sample size or the sensitivity of the measurement tool is not enough to capture significant differences. The differences in the remaining dimensions were minor (e.g., RPE2 was only -0.12), and the standard error (SE=0.30-0.41) was relatively large, which may be related to subjective reporting bias (e.g., differences in individual self-assessment of fatigue) or uncontrolled confounding variables (e.g., exercise habits, mental health).

Although the results did not reach statistical significance, the overweight group consistently showed a trend of higher fatigue scores in all dimensions. In the future, the dynamic association between weight status and fatigue experience and potential intervention strategies can be further explored by expanding the sample size, combining objective physiological indicators (e.g., blood lactate levels), or conducting longitudinal studies.

Enjoyment Responses. Figure 5 represents the distribution of enjoyment responses before (pacespre), during (pacesmid), and after (pacespost) exercise between normal-weight and overweight people through three sets of box plots. The results show that, in general, the median score of the normal-weight group (N) is generally higher than that of the overweight group (O), especially in the post-exercise stage (pacespost).

The median of the box plot of the N group is significantly higher than that of the O group (e.g., the median of the pacespost of the N group is about 6 points, and that of the O group is about 4 points).

The interquartile range is more concentrated (the boxes of the N group cover 5-7 points, and those of the O group cover 3-5 points), while the distribution range of the O group is wider (e.g., the interquartile range of the O group in mid covers 2-6 points) and is accompanied by more low-score outliers (e.g., the extreme value of nearly 2 points appears in the O group in pre); as the exercise stage progresses (from pre to post), the enjoyment response of the N group remains stable or increases slightly (e.g., the median of the pacespost of the N group is about 6 points, and that of the O group is about 4 points). The median score of group A in the post-exercise stage increased from 5 to 6 points.

In contrast, the median score of group O in the post-exercise stage decreased significantly (down by about 1 point from mid), and the number of outliers increased (for example, the extremely low value of group A in group O, close to 1 point, appeared in pacespost). It is worth noting that the inter-group differences were most significant in the post-exercise stage. The boxes of group N were concentrated in the high-score range (5-7 points), while the boxes of group O moved downward as a whole and were dispersed (3-5 points). At the same time, in the pre-exercise stage, the low-score outliers of group O (such as 2 points) contrasted with the high-score concentration trend of group N, reflecting that the overweight people had a weaker experience of pleasure throughout the exercise (especially in the later stage), and the differences between individuals were more prominent.

DISCUSSION

This study systematically compared the changes in various physiological and psychological indicators between normal-weight and overweight individuals before and after exercise intervention, revealing the potential differences in the influence of weight status on exercise response. It should also be noted that the current intervention lasted only two weeks, which is insufficient to evaluate long-term adherence directly. As such, the findings should be interpreted as short-term indications rather than definitive evidence of sustained behavioral change. The results showed that although the interaction between group and time was insignificant, there was a significant main effect of time on most variables, indicating that the intervention had a positive overall effect. The overweight group had significantly better improvements in weight, waist-to-hip ratio, body fat percentage, and waist circumference than the normal-weight group, and its maximum oxygen uptake (VO_2max) was also significantly higher than that of the normal group after intervention, indicating that exercise is more effective in improving cardiopulmonary function and body composition in overweight people (27). Although the training compliance of both groups reached 100% and no adverse reactions were reported, there were apparent differences in heart rate, subjective emotions, and fatigue perception.

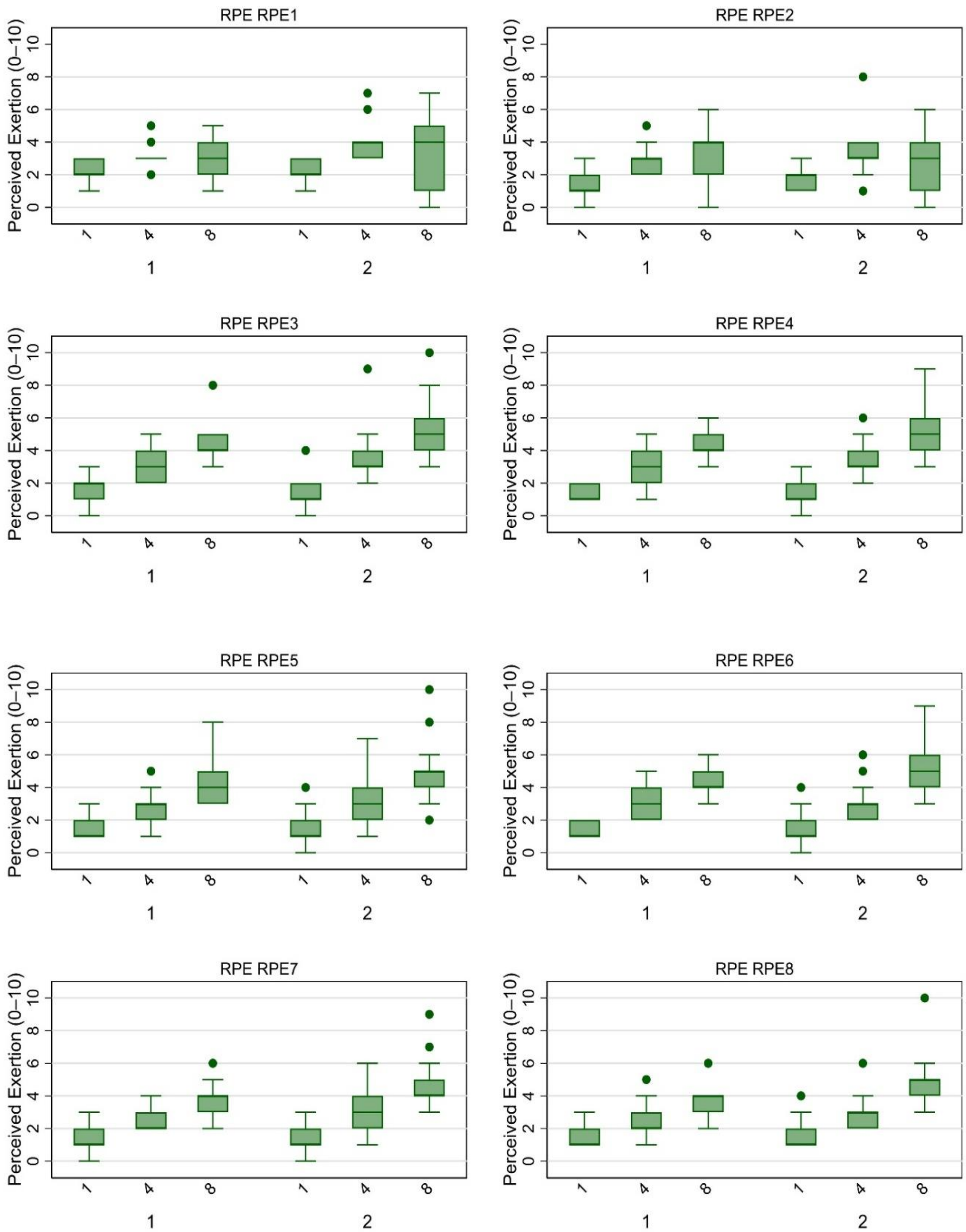

Figure 4. Ratings of perceived exertion (RPE) during HIIE across sessions 1, 4, and 8. Values represent median and IQR. *: p<0.05 vs. Normal weight group.

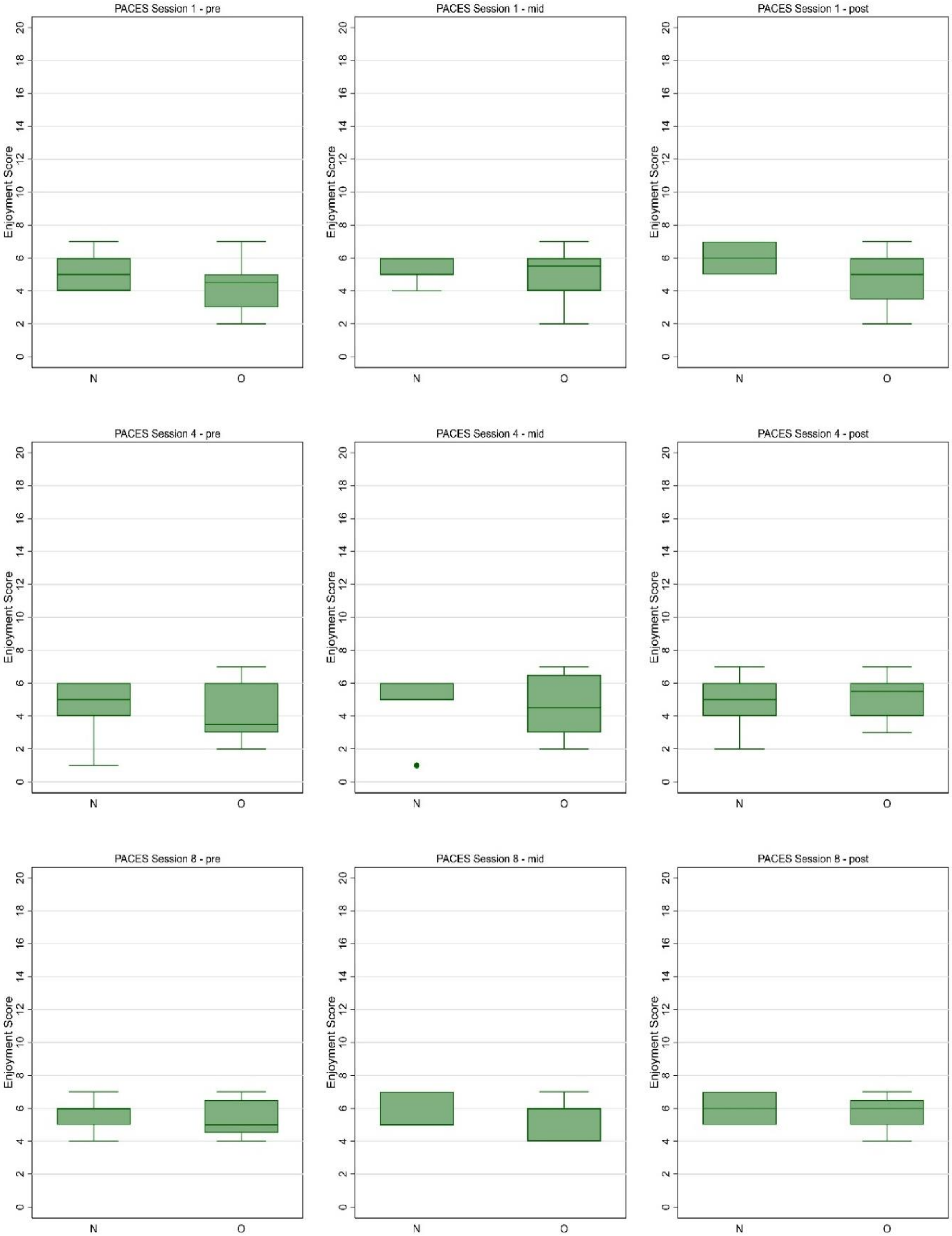

Figure 5. Exercise enjoyment responses measured by PACES before (Pre), during (Mid), and after (Post) HIIE sessions. Values shown are median ± IQR. *: p<0.05 vs. Normal weight group.

Regarding heart rate, the box plot results in Figure 2 show that the median heart rate of the overweight group was generally higher than that of the normal group in multiple stages, especially in the HR4, HR6, and HR8 stages. Its heart rate fluctuated more, and the individual differences were significant, indicating that its cardiovascular load was heavier. The independent sample t-test further showed that the heart rate of the overweight group was significantly higher than that of the normal group in seven of the eight heart rate dimensions, especially in HR1, HR4 and HR5, where the inter-group differences were the largest, and the effect size reached a medium level, suggesting that overweight may increase the cardiac load at rest or in a specific physiological state (31). However, given that the study was a cross-sectional design, the influence of confounding variables or reverse causality cannot be ruled out, and its mechanism can be further explored by combining dynamic monitoring with longitudinal research.

In terms of emotional response, although Figure 3 shows that the median score of the normal weight group in most Feeling Scale (FS) dimensions is higher than that of the overweight group, and the latter has greater emotional fluctuations and tends to be negative in multiple stages, the independent sample t-test did not find statistically significant differences, which may be related to sample size limitations or insufficient scale sensitivity. This shows that the impact of weight status on subjective emotional response is not significant under the current research conditions, and the potential association can be further explored by expanding the sample and combining psychological and physiological variables.

Similarly, although in terms of subjective fatigue (RPE), Figure 4 shows that the fatigue scores of the overweight group were higher than those of the normal group in most stages. The differences between the groups were pronounced in the later stages (such as RPE5 and RPE8), reflecting their stronger fatigue perception and accumulation of cardiopulmonary load (31), the statistical test still did not reach a significant level, suggesting that the current sample or assessment tool has limited ability to identify slight differences, and there may also be individual subjective reporting bias or external interference factors. Although overweight participants reported lower affective scores and higher fatigue, this does not necessarily undermine the potential role of HIIE in exercise adherence. Short-term negative affect may reflect initial discomfort and adaptation difficulties rather than long-term disengagement (27, 32, 33). Notably, the overweight group still significantly improved cardiorespiratory fitness and body composition, which could provide a physiological basis for sustaining exercise. Moreover, adherence is a long-term behavioral outcome that cannot be fully captured in a two-week trial. Therefore, the present findings should be interpreted as preliminary evidence that HIIE may support adherence over time, but this requires confirmation through longer follow-up studies.

Finally, in comparing exercise pleasure, Figure 5 shows that the normal weight group had higher pleasure scores before, during, and after exercise than the overweight group, especially in the post-exercise stage (pacespost). The normal group had a concentrated distribution and high scores, while the overweight group showed greater discreteness and a low score tendency, indicating that overweight individuals may experience a lower pleasure experience during exercise, especially in the later stages. However, since this part does not provide significant test results, its statistical significance still needs further verification.

In summary, although some results did not reach statistical significance, multiple trends showed that overweight individuals had more obvious physiological improvements after exercise, but showed greater fluctuations and lower feelings in subjective experience (such as emotions, fatigue, and pleasure). This suggests that future intervention strategies should not only focus on improving body composition and cardiopulmonary function, but also combine psychological guidance and incentive mechanisms to improve overweight people's exercise experience and long-term adherence rate (34), and verify these preliminary findings through larger samples and more sensitive measurement tools. A further limitation is that VO_2max was estimated from MAS rather than measured directly via CPET. While MAS has been validated in previous studies and was suitable for our field-based protocol (29), future research with direct CPET measurement is warranted to strengthen the accuracy of fitness assessment. Another important limitation of this study is that dietary intake was not assessed or controlled. Since diet can play a synergistic role with exercise in affecting body composition and perceptual responses, it is possible that unmeasured dietary variations contributed to the observed outcomes. Future studies should incorporate dietary monitoring to isolate the independent effects of HIIE better.

CONCLUSION

The present study demonstrated significant improvements in estimated VO_2max and body-composition indices among overweight college students. These findings corroborate the meta-analytic evidence that short-duration HIIE protocols are particularly effective in overweight cohorts, owing to their lower baseline fitness levels and larger window for adaptation. Moreover, the observed increase in enjoyment from session 1 to session 8 aligns with longitudinal data showing that affective responses become more positive as participants gain familiarity with interval training. Although the normal-weight group reported higher initial pleasure, the overweight group exhibited a steeper rise in enjoyment over eight sessions, a pattern consistent with the "affect-adherence" model, which posits that early positive affective shifts are predictive of longer-term exercise adherence. Consequently, the evidence supports the contention that brief, field-based HIIE can be a time-efficient strategy to enhance cardiorespiratory fitness and affective valence in inactive college students. However, longer follow-ups are required to confirm sustained behavioral adoption. Therefore, considering the impact of affective responses and health indices, HIIE shows potential as a promising strategy to facilitate future exercise adherence and to improve health outcomes among physically inactive college students. However, this conclusion should be regarded as preliminary, given the study's short duration and small sample size, and requires confirmation through long-term follow-up.

APPLICABLE REMARKS

- A 2-week HIIE training can be used to improve estimated VO_2max and body-composition indices among overweight college students.
- Affective responses become more positive as individuals become familiar with the HIIE.
- A field-based HIIE can be a time-efficient strategy to enhance cardiorespiratory fitness and affective valence.

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AUTHORS' CONTRIBUTIONS

Study concept and design: Hairul Anuar Hashim, Liu Kai. Acquisition of data: Liu Kai. Analysis and interpretation of data: Liu Kai. Drafting the manuscript: Hairul Anuar Hashim, Liu Kai. Critical revision of the manuscript for important intellectual content: Hairul Anuar Hashim. Statistical analysis: Liu Kai. Administrative, technical, and material support: Hairul Anuar Hashim, Liu Kai. Study supervision: Hairul Anuar Hashim.

CONFLICT OF INTEREST

All authors declare no conflict of interest.

FINANCIAL DISCLOSURE

No financial interests related to the production of materials in the manuscript to declare.

FUNDING/SUPPORT

No funding or support related to the production of materials in the manuscript to declare.

ETHICAL CONSIDERATION

Informed consent was obtained from all participants, and the study protocol adhered to the ethical guidelines of the 1975 Declaration of Helsinki, as approved in advance by the institution's Human Research Ethics Committee.

ROLE OF THE SPONSOR

No role of the sponsor related to the production of materials in the manuscript to declare.

ARTIFICIAL INTELLIGENCE (AI) USE

All authors declare that the use of AI was limited to enhancing the readability and language of the manuscript. AI tools were not used to perform essential authoring tasks, such as generating scientific, educational, or medical insights; drawing scientific conclusions; or providing clinical recommendations. Furthermore, no generative AI or AI-assisted tools were used to create figures, images, or artwork included in this work.

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