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Longitudinal affective response to high-intensity interval training and moderate-intensity continuous training in overweight women with polycystic ovary syndrome: a secondary analysis of a randomised trial

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Abstract

Background

Women with polycystic ovary syndrome (PCOS) experience general and PCOS-specific barriers that limit their engagement with exercise and contributes to high attrition from exercise programs, hindering the potential benefits of exercise to address their increased cardio-metabolic risk. A positive remembered affective response can predict future intentions and adherence to exercise prescription.

Objectives

To compare the longitudinal changes in remembered affect to high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT) in women with PCOS and to determine whether longitudinal changes in remembered affect are correlated with changes in fitness, body mass index, adherence and exercise enjoyment.

Methods

Physically inactive, overweight women with PCOS were randomly assigned to 12 weeks of either HIIT (n = 15) or MICT (n = 14) (3 sessions per week). Remembered affective valence (Feeling Scale) was collected after each exercise session. Cardiorespiratory fitness (VO_{2peak}) was assessed at baseline and post-intervention. Exercise enjoyment was assessed post-intervention.

Results

The longitudinal changes in the remembered affect were more positive in the HIIT group compared to MICT ($\beta = 0.017$, $p = 0.047$). HIIT was also considered more enjoyable than MICT ($p = 0.002$). Adherence was high in both groups (>90%). We found a moderate correlation with longitudinal changes between the remembered affect and change in fitness (r_s

= 0.398) and exercise enjoyment (r_s = 0.376) using the combined group, however, these were not statistically significant (p = 0.054 and p = 0.064, respectively).

Conclusions

HIIT demonstrated a more positive longitudinal remembered affective response and greater exercise enjoyment compared to MICT in overweight women with PCOS.

Introduction

Regular exercise is associated with lower all-cause mortality (Zhao et al., 2020), reduced risk of chronic disease (Leskinen et al., 2018; Li & Siegrist, 2012), and reduced incidence of anxiety (Schuch et al., 2019) and depression (Felipe B. Schuch et al., 2018). Compared to healthy women, women with polycystic ovary syndrome (PCOS) are at an increased risk of developing chronic conditions; particularly type 2 diabetes mellitus and mental health conditions (Barry et al., 2011; Moran et al., 2010). PCOS is the most common endocrine condition in women of reproductive age (Azziz et al., 2006; March et al., 2010) and is characterised by hyperandrogenism, menstrual irregularities and polycystic ovary morphology. PCOS is underpinned by reproductive and metabolic abnormalities. Consistent with the World Health Organization physical activity guidelines (Bull et al., 2020), the PCOS specific guidelines recommend a minimum of 150 minutes of moderate-intensity physical activity or 75 minutes of vigorous intensity exercise per week (Stepto et al., 2019; Teede et al., 2018). Exercise has been found to improve a range of health outcomes for women with PCOS, including increased insulin sensitivity, fitness, menstrual cycle regulation, hormonal levels and a reduction in the severity of symptoms of anxiety and depression (Almenning et al., 2015; Harrison et al., 2012; Kogure et al., 2020; Patten et al., 2020; Patten et al., 2021; Stener-Victorin et al., 2009).

Despite the health benefits associated with engagement in physical activity, a large proportion of adults in the general population do not meet the minimum physical activity recommendations (Department of Health, 2021). In 2017-2018, only 54.7% of women reported engaging in a minimum of 150 minutes of physical activity per week, with lack of time consistently reported as the greatest barrier to exercise participation (Department of Health, 2021). Although there is no population scale data, women with PCOS often have high attrition rates to exercise programs and report barriers to exercise including time limitations, low enjoyment and low confidence, all of which are pertinent for women with PCOS (Banting et al., 2014; Conte et al., 2015). In order to increase adherence and compliance to exercise in both the general population and amongst women with PCOS, there is a need to address these barriers. High-intensity interval training (HIIT) has the potential to reduce the time limitation barrier to exercise (Weston et al., 2014), and despite a greater exertion, some studies in cohorts with other chronic conditions have reported equal or greater enjoyment of HIIT as compared to standard moderate-intensity continuous training (MICT) (Astorino & Thum, 2018; Jung et al., 2014; Vella et al., 2017; Wisløff et al., 2007). However, this point is often debated, with some studies suggesting that an acute bout of moderate-intensity exercise is more enjoyable than HIIT (Decker & Ekkekakis, 2017). This debate also exists in regards to affective response, with controversy around which exercise intensity results in a more positive response. Although affect and enjoyment are conceptually related, there are key distinctions. Affective response is based on the pleasure or displeasure of a single 'in the moment' experience, whereas enjoyment is based on a global judgement based on an aggregation and evaluation of multiple experiences (Stevens et al., 2020).

There is evidence to suggest that a positively valenced affective response to exercise contributes to adherence to an exercise program (Kwan & Bryan, 2010). Previous studies have shown that a more positively valenced affect during an acute bout of exercise is associated with greater exercise engagement up to 12-months later (Williams et al., 2008). Therefore, the acute affective response has been identified as an important antecedent of physical activity through both automatic and reflective processes (Stevens et al., 2020). Additionally, more positively valenced remembered affect (i.e., recalled affective response to a completed bout/interval of exercise), has also been found to predict future intentions to be physically active and adherence to exercise prescriptions (Kwan et al., 2017). Although the affective response during physical activity and remembered affect are distinct (the former is purely affective whereas the latter is cognitively processed), there is a strong correlation between the affective response during physical activity and remembered affect (Hargreaves & Stych, 2013; Zenko et al., 2016). Nevertheless, some have argued that how an affective response to a behaviour is remembered, and not necessarily how it is experienced in the moment, may have a stronger influence on an individual's motivation to perform that behaviour in the future (Kahneman et al., 1993).

Several mechanisms have been identified that may explain variations in the affective response to exercise between and within individuals over time, including exercise intensity and duration (Ekkekakis et al., 2011), as well as multiple cognitive and contextual factors (Bourke et al., 2021). Other factors that may explain variations in the affective response to physical activity include body mass (Ekkekakis et al., 2010) and physical fitness (Magnan et al., 2013). Similarly, cognitive (Beaumont et al., 2021; Kwan et al., 2018; Kwan et al., 2011) and contextual (Graupensperger et al., 2019) factors may influence variations in the remembered affect following physical activity. Although the affective response to physical activity is variable, few studies have examined longitudinal changes in the affective response to physical activity in people involved in exercise interventions. Examining longitudinal remembered affect may provide valuable information into the likelihood of continued exercise participation. Interventions which are successful in promoting positive affective response will likely lead to increased exercise adherence and, subsequently, to enhanced health outcomes. However, there is no evidence from prospective studies comparing longitudinal changes in remembered affect for volume-matched HIIT and standard MICT in women with PCOS. Therefore, this study aims to examine longitudinal changes in remembered affect in women with PCOS enrolled in an exercise intervention, and determine whether changes differ between the HIIT and MICT interventions. Additionally, this study aims to determine if longitudinal changes in remembered affect are correlated with critical factors for women with PCOS, including changes in fitness, body mass, adherence to the intervention, and exercise enjoyment.

Methods

Study design

This study is a secondary analysis of a two-arm (HIIT versus MICT) randomised clinical trial that was conducted at Victoria University, from June 2016 to October 2019 (Patten et al., 2022). The study was approved by the Victoria University Human Research Ethics Committee (HRE 15-298) and is registered with the Australian New Zealand Clinical Trials Registry (ACTRN12615000242527). There were some deviations to the original study protocol (Patten et al., 2022), however, there were no changes made to the methods after trial commencement. All women provided written informed consent prior to participation.

Study population

Inclusion criteria were women with diagnosed PCOS aged 18-45 years, with a BMI greater than 25 kg/m^2, and who were physically inactive (engage in less than 150 minutes of physical activity per week). PCOS was diagnosed according to the Rotterdam Criteria (Rotterdam, 2004), and confirmed by an endocrinologist. Exclusion criteria included diabetes, pregnancy, smoking, illness or injury that prevented or limited exercise performance, existing participation in regular physical activity, and taking anti-hypertensive, androgen lowering, insulin sensitising, weight loss or hormonal contraceptive medications.

Study protocol

After the completion of baseline testing, participants were randomised to a 12-week HIIT or MICT intervention. Randomisation was completed by an independent biostatistician by a simple randomisation procedure using computerised sequence generation at an allocation ratio of 1:1. Randomisation was stratified according to body mass index (BMI) brackets (<35 kg/m^2 or >35 kg/m^2) to ensure equal proportions of BMI in each arm.

Anthropometric assessment

Height and weight was measured without shoes and while lightly clothed using a calibrated stadiometer (Proscale Inductive Series I, Accurate Technology Inc., USA) and a scale (HW-PW200, associated scales services). BMI was calculated as weight (kg)/height squared. Waist and hip circumferences were also measured (Jeff Coombes & Skinner, 2014).

Aerobic capacity

VO_{2peak} was assessed at baseline and following the 12-week intervention using an incremental maximal graded exercise protocol conducted on a cycle ergometer (Lode Excalibur v2.0, Groningen, The Netherlands). The initial three stages of the test consisted of three bouts of 3 minutes of cycling at 25, 50 and 75 watts, respectively, followed by an increase of 25 watts each minute thereafter until volitional exhaustion(Parker et al., 2017). Breath-by-breath expired respiratory gases were collected and analysed (Quark Cardio-Pulmonary Exercise Testing, Cosmed, Rome, Italy). Relative VO_2 data (mL/kg/min) was filtered to remove values that were two standard deviations above or below a seven breath mean. Smoothed data were subsequently averaged over a rolling seven breath mean and the largest value obtained was determined to be VO_{2peak}. Heart rate was recorded every minute and the peak heart rate (HR_{peak}) was also recorded (Polar H10, Polar Electro OY, Kempele, Finland).

Exercise interventions

Interventions were designed to match the minimum exercise recommendations for the moderate and vigorous exercise according to the international evidence-based guidelines for the assessment and management of PCOS (Teede et al., 2018), and were matched for training volume (metabolic equivalent task [MET]/minutes/week) as previously described (Hiam et al., 2019). Participants in both groups were asked to attend three weekly sessions for 12 weeks. All sessions were conducted on a stationary cycle ergometer under the supervision of an accredited exercise physiologist. For both interventions, sessions were preceded by a 5-minute warm-up at a moderate-intensity and ended with a 5-minute cool down. Heart rate monitors (Polar H10) were used in all sessions and target heart rates were achieved by altering the load on the bike according to individual fitness levels. Heart rate, $\%HR_{peak}$ and rating of perceived exertion (RPE; 6-20) (Borg, 1970) scores were recorded at the end of each interval and rest period for the HIIT group and every 5 minutes for the MICT group.

HIIT intervention

The HIIT intervention included three sessions per week: two sessions of 12 x 1-minute intervals at 90-100% peak heart rate ($\%HR_{peak}$), interspersed with 1-minute of active recovery at a light load (short-HIIT); and one session of 8 x 4-minute intervals at $90\text{-}95\%HR_{peak}$, interspersed with a 2-minute light load, activity recovery (long-HIIT).

MICT intervention

The MICT intervention consisted of three weekly sessions of 45 minutes of continuous moderate-intensity cycling at $60\text{-}75\%HR_{peak}$.

Adherence

Adherence to the exercise intervention was calculated as the ratio of the number of actual sessions attended to the total number of scheduled sessions, expressed as a percentage. Compliance to the intervention was determined by averaging the HR for each participant and comparing it to the prescribed intensity. Participants were considered compliant if >80 of all sessions were completed at the prescribed intensity.

Remembered affect

Remembered affect was the primary outcome of the present study. The Feeling Scale was adapted to measure remembered affective valence (pleasure and displeasure) and was assessed ten minutes after the end of each exercise session. Participants reported how they remembered feeling during the exercise session on an 11-point bipolar scale ranging from −5 (very bad) to +5 (very good) (Hardy & Rejeski, 1989).

Enjoyment

The Physical Activity Enjoyment Scale (PACES) was used to measure enjoyment of the interventions. The PACES is an 18-item questionnaire measured on a 7-point bipolar scale (Kendzierski & DeCarlo, 1991). A higher PACES scores reflect greater levels of enjoyment. PACES was collected at post-intervention (12 weeks) only. The Chrobach's α for this scale was 0.92.

Data analysis

All data analysis was conducted using the *lme4* (Bates et al., 2014) and *lmertest* (Kuznetsova et al., 2017) packages in R, and SPSS version 27 (IBM). Examination of missing data indicated that overall, there was a moderate amount of missing data for feeling scale responses (20.8%). Level of missing data was significantly correlated with exercise enjoyment, indicating that the data was not missing at random. All analyses were conducted on an intention-to-treat basis, including all randomly assigned participants regardless of levels of missing data. Missing data was handled using restricted maximum likelihood estimations. A linear growth curve model was estimated to examine longitudinal changes in the remembered affect over time. This model included a fixed effect of session number (centered on the first session). Additionally, age, $VO2_{peak}$ and BMI at baseline, and group allocation were included as time-invariant covariates. The model was estimated with a random intercept and a random effect for session number. To determine whether there were significant variations in changes between participants in remembered affect over time, a likelihood-ratio test was conducted comparing a model with the random effect of session number excluded and a model where the random effect was included. A significant likelihood-ratio test indicated that the model with the random effect for session number included produced a significantly better fit, indicating that this effect differed significantly between participants. To determine if changes in affect differed significantly between the HIIT and MICT groups, an interaction effect between group and session number was added to the model. Additionally, differences in enjoyment between HIIT and MICT were estimated using a Mann-Whitney U test.

In a separate analysis, a linear mixed model was estimated with participants from the HIIT group to determine if remembered affect differed between the long-HIIT and short-HIIT sessions. This model included the type of HIIT session (long vs short) entered as a fixed effect and controlled for session number. This model was estimated with a random intercept and random effects for session number and type of HIIT session.

To examine correlations of longitudinal changes in remembered affect, individual participant random slopes for session number from the linear growth curve model were extracted. A positive random slope indicates a participant had more positive longitudinal growth of remembered affect than average. These random slopes were then correlated with change in $VO2_{peak}$, change in BMI, adherence to the intervention, and exercise enjoyment. Change in BMI, adherence to the intervention, and exercise enjoyment were not normally distributed, so rank order correlation coefficients were estimated for these variables. All data is presented as mean and standard deviation and p values ≤ 0.05 were deemed statistically significant.

Results

Twenty-nine women completed the baseline assessments; 15 were randomised into the HIIT group and 14 into the MICT group. Of these participants, 24 completed the 12-week intervention (HIIT = 13, MICT = 11). One participant withdrew from the HIIT intervention due to an injury sustained at work and another became pregnant. Two participants withdrew from the MICT intervention due to changes to their work schedule and relocating to reside interstate (Figure 1). Baseline values and training data are reported in Table 1. There were no statistically significant differences at baseline between groups. All participants were Caucasian and identified as women. No adverse events occurred throughout the study period. Exercise intervention adherence was similar across the two groups for those that completed the intervention ($p > 0.05$). The HIIT group had an average adherence of 93.9 ± 3.0% (IQR: 92.6 to 97.1%) and the MICT group had an average adherence of 92.0 ± 4.8% (IQR: 88.2 to 94.1%). All participants were compliant to the prescribed intervention.

Longitudinal changes in remembered affect

Results from the linear growth curve model indicated a statistically significant increase in remembered affect over time ($\beta = 0.015$, 95% CI = 0.007, 0.024, $p = 0.001$; Figure 2). Results from the likelihood-ratio test showed that the model estimated with a random effect for session number produced a better fit ($x^2 = 13.2$, $p < 0.001$), indicating that there was variation between participants in changes in the remembered affect over time. Individual participant trajectories in remembered affect can be seen in Supplementary File 2.

Difference in remembered affect between HIIT and MICT groups

The main effect for group was statistically significant ($\beta = 0.921$, 95% CI = 0.420, 1.414, $p = 0.002$) indicating that participants in the HIIT group reported higher remembered affect on average than participants in the MICT group. Additionally, the group by session interaction was statistically significant ($\beta = 0.017$, 95% CI = 0.001, 0.033, $p = 0.047$), indicating that longitudinal changes in the remembered affect were more positive in the HIIT group compared to the MICT group. Changes in remembered affect for the HIIT and MICT groups are plotted in Figure 2. Subgroup analysis indicated that there was a statistically significant increase in remembered affect in the HIIT group (β = 0.023, 95% CI = 0.012, 0.034, p <0.001), but not in the MICT group (β = 0.006, 95% CI = -0.005, 0.018, p = 0.282).

Difference in remembered affect between long-HIIT and short-HIIT sessions

Results from the subgroup analysis of participants randomised to the HIIT intervention showed that there was a statistically significant difference in the remembered affect between short- and long-HIIT sessions, with participants reporting higher scores on the Feeling Scale during short-HIIT sessions (β = 0.833, 95% CI = 0.587, 1.076, p < 0.001).

Enjoyment of interventions

The PACES scores indicated a statistically significant difference in enjoyment between HIIT (101.8 ± 7.6) and MICT (87.9 ± 7.6), with enjoyment rated higher in the HIIT group post-intervention (p = 0.002).

Correlation between longitudinal changes in affect with changes in VO_{2peak}, changes in BMI, intervention adherence, and exercise enjoyment

Clinical outcomes of the trial have been previously reported and are included in supplementary file 1. In brief, VO_{2peak} increased in both HIIT and MICT, with greater improvements reported after HIIT. There was no change in BMI in either group. Results from the correlation analysis showed that the longitudinal changes in the remembered affect had a moderate correlation with change in VO_{2peak} and exercise enjoyment, however, did not reach statistical significance (r = 0.398, p = 0.054 and r_s = 0.376, p = 0.064, respectively). Longitudinal changes in remembered affect were not correlated to changes in BMI (r_s = -0.075, p = 0.727), or adherence to the intervention (r_s = 0.047, p = 0.814).

Discussion

This study aimed to examine longitudinal changes in remembered affective valence over the course of a 12-week exercise training intervention in women with PCOS. We found that remembered affective valence during exercise increased significantly over time. Moreover, despite having a higher affect at the beginning of the intervention, participants in the HIIT group reported more favourable changes in remembered affect over time compared to those in the MICT. The HIIT program was also considered to be more enjoyable than MICT.

The results from the current study diverge from those of previous studies, which found that the affective response during physical activity did not increase over the course of 12-16 week exercise interventions (Lacharité-Lemieux et al., 2015; Stevens et al., 2021). However, it is important to note that whereas the previous studies examined the affective response during exercise, the present study examined remembered affect reported after the physical activity was completed, during the post-session cool-down. The remembered affect reported in our study by participants randomised to the HIIT intervention was greater than those in MICT. However, it is important to recognise that although remembered affect and affect during physical activity are strongly correlated (Hargreaves & Stych, 2013; Zenko et al., 2016), this correlation is not perfect, and remembered affect may be influenced by memory heuristic biases (Stone et al., 2005). For example, physical activity induced physiological changes such as muscle soreness or laboured breathing may no longer be present after the completion of a bout of exercise, and therefore may not have as large an influence on remembered affect as affect during exercise.

There have been mixed findings regarding the difference in the affective response between HIIT and MICT interventions. Multiple meta-analysis report substantial heterogeneity between studies, with some studies reporting more favourable affective response to HIIT whilst others report more favourable affective response to MICT (Niven et al., 2021; Oliveira et al., 2018). Heterogeneity may exist due to the use of differing HIIT protocols, different populations and disease conditions. A possible explanation for why the participants in our study's HIIT intervention reported more positive remembered affect than participants in the MICT group may be the peak-and-end rule. The peak-and-end rule states that people's memories of affect during a behaviour are based on select moments of the experience, specifically the peak affect experienced during the behaviour and affect experienced at the end of the behaviour (Niven et al., 2021). In support of this hypothesis, peak-and-end affect has been found to explain 61% of the variance in remembered affect in the context of physical activity (Hargreaves & Stych, 2013). Multiple studies have demonstrated that people experience multiple peaks in affective valence that occur during periods of rest between intervals (Decker & Ekkekakis, 2017; Roloff et al., 2020). Therefore, these peaks may contribute to the positively remembered affect after HIIT. Additionally, adding a positive ending to an unpleasant task may lead to more positive recalled valence during the tasks (Kahneman et al., 1993). Given that remembered affect was measured after a cool down, this may have further augmented participants ratings of remembered affect, and this effect may have been greater in the HIIT condition due to a greater rebound effect experienced during the cool down compared to the MICT condition.

We also reported a significantly greater remembered affect to short-HIIT compared to long-HIIT sessions. The short-HIIT had an equal work-to-rest ratio of 1:1 with one-minute intervals whereas the long-HIIT had a higher work-to-rest ratio of 2:1 and a four-minute interval duration. A study assessing the impact of 1:1 work-to-rest ratio of 30 second, 60 second, 120 second intervals and heavy continuous cycling reported that the 30 and 60 second intervals in overweight-to-obese insufficiently active adults resulted in a more positive affective response than the 120 second intervals and the heavy continuous protocol (Martinez et al., 2015). Combined, these findings suggest that shorter intervals above the ventilatory threshold may be experienced and remembered more favourably, whereas longer HIIT protocols may provide no advantage over heavy continuous exercise.

In addition to reporting more favourable remembered affect on average over the study period, participants randomised to the HIIT group reported greater longitudinal increases in remembered affect. As reported previously, participants randomised to the HIIT group had significantly greater improvements in cardiorespiratory fitness than participants randomised to the MICT group (Patten et al., 2022). Additionally, although previous cross-sectional studies have demonstrated that fitness is positively associated with the affective response to physical activity (Magnan et al., 2013), this is the first study to report a trend for moderate longitudinal positive associations between fitness and affect in the context of exercise. Although these associations did not quite reach significance, it may suggest that we were underpowered and a significant association may have been detected with a larger sample size. It is possible that as participants become fitter from engaging in HIIT, they may be able to better tolerate the high-intensity exercise, and therefore report more favourable remembered affect over time (Ekkekakis et al., 2007). However, a previous study found a negative association between longitudinal changes in fitness and the valenced response to physical activity (Stevens et al., 2021). Further research confirming the longitudinal association between fitness and affective response to physical activity is warranted.

Although the longitudinal affective response to HIIT protocols has been relatively understudied, the enjoyment of HIIT in comparison to MICT has received more attention. Results reported here suggest that a 12-week HIIT intervention was perceived to be more enjoyable than 12-weeks of MICT. A meta-analysis examining the enjoyment of HIIT compared to MICT in normal weight to obese adults reported an overall small but beneficial effect of HIIT compared to MICT, with six of the 10 studies showing beneficial effects of HIIT and only one showing a harmful effect. An additional study which compared 2-weeks of HIIT and MICT in overweight individuals at risk of type 2 diabetes reported an increase in enjoyment over time in both groups (Santos et al., 2021). Similarly to our study, a previous study also reported higher enjoyment from HIIT compared to MICT despite a higher RPE (Bartlett et al., 2011). A positive correlation between a higher RPE and greater enjoyment has been previously noted, which has been suggested to occur due to a combination of stimulation and accomplishment (Bartlett et al., 2011; Raedeke, 2007). It has also been noted that a greater affective response to exercise results in a higher exercise adherence. In this study, both groups had high adherence which likely resulted in a ceiling effect, and therefore made us unable to detect differences between groups. However, affect and enjoyment should be considered when prescribing unsupervised exercise for all individuals.

There are limitations that should be acknowledged when interpreting the results of this study. Firstly, the sample size included in this study is relatively small, and as this is a secondary analysis, a power calculation was not performed. Sensitivity power analysis indicated that the study was only adequately powered to determine a large effect between the exercise conditions ($d = 0.97$). The researchers who conducted the analyses were not blinded to the group allocation. The findings of this study are also limited to overweight women with PCOS of reproductive age and are not generalisable to all women. Lastly, the exercise sessions were conducted in a laboratory and under supervision, therefore, the results of this study may not be generalisable to real-world settings.

Conclusions

The present study demonstrated that HIIT resulted in a more positive longitudinal remembered affective response compared to MICT. HIIT was also considered to be more enjoyable that MICT, however, adherence to both exercise interventions were high. Combined with the shorter time requirement, the well-known clinical benefits, positive remembered affective response and greater enjoyment, HIIT should be considered when prescribing exercise interventions in women with PCOS. Furthermore, as the short-HIIT intervals were remembered more favourably than long-HIIT intervals, short-HIIT may be the most beneficial strategy to promote exercise participation in women with PCOS. Future, long-term follow up studies are required to determine the applicability of HIIT for exercise adherence and maintenance beyond the intervention period, not only in women with PCOS, but in women in general.

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Tables

Table 1. Baseline characteristics and training data from HIIT and MICT groups

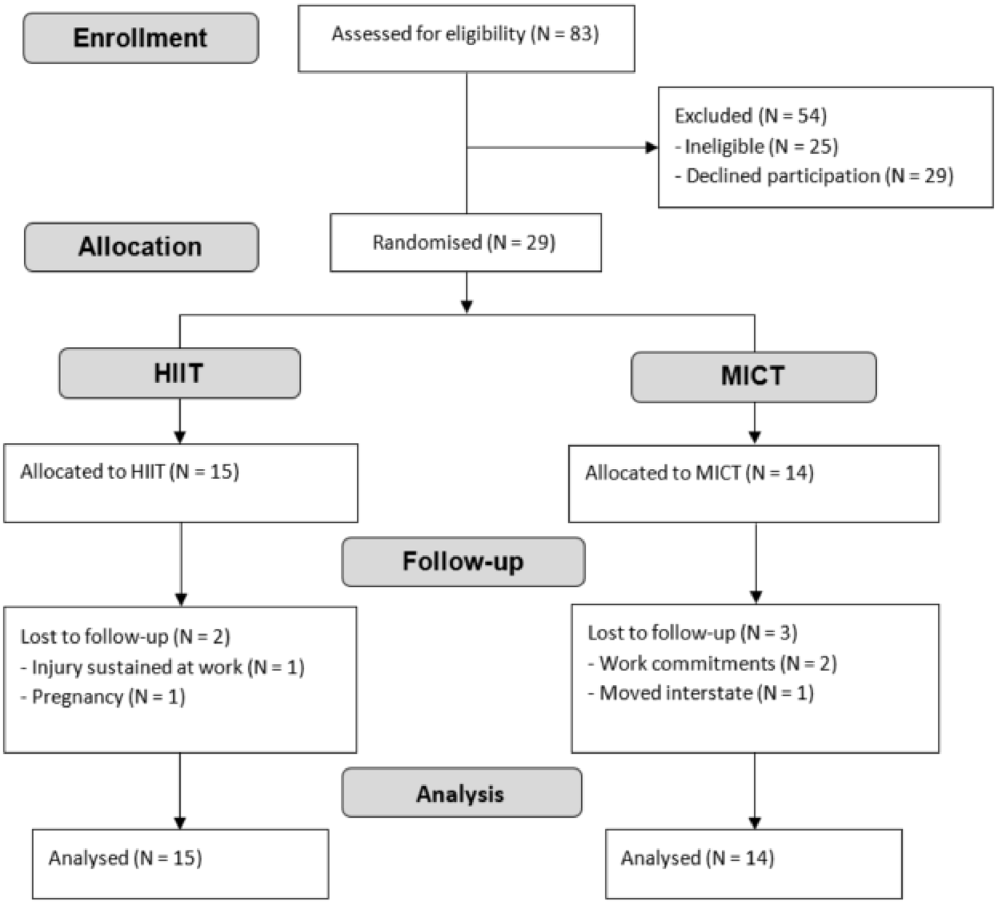
Baseline data	**HIIT (n = 15)**	**MICT (n = 14)**
Age (years)	29.7 ± 4.8	32.5 ± 6.2
VO_{2peak} (mL/kg/min)	24.8 ± 5.7	22.3 ± 3.2
$Watt_{peak}$	176.7 ± 30.6	151.8 ± 33.2
Weight (kg)	97.4 ± 19.2	102.4 ± 28.9
BMI (kg/m^2)	35.5 ± 6.8	38.4 ± 9.3
Exercise training data[a]		
Average RPE (6-20)	15.0 ± 1.6	12.4 ± 1.7
Average session heart rate (bpm)	154.3 ± 10.7	138.6 ± 6.3
Average session HR_{peak} (%)	85.4 ± 4.6	74.8 ± 3.8
Average interval heart rate (bpm)	167.1 ± 7.5	N/A
Average interval HR_{peak} (%)	92.2 ± 4.0	N/A

Bpm: beats per minute, HIIT: high-intensity interval training, HR_{peak}: peak heart rate, MICT: moderate-intensity continuous training, RPE: rating of perceived exertion.

Data are presented as mean ± standard deviation.

[a]Average of all training data across the 12-week intervention.

641 **Figures**



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643 **Figure 1.** CONSORT trial flow diagram

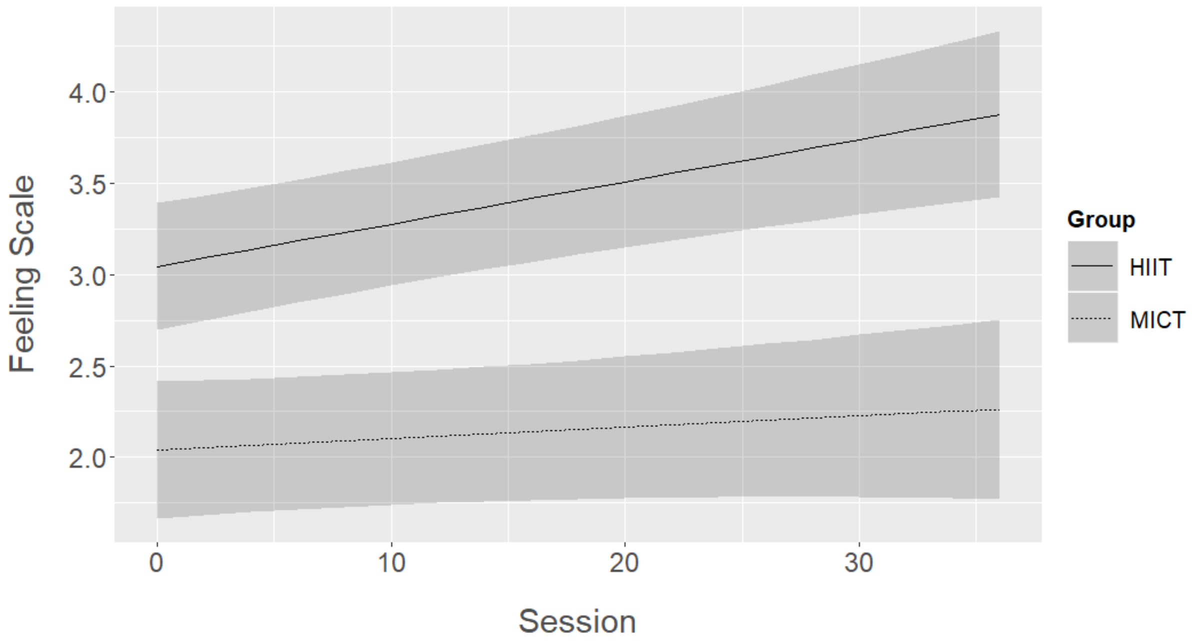

Figure 2. Feeling Scale scores for the high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT) groups across the 12-week intervention.