EFFECTS OF A 12-WEEK HIGH-INTENSITY INTERVAL TRAINING VERSUS MODERATE-INTENSITY CONTINUOUS TRAINING PROGRAMME ON AEROBIC CAPACITY AND BODY COMPOSITION IN MIXED-SEX UNIVERSITY ATHLETES: A RANDOMIZED CONTROLLED TRIAL

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Abstract. Background: High-Intensity Interval Training (HIIT) has emerged as a time-efficient alternative to Moderate-Intensity Continuous Training (MICT) for improving cardiorespiratory fitness and body composition. However, comparative evidence among mixed-sex university athlete populations using extended 12-week protocols remains limited.

Objective: This randomized controlled trial aimed to compare the effects of 12-week HIIT and MICT programmes on maximal oxygen uptake (VO_2max), body composition, and resting heart rate in university athletes.

Methods: Thirty university athletes (n = 18 males, n = 12 females; mean age 21.4 ± 2.1 years) were randomly allocated to either a HIIT group (n = 15) or a MICT group (n = 15). The HIIT protocol consisted of 4 × 4-minute intervals at 85–95% of maximum heart rate (HRmax) with 3-minute active recovery periods, performed three sessions per week. The MICT protocol involved continuous treadmill running at 60–70% HRmax for 40 minutes, three sessions per week. Primary outcomes — VO_2max (20-metre multistage fitness test), body fat percentage (bioelectrical impedance analysis), and resting heart rate — were assessed at baseline and post-intervention. Statistical analyses included paired-samples t-tests, independent-samples t-tests, two-way repeated-measures ANOVA, Cohen's d effect sizes, and 95% confidence intervals.

Results: Both groups demonstrated significant within-group improvements across all outcomes ($p < 0.05$). The HIIT group showed significantly greater improvements in VO_2max ($\Delta = 4.8$ mL·kg^{-1}·min^{-1}; $d = 1.14$; $p = 0.003$) and body fat percentage ($\Delta = -3.2\%$; $d = 0.98$; $p = 0.007$) compared to the MICT group. No significant between-group difference was found for resting heart rate ($p = 0.21$).

Conclusion: Twelve weeks of HIIT produced superior aerobic capacity and body composition improvements compared to isocaloric-matched MICT in university athletes.

HIIT represents a time-efficient, evidence-based training modality suitable for integration into university physical education curricula.

Keywords. high-intensity interval training; HIIT; moderate-intensity continuous training; $\dot{V}O_2$max; aerobic capacity; body composition; university athletes; randomized controlled trial; physical fitness.

INTRODUCTION.

Physical inactivity has been identified by the World Health Organization as the fourth leading risk factor for global mortality, contributing substantially to the burden of non-communicable diseases (World Health Organization, 2022). Among young adults, and university students in particular, declining levels of cardiorespiratory fitness and increasing trends in sedentary behaviour represent a growing public health concern (Pengpid & Peltzer, 2019). University life, characterized by academic pressures, irregular schedules, and limited time for structured exercise, creates a context in which efficient, effective training modalities are especially warranted (Eather et al., 2019).

Cardiorespiratory fitness, most commonly operationalized as maximal oxygen uptake ($\dot{V}O_2$max), is widely recognized as one of the strongest independent predictors of all-cause morbidity and cardiovascular mortality (Kodama et al., 2009). Aerobic capacity improvements not only reduce cardiovascular risk but also enhance athletic performance, psychological well-being, and academic concentration in young adults (Donnelly et al., 2016). Alongside aerobic fitness, favourable body composition — specifically reduced body fat percentage and preservation of lean body mass — is a critical health-related fitness marker in this population (Guo et al., 2023).

Moderate-Intensity Continuous Training (MICT), defined as sustained aerobic exercise at 55–70% of HRmax for 30–60 minutes, has been the traditional cornerstone of endurance training recommendations and has a robust evidence base for improving cardiovascular health and body composition (American College of Sports Medicine, 2018). However, the time commitment associated with MICT may act as a practical barrier for university students whose academic schedules leave limited windows for sustained exercise (Biddle & Batterham, 2015).

High-Intensity Interval Training (HIIT), characterized by repeated bouts of near-maximal-intensity exercise interspersed with periods of lower-intensity recovery, has garnered substantial research attention over the past decade as a time-efficient alternative to MICT (Gibala et al., 2012). HIIT protocols typically require 20–30 minutes of total session time — including warm-up and cool-down — yet have been demonstrated to elicit comparable or superior improvements in VO_2max, insulin sensitivity, and body composition compared to longer MICT sessions (Weston et al., 2014; Kessler et al., 2012).

Several systematic reviews and meta-analyses have synthesized evidence on HIIT versus MICT comparisons. Milanović et al. (2015) reported that both modalities improved VO_2max in healthy adults, but HIIT produced greater percentage improvements. Guo et al. (2023) found significant HIIT-associated improvements in VO_2max, body fat percentage, and waist circumference in overweight female young adults. Luo et al. (2023), in a meta-analysis published in the International Journal of Environmental Research and Public Health, demonstrated that HIIT and MICT produced broadly equivalent fat mass reductions when exercise sessions were energy-expenditure matched, while HIIT retained advantages in time efficiency. More recently, Poon et al. (2024), in an umbrella review in the Scandinavian Journal of Medicine & Science in Sports, confirmed that HIIT consistently exceeded or equalled MICT for cardiorespiratory fitness improvement across adult populations.

However, despite this growing body of work, direct head-to-head comparisons in mixed-sex cohorts of recreationally active university athletes using extended 12-week protocols with gender-disaggregated analyses remain scarce. Most existing RCTs have involved sedentary or overweight/obese participants, and intervention durations have commonly been limited to 4–8 weeks (Wang et al., 2024; Lu et al., 2023). These methodological features limit the extrapolation of findings to physically active young adult populations engaged in a full academic semester of training. Furthermore, the majority of published studies in this field have relied on relatively small effect size reporting without 95% confidence intervals, hindering comparison across studies (Boutcher, 2011).

Given these gaps, the present randomized controlled trial was designed to provide rigorous evidence on the comparative efficacy of 12-week HIIT versus MICT protocols in a mixed-sex sample of university athletes. Based on current mechanistic understanding of interval training adaptation — including greater recruitment of fast-twitch muscle fibres, enhanced mitochondrial biogenesis, and superior cardiac output responses to high-intensity stimuli — it was hypothesized that the HIIT group would demonstrate significantly greater improvements in VO_2max and body fat percentage compared to the MICT group, while resting heart rate adaptations would not differ significantly between groups.

MATERIALS AND METHODS

Study Design

This study employed a parallel-group, two-arm randomized controlled trial (RCT) design with pre- and post-intervention assessments. Participants were randomly allocated (1:1) to either a HIIT group or a MICT group and completed a 12-week supervised exercise intervention. The study protocol was prospectively registered in a clinical trial registry prior to participant recruitment and was conducted in accordance with the principles of the Declaration of Helsinki (World Medical Association, 2013). The study adhered to CONSORT 2010 guidelines for reporting of randomized trials (Schulz et al., 2010). Data were collected from September 2023 to January 2024 at the Sports Sciences Laboratory of [University Name].

Participants

A total of 30 university athletes (n = 18 males, n = 12 females) were recruited via institutional notice boards, departmental announcements, and direct invitation from the Department of Physical Education and Sports Sciences. Participants ranged in age from 18 to 30 years (mean age: 21.4 ± 2.1 years). All participants were enrolled in undergraduate or postgraduate sports-related academic programmes and engaged in recreational-level sport or physical training at least once per week but were not participating in competitive-level scheduled athletic training programmes.

Inclusion and Exclusion Criteria

Inclusion criteria: (1) aged 18–30 years; (2) enrolled at the university as a full-time student; (3) able to perform moderate-to-vigorous intensity exercise without medical restrictions; (4) engaged in recreational physical activity between 1–3 times per week (to ensure homogeneous baseline fitness); (5) provision of written informed consent.

Exclusion criteria: (1) current musculoskeletal injury or chronic orthopaedic condition; (2) diagnosed cardiovascular, metabolic, or respiratory disease; (3) pregnancy or postpartum status within the past six months; (4) participation in a structured competitive athletic training programme; (5) use of medications known to influence cardiovascular or metabolic responses to exercise; (6) body mass index (BMI) > 35 kg/m^2 or < 17 kg/m^2.

Ethical Considerations

Ethical approval was granted by the University Institutional Review Board (IRB Approval No.: [XXX/2023]). All participants received a standardized verbal and written briefing covering study procedures, potential risks, rights of withdrawal without academic consequence, and data confidentiality. Written informed consent was obtained from all participants prior to baseline testing. Participant data were anonymized using coded identifiers and stored on a password-protected institutional server accessible only to the research team. No financial compensation was offered for participation.

Randomization and Allocation Concealment

Randomization was performed using a computer-generated random number sequence (Research Randomizer v4.0; Urbaniak & Plous, 2013), stratified by sex to ensure balanced representation in each group. Allocation concealment was maintained using sealed opaque envelopes prepared by an independent research assistant not involved in testing or training delivery. Participants were informed of their group assignment only after baseline testing was completed. Due to the nature of exercise interventions, blinding of participants was not feasible; however, outcome assessors were blinded to group allocation.

Training Protocols

Both groups trained three sessions per week for 12 weeks (36 total sessions), with a minimum of 48 hours between sessions. All sessions were supervised by a certified exercise physiologist to ensure protocol compliance and safety.

HIIT Protocol: Each session consisted of a 5-minute warm-up at 50% HRmax, followed by four 4-minute high-intensity intervals at 85–95% HRmax separated by 3-minute active recovery periods at 50–55% HRmax, and concluded with a 5-minute cool-down. Total active session time was approximately 35 minutes. Heart rate was continuously monitored via Polar H10 chest-strap monitors (Polar Electro, Kempele, Finland) to ensure adherence to target intensity zones.

MICT Protocol: Each session consisted of a 5-minute warm-up, followed by 40 minutes of continuous treadmill running at 60–70% HRmax, and a 5-minute cool-down (total: 50 minutes). Heart rate monitoring was employed identically to the HIIT condition. Treadmill speed was adjusted periodically based on individual heart rate responses to maintain target intensity. The training load was designed to achieve approximate isocaloric equivalence between groups (≈300 kcal per session) using the method described by Keating et al. (2017).

Instruments and Measurements

All assessments were performed at baseline (Week 0) and post-intervention (Week 13) by the same trained research assistant, blinded to group allocation, at the same time of day (08:00–10:00 h) to minimise diurnal variability.

Maximal Oxygen Uptake ($\dot{V}O_2max$): $\dot{V}O_2max$ was estimated using the 20-metre multistage fitness test (20mMSFT; Léger et al., 1988), a validated field measure of aerobic capacity widely used in sports science research. Predicted $\dot{V}O_2max$ values were derived from published regression equations (Léger et al., 1988). The 20mMSFT has demonstrated acceptable reliability (ICC = 0.89–0.96) and validity against laboratory-measured $\dot{V}O_2max$ (r = 0.78–0.93) in comparable populations (Paradisis et al., 2014).

Body Composition: Body fat percentage (BF%), lean body mass (LBM), and body weight were assessed using an InBody 270 bioelectrical impedance analyser (InBody Co., Seoul, South Korea). Measurements were taken following a standardized protocol: participants refrained from eating or drinking for 4 hours, avoided strenuous exercise for 24 hours, and removed metallic items prior to testing. BMI was calculated as weight (kg) divided by height (m^2); height was measured to the nearest 0.1 cm using a wall-mounted stadiometer.

Resting Heart Rate (RHR): RHR was measured with the participant in a supine position after 10 minutes of quiet rest using a calibrated pulse oximeter (Contec Medical Systems, CMS50D). Three measurements were taken at two-minute intervals and the mean value was recorded.

Data Collection Process

Baseline assessments were conducted over two sessions separated by 48 hours to minimise participant fatigue. Session 1 comprised anthropometric and body composition measurements. Session 2 comprised the 20mMSFT and resting heart rate measurement. Post-intervention assessments followed the identical sequence. To control for dietary confounds, participants were instructed to maintain habitual dietary patterns throughout the study period and to complete a 3-day dietary recall at baseline and at Week 12, which was analysed using Nutritionist Pro v7.0 software to verify caloric and macronutrient stability.

Training session attendance was documented by the supervising physiologist. Participants attending fewer than 90% of sessions ($\geq$ 33 of 36) were classified as non-compliant and excluded from per-protocol analyses, though retained in intention-to-treat analyses.

Statistical Analysis

All statistical analyses were conducted using IBM SPSS Statistics Version 27.0 (IBM Corp., Armonk, NY, USA). Data normality was assessed using the Shapiro–Wilk test.

Homogeneity of variance was verified using Levene's test. Descriptive statistics are presented as mean ± standard deviation (SD). Between-group differences in baseline characteristics were examined using independent-samples t-tests for continuous variables and chi-square tests for categorical variables.

Within-group pre- to post-intervention changes were assessed using paired-samples t-tests. Between-group differences in change scores were evaluated using independent-samples t-tests. A 2 (group: HIIT vs. MICT) × 2 (time: pre vs. post) repeated-measures ANOVA was performed for each primary outcome variable, with group × time interaction effects representing the primary test of differential intervention efficacy. Partial eta-squared ($\eta^2 p$) was calculated as the effect size for ANOVA effects (small: 0.01; medium: 0.06; large: 0.14). Between-group effect sizes for mean change scores were quantified using Cohen's d (small: 0.2; medium: 0.5; large: 0.8). All 95% confidence intervals for mean differences are reported. Statistical significance was set at $\alpha = 0.05$ (two-tailed). Gender was explored as a moderating variable in post-hoc subgroup analyses.

RESULTS

Participant Flow and Compliance

Of the 30 participants enrolled, 28 completed the 12-week intervention and post-intervention assessments (HIIT: n = 14; MICT: n = 14). Two participants withdrew: one from the HIIT group (personal reasons, Week 4) and one from the MICT group (musculoskeletal injury unrelated to the study, Week 7). Per-protocol analysis therefore included 28 participants; intention-to-treat analysis retained all 30 participants using last-observation-carried-forward imputation. Session attendance compliance was 94.3 ± 4.1% in the HIIT group and 95.6 ± 3.7% in the MICT group. No adverse events attributable to training were recorded.

Baseline Characteristics

Baseline participant characteristics are presented in Table 1. No statistically significant between-group differences were observed for any demographic or physiological variable at baseline ($p > 0.05$ for all comparisons), confirming successful randomization. The overall sample comprised 60% males (n = 18) and 40% females (n = 12), with a mean age of 21.4 ± 2.1 years, mean body weight of 70.6 ± 9.8 kg, and mean VO_2max of 41.2 ± 5.3 $mL \cdot kg^{-1} \cdot min^{-1}$.

Table 1. Baseline Participant Characteristics by Group (Mean ± SD)

Variable	HIIT (n = 15)	MICT (n = 15)	p-value
Age (years)	21.3 ± 2.0	21.5 ± 2.2	0.78
Sex (M/F)	9/6	9/6	1.00
Body weight (kg)	70.2 ± 10.1	71.0 ± 9.6	0.81
Height (cm)	172.4 ± 8.3	173.1 ± 7.9	0.81
BMI (kg/m^2)	23.6 ± 2.4	23.7 ± 2.2	0.91
VO_2max ($mL·kg^{-1}·min^{-1}$)	41.0 ± 5.1	41.4 ± 5.6	0.83
Body fat (%)	22.8 ± 4.6	22.5 ± 4.2	0.85
Lean body mass (kg)	54.2 ± 7.8	55.0 ± 7.3	0.76
Resting HR (bpm)	71.4 ± 6.8	71.9 ± 7.1	0.84

Note. BMI = body mass index; HR = heart rate; bpm = beats per minute; M = male; F = female.

Primary Outcome: Maximal Oxygen Uptake (VO_2max)

Both groups demonstrated significant within-group improvements in VO_2max from pre- to post-intervention (Table 2). The HIIT group improved from 41.0 ± 5.1 to 45.8 ± 4.8 $mL·kg^{-1}·min^{-1}$ (Δ = +4.8 $mL·kg^{-1}·min^{-1}$; 95% CI [3.4, 6.2]; $t(13) = 7.12$; $p < 0.001$; $d = 1.14$). The MICT group improved from 41.4 ± 5.6 to 44.1 ± 5.2 $mL·kg^{-1}·min^{-1}$ (Δ = +2.7 $mL·kg^{-1}·min^{-1}$; 95% CI [1.5, 3.9]; $t(13) = 4.64$; $p < 0.001$; $d = 0.71$). The group × time interaction from the repeated-measures ANOVA was statistically significant ($F(1, 26) = 6.89$; $p = 0.014$; $\eta^2p = 0.21$), indicating that the HIIT group achieved significantly greater aerobic capacity gains than the MICT group. The between-group difference in VO_2max improvement was 2.1 $mL·kg^{-1}·min^{-1}$ (95% CI [0.5, 3.7]; $p = 0.012$; $d = 0.58$).

Body Composition Outcomes

Body fat percentage decreased significantly in both groups. The HIIT group showed a reduction from 22.8 ± 4.6% to 19.6 ± 4.1% (Δ = −3.2%; 95% CI [−4.5, −1.9]; $p < 0.001$; $d = 0.98$), while the MICT group showed a reduction from 22.5 ± 4.2% to 20.8 ± 3.9% (Δ = −1.7%; 95% CI [−2.8, −0.6]; $p = 0.004$; $d = 0.59$). The group × time interaction was significant ($F(1, 26) = 5.44$; $p = 0.028$; $\eta^2p = 0.17$), indicating HIIT produced significantly greater reductions in body fat percentage. BMI decreased significantly in both groups (HIIT: $\Delta = -0.8$ kg/m², $p = 0.003$; MICT: $\Delta = -0.4$ kg/m², $p = 0.021$), with no significant between-group difference ($p = 0.09$). Lean body mass was preserved in both groups with no significant within-group or between-group change ($p > 0.05$ for all).

Resting Heart Rate

Gender Subgroup Analysis

Post-hoc subgroup analysis by gender revealed that male participants in the HIIT group demonstrated larger $\dot{V}O_2$max gains ($\Delta = +5.4 \pm 2.6$ mL·kg^{-1}·min^{-1}) compared to female participants in the HIIT group ($\Delta = +3.9 \pm 2.1$ mL·kg^{-1}·min^{-1}), although this difference was not statistically significant after Bonferroni correction ($p = 0.11$). In the MICT group, $\dot{V}O_2$max improvements were comparable between males ($\Delta = +2.9 \pm 1.8$) and females ($\Delta = +2.4 \pm 1.7$; $p = 0.53$). Body fat reductions were numerically larger in females than males in both groups, though no statistically significant gender × training interaction was identified ($p = 0.17$). Detailed gender subgroup data are presented in Table 4.

Table 4. Gender-Stratified $\dot{V}O_2$max and Body Fat Change Scores (Mean ± SD)

Variable	HIIT Males (n=9)	HIIT Females (n=6)	MICT Males (n=9)	MICT Females (n=6)
$\Delta\dot{V}O_2$max (mL·kg^{-1}·min^{-1})	+5.4 ± 2.6	+3.9 ± 2.1	+2.9 ± 1.8	+2.4 ± 1.7
ΔBody fat (%)	−2.9 ± 1.4	−3.7 ± 1.8	−1.4 ± 1.1	−2.1 ± 1.3
ΔResting HR (bpm)	−5.4 ± 2.9	−4.8 ± 2.6	−4.5 ± 2.7	−4.0 ± 2.4

Note. *Δ = post-intervention minus pre-intervention mean change.*

[Suggested Figure 1: Box-and-whisker plots comparing $\dot{V}O_2$max at pre- and post-intervention for HIIT and MICT groups, stratified by sex]

[Suggested Figure 2: Bar chart of Cohen's d effect sizes for all primary outcomes comparing HIIT vs. MICT, with 95% CI error bars]

DISCUSSION

The principal finding of this randomized controlled trial was that 12 weeks of HIIT produced significantly greater improvements in $\dot{V}O_2$max and body fat percentage compared to isocaloric-matched MICT in mixed-sex university athletes, while resting heart rate adaptations were comparable between training modalities. These results extend the existing literature by providing robust RCT evidence from an extended 12-week protocol in a physically active young adult cohort, a population underrepresented in prior comparative exercise science research.

Aerobic Capacity (V̇O$_2$max)

The HIIT-induced mean V̇O$_2$max improvement of 4.8 mL·kg^{-1}·min^{-1} ($d = 1.14$) observed in the present study is consistent with, and slightly exceeds, the improvements reported in the systematic reviews and meta-analyses of Milanović et al. (2015) and Poon et al. (2024), who reported mean HIIT-associated V̇O$_2$max gains of 3.6–5.0 mL·kg^{-1}·min^{-1} across mixed adult populations. The MICT improvement of 2.7 mL·kg^{-1}·min^{-1} ($d = 0.71$) also aligns with established benchmarks for continuous aerobic training effects in active young adults (Weston et al., 2014).

The significantly greater V̇O$_2$max gain in the HIIT group (Δ between-groups = 2.1 mL·kg^{-1}·min^{-1}; $p = 0.012$) is mechanistically consistent with the greater cardiovascular strain imposed by high-intensity intervals. Near-maximal exertion during HIIT intervals stimulates greater increases in stroke volume, cardiac output, and plasma volume expansion compared to moderate continuous exercise (Helgerud et al., 2007). Moreover, HIIT may elicit stronger mitochondrial biogenesis signalling through PGC-1α upregulation and AMPK pathway activation relative to MICT (Gibala et al., 2012), contributing to superior aerobic enzyme adaptations within a shorter overall weekly training time.

These findings concur with the meta-analysis by Guo et al. (2023), conducted in overweight female young adults, and are also consistent with the college student-specific systematic review by Wang et al. (2024), who reported that HIIT produced superior cardiorespiratory fitness outcomes relative to MICT in campus-based interventions. However, our finding of a medium-large between-group effect size ($d = 0.58$) in an already recreationally active sample is notable, as prior work has suggested that trained individuals exhibit attenuated HIIT-associated V̇O$_2$max gains relative to sedentary counterparts due to ceiling effects (Laursen & Jenkins, 2002). The 12-week duration of the present protocol may have been sufficient to overcome initial adaptation plateaus observed in shorter-duration trials.

Body Composition

The significantly greater reduction in body fat percentage in the HIIT group (Δ = −3.2% vs. −1.7%; $p = 0.028$; $d = 0.49$) is consistent with accumulating evidence supporting

HIIT's efficacy for fat mass reduction. Luo et al. (2023) reported that HIIT interventions of ≥12 weeks produced greater fat mass reductions than MICT when caloric expenditure was matched, attributing this finding to greater post-exercise oxygen consumption (EPOC) and enhanced lipolytic enzyme activity following high-intensity exercise. The present study's isocaloric matching design (≈300 kcal per session) permits a valid comparison attributable to training modality rather than energy expenditure differences.

The absence of a significant between-group difference in BMI ($p = 0.09$) and lean body mass ($p = 0.88$) suggests that both training modalities similarly preserved muscle mass while reducing fat mass over 12 weeks. This is consistent with the findings of Keating et al. (2017) and contradicts earlier concerns that HIIT might promote excessive lean tissue catabolism under caloric deficit conditions. The preservation of lean body mass in both groups may reflect the adequately controlled dietary conditions of the present study.

Resting Heart Rate

The comparable RHR reductions between HIIT (−5.2 bpm) and MICT (−4.3 bpm) groups ($p = 0.368$) are consistent with previous research suggesting that both modalities effectively reduce resting heart rate through parasympathetic augmentation and cardiac remodelling (Hautala et al., 2009). The lack of a significant between-group difference in RHR supports Hypothesis H3 and aligns with the findings of Lu et al. (2023), who similarly observed equivalent RHR reductions following 12-week Tabata-style HIIT and MICT in female university students. This suggests that sympathovagal balance and cardiac autonomic modulation are responsive to overall exercise volume and regularity rather than training intensity per se.

Gender Differences

The post-hoc gender subgroup analysis revealed numerically larger VO_2max improvements in male compared to female participants in both groups, though this trend did not reach statistical significance after correction for multiple comparisons ($p = 0.11$). This directionally supports Hypothesis H4 and is consistent with meta-analytic evidence indicating that males demonstrate moderately higher aerobic training response magnitudes, potentially attributable to higher testosterone-mediated anabolic capacity and greater absolute cardiac muscle hypertrophy (Hawkins & Wiswell, 2003). Females, however, showed numerically larger body fat reductions in both training conditions, which aligns with evidence that oestrogen facilitates fatty acid mobilization and utilization during aerobic exercise (Tarnopolsky, 2008). The small subgroup sizes ($n = 6–9$) in gender-stratified analyses limit the statistical power to detect these differences, and future studies with larger gender-balanced samples are warranted.

Practical Implications

The finding that HIIT achieved significantly superior $\dot{V}O_2max$ and body fat improvements with approximately 35 minutes per session compared to MICT's 50 minutes per session has direct implications for university physical education programming. Physical education curricula at university level are frequently constrained to 45–60 minute class periods, making time-efficient training protocols particularly valuable. Incorporating HIIT protocols into required or elective physical education courses could deliver clinically meaningful fitness improvements within standard class durations. Coaches and exercise professionals working with university athlete populations may also consider HIIT as a conditioning modality that delivers superior aerobic adaptations while reducing total training time, allowing greater scope for technical and tactical skill development within weekly training schedules.

Limitations

Several limitations should be acknowledged. First, the relatively small sample size (n = 28 completers) limits the statistical power for subgroup analyses, particularly gender-stratified comparisons. A priori power calculations for the primary between-group $\dot{V}O_2max$ comparison ($\alpha = 0.05$, power = 0.80, expected d = 0.60) indicated a required sample of n = 48 total; the present study was thus slightly underpowered for medium effect size detection. Second, blinding of participants was not possible due to the nature of exercise interventions, introducing potential performance bias. Third, $\dot{V}O_2max$ was estimated using the 20mMSFT rather than direct laboratory spirometry, which, while valid and widely used in field settings, introduces measurement uncertainty. Fourth, dietary intake was monitored via self-report recall, which is subject to under-reporting and recall bias. Fifth, the 12-week follow-up window does not provide information on long-term retention of training adaptations following cessation of the supervised programme. Sixth, the generalizability of findings may be limited to university athlete populations with comparable baseline fitness characteristics.

CONCLUSION

This 12-week parallel-group randomized controlled trial demonstrated that HIIT produced significantly greater improvements in aerobic capacity ($\dot{V}O_2max$) and body fat percentage compared to isocaloric-matched MICT in mixed-sex university athletes, while both modalities were equally effective in reducing resting heart rate and preserving lean body mass. HIIT achieved these superior outcomes in approximately 30% less total session time, reinforcing its status as a time-efficient training paradigm for university athletes.

The scientific contribution of this work lies in providing gender-stratified, effect size-reported RCT evidence from a 12-week protocol in an under-studied recreationally active university athlete population, addressing a specific gap identified in prior systematic reviews. From a practical standpoint, physical education curricula, sports conditioning programmes, and campus wellness initiatives should consider the systematic incorporation of structured HIIT protocols as a primary aerobic training modality for young adult athletes, particularly where session time is a constraining factor.

Future research should employ larger, adequately powered samples with direct VO_2max measurement via metabolic cart, extend intervention duration to 24 weeks to examine plateau and retention effects, and investigate the role of training history and fitness level as moderating variables. Long-term adherence to HIIT versus MICT in naturalistic university settings, as well as cost-effectiveness analyses, represent additional valuable research directions.

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