

Original research papers

FEASIBILITY AND PRELIMINARY EFFECTS OF A SIX-WEEK EQUIPMENT-FREE HIGH-INTENSITY INTERVAL RESISTANCE TRAINING INTERVENTION IN UNIVERSITY STUDENTS: A NON-RANDOMIZED PILOT STUDY

ANDRÉ BENTO^{1,2,3}, PEDRO CONCEIÇÃO¹, NUNO LOUREIRO^{1,2,4}, HELENA FERREIRA-BARBOSA^{1,2}

¹Polytechnic University of Beja, Portugal

²SPRINT – Sport Physical activity and health Research & INnovation CenTer – Portugal

³CHRC – Comprehensive Health Research Centre, Department of Sport and Health, School of Health and Human Development, University of Évora, Portugal

⁴ISAMB – Instituto de Saúde Ambiental, Faculdade de Medicina, Universidade de Lisboa, Portugal

Mailing address: André Bento, Department of Arts, Humanities and Sports, School of Education, Polytechnic University of Beja, 7800-295 Beja, Portugal, e-mail: andre.bento@ipbeja.pt

Abstract

Introduction. Physical inactivity is linked to poorer mental health and an increased risk of chronic diseases. High-intensity interval resistance training (HIRT) may be a strategy for improving well-being. The aim of this pilot study was to examine the feasibility and preliminary effects of a six-week equipment-free HIRT program on physical fitness, body composition, and mental health symptoms in university students. **Material and Methods.** In a longitudinal, non-randomized controlled study, 16 undergraduates (intervention group [IG], $n = 7$; control group [CG], $n = 9$; mean age 21.0 ± 2.3 years; 94% male) were assessed before and after the intervention. The IG completed biweekly 31-minute HIRT sessions for six weeks. Outcomes included push-up test, handgrip strength, squat jump, medicine ball throw, Yo-Yo Intermittent Recovery Test Level 1, and mental health measured by the Hospital Anxiety and Depression Scale. Baseline-adjusted ANCOVA tested group differences at post-intervention. **Results.** Significant group effects favoured the IG for push-up performance ($p = .014$) and cardiorespiratory fitness (Yo-Yo test; $p = .025$). No significant between-group differences were found for handgrip strength, squat jump, seated medicine ball throw, body composition, anxiety, or depressive symptoms (all $p > .05$). Within the IG, total minutes of high-intensity activity were negatively correlated with fat mass ($r = -0.856$, $p = .014$) and depressive symptoms ($r = -0.943$, $p = .001$). **Conclusions.** This non-randomized pilot study suggests that a six-week equipment-free HIRT intervention is feasible and may improve upper-body muscular endurance and cardiorespiratory fitness in university students. No significant between-group effects were observed for anxiety, depressive symptoms, or body composition. Associations between time spent at high intensity, fat mass, and depressive symptoms should be interpreted as exploratory and hypothesis-generating, requiring confirmation in adequately powered randomized controlled trials.

Keywords: high-intensity training, muscular endurance, mental health, anxiety, depression, body composition

Introduction

The transition to university education represents a critical phase in young adults' lives in terms of health-related behaviours. This transition is often accompanied by greater academic demands and changes in living conditions, contributing to a decline in physical activity (PA) and an increase in sedentary behaviours [1, 2]. Importantly, this period also coincides with elevated vulnerability to mental health symptoms, including anxiety and depression, which can negatively affect quality of life and academic functioning [3]. Among children and adolescents, PA enhances physical fitness, bone health, and body composition [4]. Physical fitness (encompassing strength, flexibility, body composition, and cardiorespiratory fitness [CRF]) reflects an individual's functional capacity and directly impacts health promotion [5, 6, 7]. Despite its well-documented benefits, physical inactivity remains a major concern: in 2022, about 31% of the global population did not meet PA recommendations [8]. In Portugal, approximately 14% of annual deaths are linked

to physical inactivity [9], with a particularly high prevalence among university students, who also show increased depressive symptoms associated with sedentary behaviour and poor sleep quality [10]. Common barriers to regular PA include lack of time, motivation, and financial resources [9, 11]. In this regard, High-Intensity Interval Training (HIIT) stands out as an effective and accessible strategy, given its short duration, low cost, and minimal equipment requirements, supporting the promotion of healthier lifestyles [12].

Although exercise interventions are generally associated with better mental health in university students, the psychological effects are not uniform. Meta-analytic evidence suggests reductions in depression and anxiety, but these findings are tempered by substantial heterogeneity and low certainty, and several randomized trials have reported null or inconsistent effects, particularly for anxiety and when exercise is compared with active controls. Direct evidence for equipment-free HIRT in university students remains scarce [13, 14].

HIIT and High-Intensity Resistance Training (HIRT) are training approaches that can improve physical fitness and reduce chronic disease risk, benefiting both physical and mental aspects. From a physiological perspective, these methodologies involve efforts above 70% of VO_2max . In terms of heart rate, the target training zone is typically between 85% and 95% of the maximum [15]. Authors such as Buchheit and Laursen [16] state that spending several minutes at $\geq 90\%$ of VO_2max can be an effective stimulus for promoting cardiovascular adaptations. There are also reported reductions in fat mass and improvements in VO_2max in participants, which may be related to the higher post-exercise energy expenditure that HIIT implements in the body [17, 18]. Several studies have demonstrated that HIIT is associated with increases in overall energy expenditure and improvements in body composition, particularly when compared to traditional moderate-intensity exercise. Rather than attributing these effects primarily to post-exercise oxygen consumption, which appears to be modest and may be compensated for over 24 hours, the benefits of HIIT can be better explained by its time-efficient nature and high training stimulus [18, 19, 20]. At this point, the body tries to metabolize fat, recovers the muscle glycogen reserve used during the stimulus, there is an increase in the sympathetic nervous system, and the activity of some hormones (insulin, cortisol, growth hormone) increases [21, 22]. Although HIRT has traditionally been described with external loads, resistance stimuli can also be delivered through bodyweight exercise when the movements are performed at sufficient intensity. For this reason, the HRmax and VO_2max thresholds cited here should be understood as general markers of high-intensity effort derived from interval-training literature, rather than as direct surrogates of mechanical or neuromuscular loading in resistance exercise.

On a mental and psychological level, it is necessary to continue investigating the relationship between these topics. However, there are some studies that report improvements not only in mental health and associated disorders, but also in cognitive function, attention, and concentration in adolescents and young adults [23, 24, 25, 26]. Evidence from the study by White et al. [27] indicates that the relationship between PA and mental health is mediated by multiple factors, including affect, self-esteem, self-efficacy, body image satisfaction, resilience, social support, and perception of physical health, highlighting the multifactorial pathways through which exercise can influence psychological well-being. Considering these mediators when designing and prescribing PA interventions may increase their impact on mental health outcomes.

Both methodologies, HIRT and HIIT, offer improvements in physical condition, motor development, sports performance, prevention of cardiometabolic diseases, as well as benefits in blood pressure control, insulin sensitivity, and body composition [28]. HIRT shares the interval-based organization of HIIT (work bouts interspersed with recovery) but differs in modality and in how intensity is operationalized. Whereas HIIT typically refers to interval-based aerobic/cyclical exercise (running or cycling) quantified by speed/power or physiological markers, HIRT applies the same principle to resistance exercises. As originally described by Paoli et al. [20], HIRT often uses relatively high external loads and short intra-set recovery (rest-pause/cluster-type configurations) to maintain high effort across brief bouts, thereby targeting muscular strength and endurance in a time-efficient manner. The “resistance” component of HIRT does not necessarily require traditional free weights or machines; resistance-type stimuli can also be delivered through structured bodyweight exercises performed at high effort, providing

a practical and accessible alternative when equipment or facilities are limited [29, 30]. These approaches align with global fitness market trends, as demonstrated in the American College of Sports Medicine (ACSM) report for 2025, where this type of training ranks sixth in the top trends, and other practices such as mental health training and functional training also gain prominence [31]. HIRT adapts interval principles to emphasize repeated bouts of multi-joint, whole-body exercises that may improve muscular endurance and functional capacity while maintaining a low logistical burden. Although a growing body of literature has examined HIIT in young populations [18, 23, 24, 25], evidence specifically investigating HIRT, particularly equipment-free protocols, among university students remains scarce, especially regarding its combined effects on both mental health and physical fitness outcomes. Given the increasing interest in scalable, low-cost exercise strategies, evaluating HIRT feasibility and preliminary effects on both physical fitness and mental health in university students is a relevant research gap.

Therefore, considering the alarming data on physical inactivity and its health impacts, the barriers to PA practice, and its relationship with depressive symptoms, the study intends to contribute valuable insights into strategies for promoting both mental and physical well-being among university students, providing preliminary evidence on the feasibility and potential effects of innovative and time-efficient training methods in combating sedentarism and its associated consequences. The aim of this pilot study was to examine the feasibility and preliminary effects of a six-week equipment-free HIRT program on physical fitness, body composition, and mental health symptoms in university students. Specifically, it seeks to assess the impact of HIRT on symptoms of anxiety and depression, as well as on upper- and lower-limb muscular power, maximal strength, body composition, and aerobic fitness. Given the limited prior data and feasibility constraints, this investigation was prospectively positioned as a pilot study with an estimation focus. Accordingly, this pilot study aimed to evaluate feasibility (recruitment, retention, adherence, and safety) and estimate preliminary effects of a six-week, equipment-free HIRT program on (i) mental health symptoms (anxiety and depression) and (ii) physical fitness outcomes (upper-body muscular endurance, lower-limb power, upper-limb power, handgrip strength, body composition, and CRF). However, evidence regarding the effects of brief high-intensity exercise interventions on anxiety and depressive symptoms remains mixed, particularly in small samples, non-clinical populations, and short-duration interventions. Therefore, psychological outcomes in pilot trials should be interpreted cautiously and primarily used to generate hypotheses for future studies.

Material and Methods

Study design

This study followed a longitudinal, non-randomized controlled intervention design conducted between October and December 2024. This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. The study involving human participants was reviewed and approved by the Polytechnic University of Beja Institutional Ethics Committee (Approval No. 39/2024). All participants were informed about the study procedures and provided written informed consent prior to participation.

Participants were allocated into two groups: an intervention group (IG) that completed the HIRT program, and a control group (CG) that maintained their usual daily routines witho-

ut structured exercise. The allocation was based on voluntary enrolment and availability, rather than random assignment. This pragmatic allocation procedure was adopted because the intervention required attendance at fixed supervised sessions, and participants' academic schedules limited the feasibility of random allocation. However, this approach introduces a risk of self-selection bias. Students who volunteered for the HIRT group may have differed from controls in motivation, availability, baseline exercise preferences, perceived need for exercise, or expectations regarding the intervention. Therefore, between-group differences should be interpreted cautiously and cannot be attributed solely to the intervention.

Both groups underwent baseline (pre-intervention) and follow-up (post-intervention) assessments conducted under standardized laboratory conditions by the same evaluator, who was not blinded to group allocation. Because allocation was self-selected based on availability and willingness to participate, baseline differences and selection bias cannot be ruled out; interpretation of between-group effects, particularly for mental health outcomes, is therefore cautious.

The study was designed as a pilot feasibility trial, aiming to examine the preliminary effects of HIRT on physical fitness (muscular strength, power, body composition, and CRF) and mental health (anxiety and depression symptoms). The intervention adhered to the Consensus on Exercise Reporting Template (CERT) to ensure reproducibility of exercise protocols, intensity monitoring, and adherence reporting (32).

Eligibility criteria

Students were eligible if they were enrolled in higher education, were available to attend the scheduled assessments and training sessions and provided written informed consent. Participants were excluded from the final analysis if they missed one or both assessment sessions or, for the HIRT group, attended fewer than 75% of the planned training sessions (<9/12 sessions).

Subjects and Research Context

The target population of this study consisted of university students. From this population, a total sample of 16 participants was recruited and allocated into two groups: an IG ($n = 7$), which completed a six-week HIRT protocol, and a CG ($n = 9$), which did not engage in any structured training during the same period. The study followed a non-randomized design. Although the total sample consisted of 16 participants, the initial sample was larger at the beginning of the study. It was necessary to establish some eligibility criteria to ensure the quality of the study. Poor attendance at training sessions and pre- and post-intervention assessments was the main factor for exclusion for many of the participants in this study. This allowed us to arrive at the final total sample, ensuring that all participants had completed all the pre- and post-intervention assessments and, in the case of the IG, had attended at least 75% of the training sessions.

Participant flow was as follows: 123 students were reached and 23 completed baseline assessments, corresponding to a recruitment/enrolment rate of 18.7%; 16 completed post-intervention assessments and were included in analyses (IG $n = 7$; CG $n = 9$), corresponding to a retention rate of 69.6% from baseline and an attrition rate of 30.4%. The final analysed sample represented 13.0% of the students initially invited. Attrition occurred due to missing assessment sessions and, in the IG (<75% of sessions), insufficient training attendance. "Poor attendance" was defined as missing one or both assessment sessions and/or attending fewer than 9 of 12 planned training sessions. In the

IG, four participants were lost to follow-up due to missing one or both assessment sessions and/or attending fewer than 9 of 12 planned sessions. In the CG, three participants were lost to follow-up due to missing post-intervention assessments. No withdrawals were attributed to adverse events (Fig. 1).

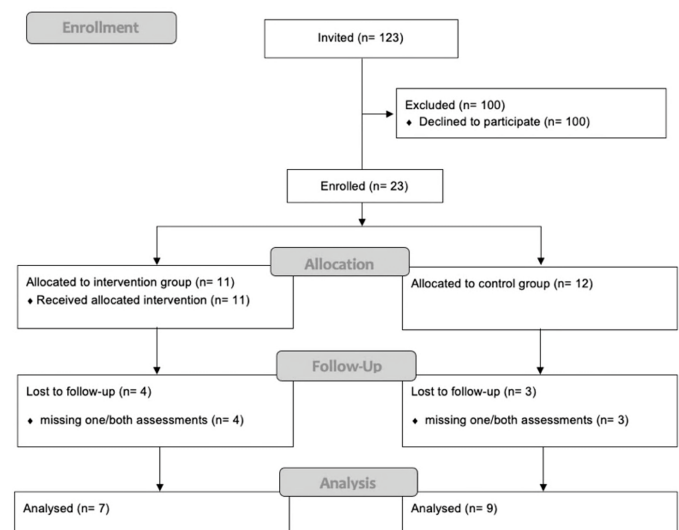


Fig. 1. Study design.

Participants in the IG were those who voluntarily committed to and took the initiative to participate in the proposed program. The mean age of the overall sample was 21.0 ± 2.3 years. In terms of sex distribution, the sample included 94% male participants and 6% female participants. In this study, the term sex refers to biological attributes (male or female) as reported by participants.

The final sample included 16 participants, of whom 15 were male (94%) and one was female (6%). The mean age of the overall sample was 21.00 ± 2.34 years. Participants were allocated to the IG ($n = 7$) or CG ($n = 9$). The IG consisted of participants who voluntarily committed to and initiated participation in the proposed programme, reflecting the non-randomized nature of the study design. Baseline characteristics by group are presented in Table 1. Participants in the IG were slightly younger than those in the CG (20.43 ± 1.90 vs. 21.44 ± 2.65 years), corresponding to a standardized difference of $d = -0.43$. The sex

Table 1. Baseline characteristics of the participants by group

Variable	IG ($n = 7$)	CG ($n = 9$)	Standardized difference
Age, years	20.43 ± 1.90	21.44 ± 2.65	-0.43
Male, n (%)	7 (100)	8 (88.9)	—
Female, n (%)	0 (0)	1 (11.1)	—
Height, m	1.67 ± 0.06	1.73 ± 0.08	-0.76
Weight, kg	63.90 ± 11.15	72.49 ± 8.09	-0.90
BMI, kg/m ²	22.96 ± 3.39	24.44 ± 3.03	-0.46
Fat mass, %	15.57 ± 5.99	18.02 ± 7.85	-0.34
Lean mass, kg	53.47 ± 6.18	58.54 ± 7.19	-0.75

Note. Values are presented as mean $\pm$ standard deviation unless otherwise stated. Standardized differences were calculated as Cohen's d using the pooled standard deviation and expressed as IG – CG. Negative values indicate lower baseline values in the IG compared with the CG. IG = intervention group; CG = control group; BMI = body mass index.

distribution was also imbalanced, with all participants in the IG being male, whereas the CG included eight male participants and one female participant. Standardized baseline differences suggested that, compared with the CG, the IG had lower baseline values for body mass, height, lean mass, BMI, and fat mass. The largest standardized differences were observed for body mass ($d = -0.90$), height ($d = -0.76$), and lean mass ($d = -0.75$), suggesting relevant baseline imbalance between groups. These baseline differences were considered when interpreting the intervention effects, and post-intervention outcomes were analysed using baseline-adjusted ANCOVA models.

Sample size estimation and justification

As this investigation was prospectively positioned as a pilot trial, no formal a priori power calculation was performed. Sixteen university students were enrolled and allocated to the IG ($n = 7$) and CG ($n = 9$). The pilot objectives were to assess feasibility and to obtain preliminary parameter estimates to inform the sample-size planning of a future definitive trial. Consistent with this positioning, analyses emphasize effect sizes and 95% confidence intervals for the pre-specified outcomes (HADS, push-ups, Yo-Yo, handgrip, SMBT, squat jump).

Assessment Procedures

The pre- and post-intervention assessments were conducted in the gymnasium of the Polytechnic University of Beja, preferably in the morning for most participants, following a consistent and logical sequence of tests. When participants were unable to attend the morning sessions, alternative times were scheduled according to individual availability.

Mental health was assessed first, followed by body composition. The physical assessment began with strength tests, alternating between lower and upper limbs to minimize fatigue that could affect performance. Finally, CRF was evaluated. This sequence was maintained throughout all assessments, with each protocol strictly followed and every test carefully demonstrated and explained to ensure participants' full understanding.

Participants were asked to maintain their usual routines during the study period. However, additional PA outside the intervention was not objectively monitored, and dietary intake, sleep behaviour, and other lifestyle factors were not systematically recorded. These factors are therefore acknowledged as potential confounders.

Research instrument

The data collection instrument was a questionnaire that included sociodemographic questions and questions characterizing the participants, as well as the HADS – Hospital Anxiety and Depression Scale validated for the Portuguese population by Pais-Ribeiro et al. [33]. In the present study, internal consistency estimates were not calculated because the very small sample size precluded reliable estimation of Cronbach's alpha. This questionnaire is directed towards mental health, specifically anxiety and depression. The questionnaire consists of a total of 14 multiple-choice questions. Of the 14 questions, 7 are directed towards depressive symptoms and the remaining 7 towards anxiety. All questions have an associated scale, and at the end, the total points associated with each part of the questionnaire will be summed.

Measures

Yo-Yo test

The Yo-Yo Intermittent Recovery Test Level 1 (YYIRI) was used to test CRF as it is recommended to ensure the battery

provides a complete understanding of the athlete's physical capabilities [34]. The test consists of incremental shuttle running starting from the speed of 8 km·h⁻¹ until exhaustion. The maximum running speed is 14.5 km·h⁻¹. Each shuttle run consists of 2 × 20 m interspersed by 10 s of active recovery (slow jog or walk) for a short 2.5 m shuttle. There are multiple shuttle runs within each speed stage. A pre-recorded audio track dictates the running speed. By the time each audio is played, participants must have crossed the 20 m line completely with both feet. The test ended after two consecutive failures to reach the line in time. Using the following equation, the total number of laps were utilized to estimate VO₂max: $IRT1 \text{ distance (m)} \times 0.0084 + 36.4 \text{ (ml kg}^{-1}\text{min}^{-1}\text{)}$ [35]. During testing, telemetric heart rate (HR) was used to monitor HR. The maximum HR was represented by the peak HR observed during the test [35, 36]. The primary Yo-Yo outcome used for analysis was the number of completed shuttles. Estimated VO₂max was calculated descriptively using the published equation but was not used as the primary inferential outcome.

Push-up test

Upper-body muscular endurance was assessed using the push-up test [37]. The test started with the participants' hands and feet touching the floor, and their body in a plank position, with their feet apart and their hands positioned below the shoulder line. With the body straight (without arching up or slumping down) and only the hands and toes touching the floor the participants should lower the body until forming a 90° angle between the arm and the forearm and then return to the starting position. This action was repeated with a previously defined cadence of 20 push-ups per minute. Repetitions were counted only if participants maintained a straight body alignment (no excessive trunk flexion/extension), reached approximately 90° elbow flexion at the bottom position, and returned to full elbow extension at the top. A metronome guided the cadence (20 rep/min). The test was terminated when the participant could not maintain cadence for two consecutive repetitions, failed to meet form criteria, or voluntarily stopped. Pauses were not permitted beyond the cadence interval.

Handgrip test

Grip strength was assessed using a Hand Dynamometer (Hydraulic Hand Dynamometer, Jamar, Warrenton, USA), with participants seated, their elbow positioned at a 90-degree angle by their side, and their wrist in a neutral position. The seated position with the elbow at 90-degree and wrist neutral follows widely used standardized testing recommendations, supporting comparability and measurement reliability. The mean of three trials for each hand was calculated, following a standardized protocol that has been well-documented for its reliability [38].

Seated medicine ball throw

The upper-limb power was assessed through Seated Medicine Ball Throw (SMBT). The SMBT consists of a medicine ball (2 KG) throw, performed as a chest pass while sitting with legs extended and the head resting against a wall. During the throw, the participant must maintain contact with the wall, both with their back and head. The evaluator measures the distance from the starting point to the first point of contact of the ball with the ground. Each participant performed three trials separated by 90 s of rest. The best distance (m) was retained for analysis [39].

Squat jump test

The lower-limb power was assessed using the Squat Jump (SJ). In SJ test (OptoJump version 1.13.24, Microgate®) participants start from an isometric semi-squat position before performing a vertical jump. It is crucial that the participant maintains full extension of the hips, knees, and ankles while airborne,

avoiding knee flexion that could compromise the test's validity. Jump height (cm) was derived from flight time recorded by the OptoJump system using the manufacturer's standard algorithm. Each participant is allowed three attempts, with a minimum of two minutes of rest between trials, to minimize fatigue effects and improve reliability [34]. The best of three valid trials was retained for analysis.

Body composition

Participants' body composition and body mass were measured to the nearest 0.1 kg in light sportswear on a bioelectrical impedance scale (TANITA SC-330; Tanita Corporation, Tokyo, Japan), and height was measured to the nearest 1 mm using a portable stadiometer (Seca 213, Seca, Hamburg, Germany). Body composition measurements (body fat, lean body mass and basal metabolic rate) were performed through a bioelectrical body impedance. To reduce variability in bioelectrical impedance outcomes, assessments were scheduled at a similar time of day for each participant when possible. Participants were instructed to avoid strenuous exercise and alcohol for 24 h, and caffeine for 3 h prior to testing, to maintain usual hydration, and to void their bladder immediately before measurement. Although standardized pre-assessment instructions were provided, bioelectrical impedance is sensitive to hydration status, recent exercise, food intake, and other factors. Therefore, body composition outcomes should be interpreted cautiously.

HIRT protocol

For the HIRT exercise sessions, it was important to find a protocol that met the objectives of our study. The chosen protocol was created by Bento and Loureiro [40] which is described in detail below based on CERT [32].

The training program uses a model similar to calisthenics or circuit training, with exercises chosen for not requiring additional equipment and for engaging most major muscle groups. The sequence aimed to alternate the main muscle groups engaged, minimizing localized muscle fatigue.

The program lasted six weeks, every Tuesday and Thursday, from November 5 to December 12, 2024, totalling 12 sessions. Each exercise session lasted 31 minutes. The program did not include any external load, with all exercises performed using body weight. However, participants were encouraged and motivated to perform the maximum number of repetitions per work interval and to respect work and rest times, ensuring each work interval was performed at maximum volition effort. In this program, the "resistance" component was provided by multi-joint movement patterns, high exercise density, short recovery periods, and maximal intended effort during each work interval. Therefore, this intervention should be interpreted as an equipment-free/bodyweight HIRT protocol rather than as a traditional load-based resistance-training intervention.

The exercise session structure lasted 31 minutes, divided into three distinct phases: five minutes of warm-up, 24 minutes of the conditioning phase, and two minutes for stretching exercises (Fig. 2). The IntervalTimer app was used for work and rest time control and timing, and a speaker was used to ensure the sound was audible to all participants. The warm-up phase lasted about five minutes and included three sets of two exercises (Jumping Jack and Mountain Climber), with 45 seconds of rest between each set. Each exercise lasted 30 seconds, interspersed with 15 seconds of rest between them. The main phase of the protocol lasted about 24 minutes and consisted of four sets of seven exercises (squat jump, push up, jumping lunge, spiderman plank, burpee, superman plank, high knee skipping in place), interspersed with 45 seconds of rest. For each 30-second work interval, participants were instructed to perform as

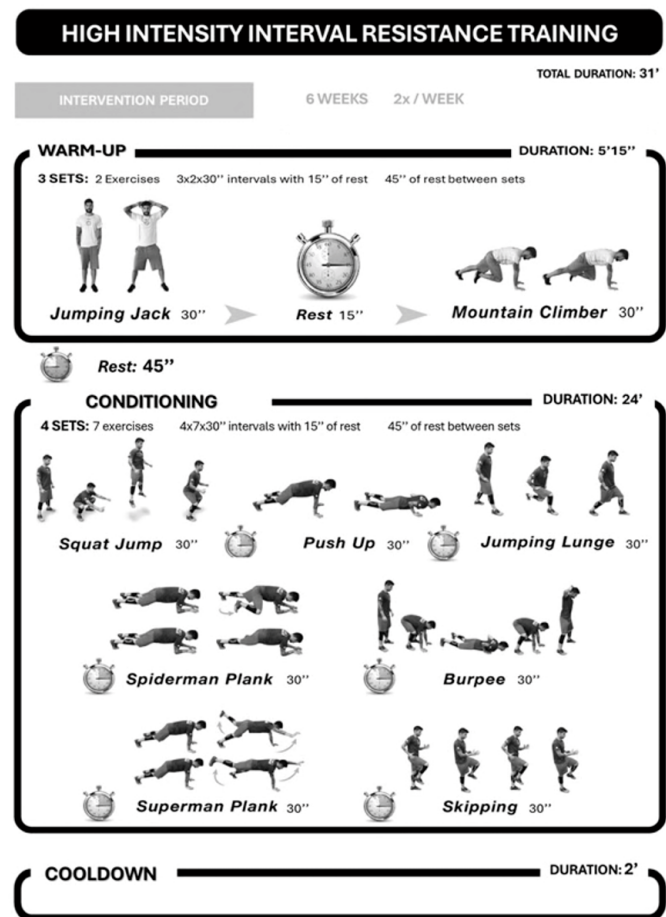


Fig. 2. Training session structure.

many repetitions as possible with maximal intended effort while maintaining proper technique. Tempo was self-selected but standardized verbal instructions emphasized controlled landings and full range of motion. The self-selected tempo allowed participants to perform each work interval at maximal intended effort while maintaining correct technique. However, because repetition tempo was not externally standardized, differences in movement speed may have influenced mechanical load and training stimulus between participants.

The cool-down phase lasted about 2 minutes and consisted of stretching movements for the main muscle groups engaged during the session. Progression was standardized rather than individually prescribed. During the first two weeks, participants completed three sets to allow familiarization and adaptation. From week three onwards, the conditioning phase increased to four sets. Individual exercise modifications were allowed when participants reached fatigue, but these modifications were used to maintain technical quality and safety rather than to prescribe individualized progression. When participants reached exhaustion or muscle fatigue, they had the option to perform exercises without jumping or with less impact (squat jump, lunge, skipping), with knee support on the ground (push up), or remain in a plank position (spiderman plank, superman plank). All sessions were supervised by the same two professional trainers with degrees in Sport and Exercise Sciences. The trainers corrected technical execution and provided standardized verbal encouragement focused on maintaining effort, correct technique, and adherence to work/rest intervals.

Before each session, an HR monitor (Polar OH1, Polar, Kempele, Finland) was correctly placed on each participant. HR was monitored throughout the session (warm-up, conditioning, cool-down), with the signal transmitted in real-time via Bluetooth technology from the Polar OH1 to an iPad (iPad 8th generation, Apple, Cupertino, USA) running the Polar Team app version 1.9.5. Data from each participant were subsequently recorded in Excel. Data on the Rated Perceived Exertion (RPE) of each participant were recorded on a sheet and collected at various points during the training, namely: at the end of the warm-up, at the end of each series of the main phase, and at the end of the stretching phase. At the end of each series, the adapted version of the Borg scale (0-10) was individually shown to the participants, who had to point to the value corresponding to their perceived effort at that moment [41].

In the first two weeks of training, which served as an adaptation period to the protocol, participants had to remain for at least 10 minutes and 30 seconds in a high-intensity zone $\geq 90\%$ of their maximum HR to achieve the desired internal training load. In the remaining weeks, they had to remain for at least 14 minutes in this high-intensity zone.

The HR values were expressed as a percentage of the individual HRmax determined according to the peak HR recorded during the Yo-Yo test. A cut-point of $\geq 90\%$ of maximal HR was a criterion for satisfactory compliance to high-intensity exercise [16]. The $\geq 90\%$ HRmax threshold was used as an indicator of internal cardiovascular intensity and training-load monitoring, rather than as a direct measure of mechanical or neuromuscular load. For each session, the total minutes spent in high-intensity activity were recorded (t-RED).

The subjective and physiological loads were quantified using training impulse (TRIMP). In this approach, Foster's session RPE (b-IL) method [42] was used to assess subjective fatigue levels, while Edwards' five-zone TRIMP (e-IL) [43] was applied based on HR characteristics. The b-IL was computed by multiplying the duration of the exercise based on RPE [44]. The e-IL was determined according to Edwards [45] based on the time spent in five specific training zones in relation to each individual maximum HR. The zones were categorized as follows: zone 1 (50-59% of HRmax), zone 2 (60-69% of HRmax), zone 3 (70-79% of HRmax), zone 4 (80-89% of HRmax) and zone 5 (90-100% of HRmax). The e-IL for each session was calculated by multiplying the duration of time spent in each training zone by the corresponding zone number (1-5), and the values obtained were added together to generate a cumulative score.

In addition to the training program, the professional trainers created a welcoming and friendly environment during the sessions, trying to maintain adherence and encouraging participants to complete the training program. Verbal feedback, both individual and group, and more enjoyable music choices for the participants were strategies to motivate them.

Retention was calculated as the proportion of participants who completed post-intervention assessments ($n = 16$) among those who completed baseline assessments ($n = 23$), yielding a retention rate of 69.6%. Adherence within the IG was defined as attendance $\geq 75\%$ of planned sessions ($\geq 9/12$).

Regarding adverse events, the training sessions rarely started at the scheduled time. The delay was due to the waiting period required to ensure the presence of as many study participants as possible, which ended up disadvantaging those who were punctual. On some occasions, the heart rate monitor straps (Polar OH1) became misaligned during the session, requiring special attention from the supervising professionals. Although

no injuries or emergencies occurred, all study participants were covered by insurance.

With respect to the estimated economic cost, the expenses associated with the program were limited to the remuneration of the Physical Education professionals for each training session. Based on a session rate of €15, and considering the 12 training sessions, the time allocated for assessments, and the involvement of two professionals, the total estimated cost amounts to €660.

As for equipment, each heart rate monitor costs €47.92; multiplying this by the seven units needed totals €335.44. Adding the cost of the iPad used (approximately €300), the total for necessary materials amounts to €635.44. Therefore, the overall estimated cost of the study, including both personnel and equipment, was €1,295.44.

Data analysis

Descriptive statistics are presented as mean $\pm$ standard deviation (SD) for continuous variables and frequencies and percentages for categorical variables at baseline and post intervention, alongside within group changes (Δ = post – baseline) and the between group difference in change. Given the non-randomized design, standardized baseline differences were calculated to describe the magnitude of between-group imbalance at baseline. For continuous variables, Cohen's d was calculated as the difference between the IG and CG means divided by the pooled SD. Positive values indicate higher baseline values in the IG, whereas negative values indicate lower baseline values in the IG compared with the CG. Due to the small sample size, baseline differences were interpreted descriptively rather than through null-hypothesis significance testing.

For each outcome, a baseline-adjusted ANCOVA was conducted, with the post-intervention value as the dependent variable, group as the fixed factor, and the corresponding baseline value as the covariate. Adjusted marginal means, adjusted mean differences between groups, 95% confidence intervals, F values, p values, and partial eta-squared values were reported.

The assumptions of ANCOVA were assessed before interpreting the models. Homogeneity of error variances was examined using Levene's test. No significant violations were observed for any outcome, with Levene's test p values ranging from .162 to .970. Residual normality, homoscedasticity, and influential observations were assessed through inspection of residual plots, Q-Q plots, standardized residuals, and Cook's distance.

Corrections for multiple comparisons were considered. However, given the pilot and exploratory nature of the study, the small sample size, and the emphasis on estimation rather than confirmatory hypothesis testing, no formal multiplicity correction was applied. Therefore, unadjusted p values are reported alongside adjusted mean differences, 95% confidence intervals, and effect sizes, and the findings are interpreted cautiously.

Additionally, a bivariate analysis was conducted within the IG to explore associations between variables, using Pearson's correlation coefficient for parametric data or Spearman's rank correlation for non-parametric data. Correlation strength was interpreted as follows: $r \leq 0.49$ (weak), $0.50 \leq r \leq 0.74$ (moderate), and $r \geq 0.75$ (strong), according to Portney and Watkins (46).

All statistical analyses were performed using SPSS software version 31.0 (IBM Corp., Armonk, NY, USA), with a significance level set at $p < 0.05$.

Results

To evaluate between-group differences in physical fitness outcomes, baseline-adjusted ANCOVAs were conducted for each variable, with the post-intervention score entered as the dependent variable and the corresponding baseline value included as a covariate.

Descriptive means at baseline and post intervention are presented in Table 2, whereas baseline-adjusted ANCOVA results are presented in Table 3. The largest improvements were

Table 2. Descriptive Statistics by Group at Baseline and Post-Intervention (M $\pm$ SD)

Outcome	Group	n	Baseline (M $\pm$ SD)	Post (M $\pm$ SD)
Yo-Yo (shuttles)	IG	7	36.14 $\pm$ 11.20	39.14 $\pm$ 15.01
	CG	9	40.11 $\pm$ 22.06	33.44 $\pm$ 15.27
Push-ups (reps)	IG	7	27.71 $\pm$ 6.85	34.14 $\pm$ 7.90
	CG	9	20.00 $\pm$ 3.77	19.78 $\pm$ 5.40
SMBT (m)	IG	7	4.69 $\pm$ 0.55	4.91 $\pm$ 0.75
	CG	9	4.83 $\pm$ 0.77	5.04 $\pm$ 0.71
Fat mass (%)	IG	7	15.57 $\pm$ 6.00	16.34 $\pm$ 5.85
	CG	9	18.02 $\pm$ 7.85	19.16 $\pm$ 6.48
Handgrip right (kg)	IG	7	41.57 $\pm$ 9.59	43.86 $\pm$ 8.19
	CG	9	42.22 $\pm$ 7.76	45.00 $\pm$ 6.52
Handgrip left (kg)	IG	7	42.57 $\pm$ 9.62	41.86 $\pm$ 10.37
	CG	9	42.56 $\pm$ 6.69	43.78 $\pm$ 6.65
Squat jump (cm)	IG	7	35.33 $\pm$ 5.05	32.79 $\pm$ 6.19
	CG	9	29.80 $\pm$ 5.32	30.48 $\pm$ 6.20
Anxiety (score)	IG	7	4.57 $\pm$ 1.72	4.43 $\pm$ 1.81
	CG	9	4.67 $\pm$ 3.00	5.22 $\pm$ 3.63
Depression (score)	IG	7	5.57 $\pm$ 1.62	6.14 $\pm$ 1.77
	CG	9	5.56 $\pm$ 2.01	6.22 $\pm$ 3.60

Note. Values are means (M) and standard deviations (SD). No inferential statistics are shown in this table; between-group comparisons are reported in the text using baseline-adjusted ANCOVA.

observed in the IG for push ups ($\Delta +6.43$) and the Yo Yo test ($\Delta +3.00$ versus -6.67 in CG), whereas changes were small or comparable between groups for the SMBT and handgrip strength. Isometric strength showed minimal net differences between groups (right arm: $\Delta +2.29$ vs $+2.78$; left arm: $\Delta -0.71$ vs $+1.22$). For squat performance, the IG showed a modest decrease ($\Delta -2.54$), while the CG showed a slight increase ($\Delta +0.68$). These descriptive patterns are consistent with the baseline adjusted ANCOVA findings reported (significant group effects for push ups and Yo Yo; no significant effects for SMBT, handgrip, isometric strength, or squat).

For aerobic capacity, assessed using the Yo-Yo test, the baseline-adjusted ANCOVA revealed a significant group effect, $F(1, 13) = 6.42$, $p = .025$, partial $\eta^2 = .331$. Adjusted marginal means indicated higher post-intervention scores in the IG ($M = 40.82$) than in the CG ($M = 32.14$), with an adjusted mean difference of 8.68 shuttles, 95% CI [1.28, 16.08].

For upper-body muscular endurance, assessed using push-ups, the baseline-adjusted ANCOVA also revealed a significant group effect, $F(1, 13) = 8.03$, $p = .014$, partial $\eta^2 = .382$. Adjusted marginal means favoured the IG ($M = 29.44$) compared with the CG ($M = 23.43$), with an adjusted mean difference of 6.01 repetitions, 95% CI [1.43, 10.59].

No significant baseline-adjusted group effects were observed for the seated medicine ball throw, fat mass percentage, or handgrip strength. For the seated medicine ball throw, adjusted means were virtually identical between groups, $F(1, 13) = 0.00$, $p = .985$, partial $\eta^2 < .001$, adjusted mean difference = -0.005 m, 95% CI $[-0.52, 0.51]$. For fat mass percentage, the adjusted mean difference was -0.76% , 95% CI $[-2.84, 1.31]$, $F(1, 13) = 0.63$, $p = .442$, partial $\eta^2 = .046$. For handgrip strength, no significant group effects were found for either the right hand, adjusted mean difference = -0.70 kg, 95% CI $[-5.65, 4.24]$, $F(1, 13) = 0.09$, $p = .764$, partial $\eta^2 = .007$, or the left hand, adjusted mean difference = -1.93 kg, 95% CI $[-7.39, 3.52]$, $F(1, 13) = 0.59$, $p = .457$, partial $\eta^2 = .043$.

For lower-body power, assessed using the squat jump, the baseline-adjusted ANCOVA did not indicate a significant group effect, $F(1, 13) = 3.37$, $p = .089$, partial $\eta^2 = .206$. Adjusted marginal means suggested lower post-intervention values in the IG ($M = 29.58$ cm) than in the CG ($M = 32.97$ cm), but the adjusted mean difference did not reach statistical significance, adjusted mean difference = -3.40 cm, 95% CI $[-7.40, 0.60]$.

Table 3. Baseline-adjusted ANCOVA results for post-intervention outcomes.

Outcome	Adjusted IG mean	Adjusted CG mean	Adjusted mean difference IG-CG	95% CI	F (1, 13)	p	partial η^2
Yo-Yo (shuttles)	40.82	32.14	8.68	[1.28, 16.08]	6.42	.025	.331
Push-ups (reps)	29.44	23.43	6.01	[1.43, 10.59]	8.03	.014	.382
SMBT (m)	4.98	4.99	-0.005	[-0.52, 0.51]	0.00	.985	<.001
Fat mass (%)	17.50	18.26	-0.76	[-2.84, 1.31]	0.63	.442	.046
Handgrip right (kg)	44.11	44.81	-0.70	[-5.65, 4.24]	0.09	.764	.007
Handgrip left (kg)	41.85	43.78	-1.93	[-7.39, 3.52]	0.59	.457	.043
Squat jump (cm)	29.58	32.97	-3.40	[-7.40, 0.60]	3.37	.089	.206
Anxiety (score)	4.48	5.18	-0.70	[-2.73, 1.32]	0.56	.466	.042
Depression (score)	6.13	6.23	-0.10	[-2.04, 1.84]	0.01	.913	.001

Note. Values are adjusted marginal means from ANCOVA models with the post-intervention value as the dependent variable and the corresponding baseline value as covariate. Adjusted mean difference represents IG minus CG. CI = confidence interval; SMBT = seated medicine ball throw.

For psychological outcomes, baseline-adjusted ANCOVAs indicated no significant intervention effects. For anxiety, adjusted marginal means were 4.48 in the IG and 5.18 in the CG, $F(1, 13) = 0.56$, $p = .466$, partial $\eta^2 = .042$, adjusted mean difference = -0.70 , 95% CI $[-2.73, 1.32]$. Similarly, for depressive symptoms, adjusted marginal means were 6.13 in the IG and 6.23 in the CG, $F(1, 13) = 0.01$, $p = .913$, partial $\eta^2 = .001$, adjusted mean difference = -0.10 , 95% CI $[-2.04, 1.84]$.

Overall, the intervention showed favourable baseline-adjusted effects on aerobic capacity and upper-body muscular endurance, with moderate-to-large effect sizes. For the remaining physical and psychological outcomes, confidence intervals included zero, indicating uncertainty around the magnitude and direction of the between-group differences.

The mean training load response and volume during HIRT intervention are displayed in Table 4.

Exploratory within-group correlation analyses were conducted in the IG only. A positive association was observed between e-IL and b-IL $r = 0.888$ ($p = 0.008$), suggesting consistency between physiological and perceived training-load indicators. Negative associations were also observed between t-RED and "Fat Mass" $r = -0.856$ ($p = 0.014$), and between t-RED and "Depression" $r = -0.943$ ($p = 0.001$). However, these findings are exploratory and should not be interpreted as evidence of intervention effectiveness (Tab. 5).

Discussion

The aim of this study was to examine the feasibility and preliminary effects of a six-week equipment-free HIRT program on physical fitness, body composition, and mental health symptoms in university students. Based on the results obtained, the

main conclusion is that the intervention was feasible among completers and was associated with significant baseline-adjusted between-group differences in upper-body muscular endurance and cardiorespiratory fitness. No significant intervention effects were observed for anxiety, depressive symptoms, body composition, handgrip strength, upper-limb power, or lower-limb power.

The muscular endurance improvement observed in this study is in line with the results of previous research which has found similar gains after performing the HIRT program [47, 48]. In addition, other studies show that HIRT is effective for both overall strength improvement and performance enhancement [49, 50, 51, 52]. For CRF, baseline adjusted ANCOVA indicated a significant between group difference at post intervention favouring the IG. However, studies applying higher HIRT training volumes have typically reported larger and more consistent improvements, suggesting that training dose may moderate the magnitude of CRF adaptation [22, 47, 53]. These findings suggest that the duration and/or training volume of the intervention may have been insufficient to elicit measurable changes in CRF [54].

The SMBT has not presented any significant improvements for the IG. These data are in line with some of the latest literature such as the meta-analysis by Wang et al. [55] that suggests HIRT has a limited impact on upper-body muscle strength in athletes. In the study carried out by Helén et al. [56], there were significant improvements in upper-limb power; however, despite being a HIRT-based protocol, the study used external loading in its intervention. Although SMBT is an exercise commonly used to assess upper-body strength and explosive power, the fact that no improvements in the IG were recorded in the study may be related to the specificity of the HIRT training applied, since the training did not include stimuli specifically targeting upper-body explosive power in the seated position. In addition, the exercise may not have been sensitive enough to reflect the neuromuscular gains obtained in more dynamic contexts or in kinetic chains different from those trained.

The absence of significant improvements in the handgrip strength test reinforces the highly specific nature of training adaptations. Although grip strength is often used as a global indicator of strength and functional health [57], this test does not directly assess the movement patterns or neuromuscular demands predominant in the HIRT protocol applied. Although the program includes exercises such as push-ups, the mechanical load imposed on the grip system is relatively stable and non-progressive and does not constitute a sufficient stimulus to promote measurable adaptations in this test. The lack of

Table 4. Training load of IG.

	IG (n = 7)
Planned Sessions (n)	12
t-RED, min, mean (SD)	65.1 (20.7)
e-IL, AU, mean (SD)	110.9 (2.0)
RPE/session, mean (SD)	8.6 (0.4)
b-IL, AU, mean (SD)	1728.3 (166.7)

Abbreviations: AU: arbitrary units; b-IL: Foster's TRIMP; e-IL: Edwards' TRIMP; RPE: rating of perceived exertion; t-RED: Time in minutes $\geq 90\%$ HRmax. Note: Values are presented as mean (SD).

Table 5. Correlations among study variables in IG.

		1	2	3	4	5	6	7	8
1.	t-RED	x							
2.	e-IL	,261	x						
3.	Δ BMI	-,492	-,822*	x					
4.	Δ Bodyweight	-,419	-,839*	,996**	x				
5.	Δ Fat Mass	-,856*	-,654	,731	,691	x			
6.	Δ Yo-Yo†	-,334	-,222	-,259	-,259	,187	x		
7.	Δ SMBT	-,327	-,086	-,095	-,138	,120	,820*	x	
8.	Δ Symptoms of Depression	-,943**	-,106	,401	,336	,783*	,455	,089	x

BMI: Body mass index; e-IL: Edwards' TRIMP; SMBT: Seated Medicine Ball Throw; t-RED: Time in minutes $\geq 90\%$ HRmax/session. * – Correlation is significant at the 0.05 level (2-tailed); ** – Correlation is significant at the 0.01 level (2-tailed); † – Spearman correlation coefficient. Δ : Post - Pre.

improvement in the handgrip strength test was also observed in other studies, where the authors did not identify significant gains in this measure [58, 59]. In the case of studies such as Adami et al. [60] and Chukhlantseva et al. [61], where HIRT training was applied with an external load, it proved to be effective in improving the handgrip test. For future studies, it could be interesting to incorporate specific exercises for the upper limbs into the HIRT protocols with the use of external loads, which can lead to changes in the previously mentioned upper-body capacities.

Despite the inclusion of plyometric exercises in the protocol, such as SJ, no significant improvements in lower-limb power were observed. In contrast, a systematic review with different studies suggests that HIRT may have a positive effect on lower-limb power [55]. The same authors also point out that there may be other, more efficient methodologies for improving this ability. Other research also showed that HIRT can improve lower-limb power by using external load [61, 62]. The decrease in SJ performance observed in the IG was unexpected. Possible explanations include residual fatigue from the high-density bodyweight protocol, insufficient recovery between sessions or assessments, familiarization effects, and measurement variability. Although the protocol included jumping exercises, these were performed under fatigue, which may not have provided an optimal stimulus for improving maximal lower-limb power. In addition, the absence of external load, limited progressive overload, and possibly insufficient frequency or volume may have reduced the neuromuscular stimulus required to induce measurable adaptations in SJ performance. Since SJ requires a high rate of force development, future HIRT protocols aiming to improve lower-limb power should consider more specific progression strategies, greater neuromuscular specificity, and standardized recovery before assessment.

The primary baseline-adjusted analyses did not demonstrate significant between-group effects for anxiety or depressive symptoms. Nevertheless, exploratory within-group correlations in the IG suggested an inverse association between time dedicated to high-intensity activities and depressive symptoms. This finding, however, is based on a very small sample and should be interpreted with extreme caution, as it may be unstable and influenced by individual data points. Therefore, this result should be considered hypothesis-generating rather than evidence of intervention effectiveness and requires confirmation in adequately powered randomized studies. The observed association is consistent with previous findings by Wang et al. [63], who reported similar relationships, although the present study cannot confirm a causal effect of HIRT on mental health. Martland et al. [64] also observed improvements in mental health following high-intensity training, and Goldfield et al. [65] suggested that combined training, such as HIRT, may improve depressive symptoms in adolescents, particularly among those with overweight or obesity. Thus, while causality cannot be assumed in this study, equipment-free HIRT may represent a good alternative for those who find other longer alternatives boring and less enjoyable [47, 66, 67]. Similarly, the correlation between volitional intensity values and fat mass percentage indicates a negative association, suggesting that as the time invested in high-intensity activities increases, fat mass values tend to decrease. These results are in line with the findings of other studies that used similar methodologies and reported improvements in body composition and a reduction in fat mass percentage [21, 51, 53, 68]. Other studies have shown that the loss of fat mass tends to be more pronounced in individuals who are overweight or obese, and that HIRT has been associated with improvements in

body composition in the general population [18, 69]. However, the present study did not demonstrate a significant baseline-adjusted between-group effect on fat mass. Although exploratory correlations suggested an association between time spent at high intensity and changes in fat mass, this finding should be interpreted cautiously because of the very small sample size, short intervention duration, lack of dietary monitoring, and the limitations of bioelectrical impedance analysis.

The internal training load and the subjective perception of total training effort correlated positively, meaning that the subjective perception of effort felt by the participants corresponds to the real internal training load measured by the HR monitors. Normally, training is prescribed and monitored considering an individual's HRmax; however, these correlational results indicate that subjective perception of effort appears to be a good alternative to new technologies, as it is accessible and practical [70]. Several studies reinforce the importance of using both methods, guaranteeing a more complete monitoring of training [28, 71, 72, 73]. This suggests that subjective effort perception is consistently associated with objective measures of training load, providing a viable alternative for individuals without access to advanced tracking technologies. This correlation suggests that the perceived effort values reported by the participants are consistent, whether considering each work set individually or the training session. The positive correlation between e-IL and b-IL validated the consistency of the effort perception reported by participants, both at the individual set level and across the entire training session. This reinforces the reliability of effort perception as a valuable component in training assessment.

Practical and theoretical implications

From a practical perspective, the findings of this study suggest that a short, equipment-free HIRT program may be a feasible and low-cost strategy to improve selected fitness outcomes, particularly upper-body muscular endurance and cardiorespiratory fitness, among university students. These results make this program a valuable alternative to more traditional, time-consuming workout routines. Additionally, the results emphasize the relevance of subjective effort perception as a practical and cost-effective tool for monitoring training intensity, offering an accessible alternative for those without advanced fitness-tracking technology.

From a theoretical standpoint, this study provides preliminary estimates of feasibility, training load, adherence, and outcome variability that may inform the design of future randomized controlled trials. The observed correlations between high-intensity activity, depressive symptoms, and body composition provide further evidence of the interconnectedness between physical exercise and mental well-being. Moreover, the study reinforces the validity of subjective perception measures in training assessment, highlighting their potential as a reliable proxy for internal training load.

Limitations of the study and future research

One of the main limitations of this study is the small sample size, which compromises the ability to generalize the results. Furthermore, despite the normality tests carried out, the distribution of the data may also be influenced by the small sample size. Low variability and the presence of outliers can compromise the validity of the statistical tests applied (type I error). Small samples increase the variability of the data and reduce statistical power, which can limit the detection of significant differences

between groups (type II error). In addition, it is believed that longer intervention periods, lasting more than six weeks, could yield other results. Also, no formal correction for multiple comparisons was applied. Although this decision was made to avoid increasing type II error in a small exploratory pilot study, the results should be interpreted cautiously and confirmed in adequately powered trials.

The non-randomized, self-selected allocation is a major limitation. Participants who chose to enrol in the IG may have been more motivated or more available than those in the CG, which may have influenced adherence, effort during training, and outcome changes. Another limitation was the high attrition rate, with only 16 of the 23 participants who completed baseline assessments included in the final analyses, and the fact that the sample was recruited from a single university, which may introduce selection bias and limit the representativeness of the results for other populations with different sociodemographic profiles and fitness levels. In addition, sex imbalance in the sample may limit the external validity of the findings, particularly for psychological outcomes, as anxiety and depressive symptoms, exercise preferences, and responses to training may differ by sex. The predominance of male participants limits the generalizability of the findings, particularly to female populations, highlighting the need for more sex-balanced samples in future studies. Therefore, the findings should not be generalized to female university students without confirmation in more balanced samples.

Although the study attempted to isolate the effects of the intervention, uncontrolled external factors such as lifestyle, diet, sleep patterns, and other types of PA may have influenced the results. Furthermore, PA levels in the CG were not objectively monitored, which may represent a methodological limitation, as potential changes in their habitual activity could have influenced between-group comparisons. Lastly, body composition was assessed using bioelectrical impedance analysis, which is sensitive to hydration status, recent physical activity, food intake and other pre-assessment conditions.

Recognizing these limitations is essential for a critical interpretation of the results and to guide future research. Future studies could benefit from larger more heterogeneous samples in different educational institutions, longer interventions and more comprehensive assessment methods to strengthen the validity and generalizability of the results. Future studies could also include activity diaries or objective monitoring of PA levels outside of the intervention. Importantly, as a pilot study, the present investigation provides preliminary effect size estimates, variability parameters, and feasibility indicators (recruitment, adherence, and safety), which can inform sample size calculations, outcome selection, and protocol refinements for future randomized controlled trials designed to test the effectiveness of HIRT more definitively in university student populations.

Despite the limitations, this study presents many positive aspects, namely the longitudinal, non-randomized controlled intervention design and the objective and subjective measurement of internal load. HR has become one of the most common training monitoring variables. Adjusting exercise intensity using HR has been a valid option, especially during prolonged and submaximal training periods. The ideal duration of exercise and rest intervals remain ambiguous, and the dose-response relationships of HIIT volume and intensity are not established. With this study, it is intended to provide new HIIT (HIRT) protocols with less volume (only twice a week) and higher density (less rest in each interval), which include resistance exercises through calisthenics.

In this sense, the strengths of this study include the supervised nature of the intervention, the practical equipment-free protocol, the use of both objective and subjective training-load monitoring, and the reporting of feasibility indicators such as recruitment, retention, adherence, and safety.

Conclusions

This non-randomized pilot study suggests that a six-week equipment-free HIRT program is feasible among university students who complete the intervention and may improve upper-body muscular endurance and cardiorespiratory fitness. No significant between-group effects were observed for anxiety, depressive symptoms, body composition, handgrip strength, upper-limb power, or lower-limb power. Exploratory associations between time spent at high intensity, depressive symptoms, and fat mass should be interpreted with caution and considered hypothesis-generating only. Larger randomized controlled trials with balanced samples, objective monitoring of PA outside the intervention, and control of lifestyle factors are needed to determine the efficacy of HIRT for mental health and body composition outcomes.

References

1. Small M., Bailey-Davis L., Morgan N., Maggs J. (2013). Changes in eating and physical activity behaviors across seven semesters of college: living on or off campus matters. *Health Education & Behavior* 40(4), 435-441. DOI: 10.1177/1090198112467801
2. Thomas A.M., Beaudry K.M., Gammage K.L., Klentrou P., Josse A.R. (2019). Physical activity, sport participation, and perceived barriers to engagement in first-year Canadian university students. *Journal of Physical Activity and Health* 16(6), 437-446. DOI: 10.1123/jpah.2018-0198
3. World Health Organization (2005). *Promoting mental health: Concepts, emerging evidence, practice*. Geneva: World Health Organization.
4. World Health Organization (2024). *Physical activity*. Retrieved 28 August, 2026 from: <https://www.who.int/health-topics/physical-activity>
5. Allender S., Cowburn G., Foster C. (2006). Understanding participation in sport and physical activity among children and adults: a review of qualitative studies. *Health Education Research* 21(6), 826-835. DOI: 10.1093/her/cyl063
6. Caspersen C.J., Powell K.E., Christenson G.M. (1985). Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Reports* 100(2), 126-131.
7. Ruivo R. (2019). *New manual of exercise assessment and prescription*. 1st ed. Self. [in Portuguese]
8. Pan American Health Organization (2024). *Nearly 1.8 billion adults at risk of disease from not doing enough physical activity*. Retrieved 28 August, 2026 from: <https://www.paho.org/en/news/26-6-2024-nearly-18-billion-adults-risk-disease-not-doing-enough-physical-activity>
9. Direção-Geral da Saúde (2017). *National Program for the Promotion of Physical Activity 2017*. Retrieved 28 August, 2026 from: https://extranet.who.int/ncdccs/Data/PRT_BI2_DGS_PNPAF2017_V8.pdf. [in Portuguese]
10. Sabino B., Loureiro V., Pereira S., Ferreira-Barbosa H. (2023). Health behaviours and depressive symptoms in higher education Portuguese students. *Advances in Rehabilitation* 37(4), 20-28. DOI: 10.5114/areh.2023.133104

11. Silva C.S., Godinho C., Encantado J., Rodrigues B., Carraça E.V., Teixeira P.J. et al. (2023). Implementation determinants of physical activity interventions in primary health care settings using the TICD framework: a systematic review. *BMC Health Services Research* 23(1), 1082. DOI: 10.1186/s12913-023-09881-y
12. Thums I., Antunes F. (2019). The HIIT method and its benefits for quality of life in the 21st century. *SAJES - Revista da Saúde da AJES* 5(9), 53-70. [in Portuguese]
13. Lucibello K.M., Paolucci E.M., Graham J.D., Heisz J.J. (2020). A randomized control trial investigating high-intensity interval training and mental health: A novel non-responder phenotype related to anxiety in young adults. *Mental Health and Physical Activity* 18, 100327. DOI: 10.1016/j.mhpa.2020.100327
14. Philippot A., Moulin P., Charon M.-H., Balestra C., Dubois V. et al. (2022). Feasibility of online high-intensity interval training (HIIT) on psychological symptoms in students in lockdown during the COVID-19 pandemic: A randomized controlled trial. *Frontiers in Psychiatry* 13, 904283. DOI: 10.3389/fpsy.2022.904283
15. Ito S. (2019). High-intensity interval training for health benefits and care of cardiac diseases - The key to an efficient exercise protocol. *World Journal of Cardiology* 11(7), 171-188. DOI: 10.4330/wjc.v11.i7.171
16. Buchheit M., Laursen P.B. (2013). High-intensity interval training, solutions to the programming puzzle: Part I: cardiopulmonary emphasis. *Sports Medicine* 43(5), 313-338. DOI: 10.1007/s40279-013-0029-x
17. Ahlert M., Matzenbacher F., Albarello J.C.D.S., Halmen-schlager G.H. (2019). Comparison of EPOC and recovery energy expenditure between HIIT and continuous aerobic exercise training. *Revista Brasileira de Medicina do Esporte* 25(1), 20-23. DOI: 10.1590/1517-869220192501181346
18. Alonso-Fernández D., Fernández-Rodríguez R., Taboada-Iglesias Y., Gutiérrez-Sánchez Á. (2019). Impact of a HIIT protocol on body composition and VO₂max in adolescents. *Science & Sports* 34(5), 341-347. DOI: 10.1016/j.scispo.2019.04.001
19. Falatic J.A., Plato P.A., Holder C., Finch D., Han K., Cisar C.J. (2015). Effects of kettlebell training on aerobic capacity. *The Journal of Strength & Conditioning Research* 29(7), 1943-1947. DOI: 10.1519/JSC.0000000000000845
20. Paoli A., Moro T., Marcolin G., Neri M., Bianco A. et al. (2012). High-intensity interval resistance training (HIRT) influences resting energy expenditure and respiratory ratio in non-dieting individuals. *Journal of Translational Medicine* 10(1), 237. DOI: 10.1186/1479-5876-10-237
21. Feito Y., Hoffstetter W., Serafini P., Mangine G. (2018). Changes in body composition, bone metabolism, strength, and skill-specific performance resulting from 16-weeks of HIFT. *PLOS ONE* 13(6), e0198324. DOI: 10.1371/journal.pone.0198324
22. Menz V., Marterer N., Amin S.B., Faulhaber M., Hansen A.B., Lawley J.S. (2019). Functional vs. running low-volume high-intensity interval training: effects on VO₂max and muscular endurance. *Journal of Sports Science & Medicine* 18(3), 497-504.
23. Cooper S.B., Dring K.J., Morris J.G., Sunderland C., Banelow S., Nevill M.E. (2018). High intensity intermittent games-based activity and adolescents' cognition: moderating effect of physical fitness. *BMC Public Health* 18(1), 603. DOI: 10.1186/s12889-018-5514-6
24. de Diego-Moreno M., Álvarez-Salvago F., Martínez-Amat A., Boquete-Pumar C., Orihuela-Espejo A. et al. (2022). Acute effects of high-intensity functional training and moderate-intensity continuous training on cognitive functions in young adults. *International Journal of Environmental Research and Public Health* 19(17), 10608. DOI: 10.3390/ijerph191710608
25. Jiménez-Maldonado A., Antunes B.M., Reyes R.A., Rentería I., Blanco-Salazar A. et al. (2025). High-intensity circuit training improves cognitive performance independent of changes in sBDNF levels in active college students. *Physiology & Behavior* 295, 114916. DOI: 10.1016/j.physbeh.2025.114916
26. Trujillo-Gutiérrez F.J., López-Aguilar J., Álvarez-Salvago F., Morente-Oria H., Jiménez-García J.D. (2025). Acute effects of a single-bout session of high-intensity functional training and moderate-intensity functional training on cognitive functions, anxiety, and stress in healthy adults. *Applied Sciences* 15(1), 439. DOI: 10.3390/app15010439
27. White R.L., Vella S., Biddle S., Sutcliffe J., Guagliano J.M. et al. (2024). Physical activity and mental health: a systematic review and best-evidence synthesis of mediation and moderation studies. *International Journal of Behavioral Nutrition and Physical Activity* 21(1), 134. DOI: 10.1186/s12966-024-01676-6
28. Schmitz B., Niehues H., Thorwesten L., Klose A., Krüger M., Brand S.-M. (2020). Sex differences in high-intensity interval training – are HIIT protocols interchangeable between females and males? *Frontiers in Physiology* 11, 38. DOI: 10.3389/fphys.2020.00038
29. Machado A.F., Zovico P.V.C., Evangelista A.L., Rica R.L., Miranda J.M.d.Q. et al. (2022). Psychophysiological responses of exercise distribution during high intensity interval training using whole body exercise. *Frontiers in Physiology* 13, 912890. DOI: 10.3389/fphys.2022.912890
30. Poon K. (2022). Effects of aerobic exercise and high-intensity interval training on the mental health of adolescents living in poverty: protocol for a randomized controlled trial. *JMIR Research Protocols* 11(1), e34915. DOI: 10.2196/34915
31. Newsome A.N.M., Batrakoulis A., Camhi S.M., McAvoy C., Sansone J. et al. (2024). 2025 ACSM Worldwide Fitness Trends: Future directions of the health and fitness industry. *ACSM's Health & Fitness Journal* 28(6), 11-25. DOI: 10.1249/FIT.0000000000001017
32. Slade S.C., Dionne C.E., Underwood M., Buchbinder R. (2016). Consensus on Exercise Reporting Template (CERT): Explanation and elaboration statement. *British Journal of Sports Medicine* 50(23), 1428-1437. DOI: 10.1136/bjsports-2016-096651
33. Pais-Ribeiro J., Silva I., Ferreira T., Martins A., Meneses R. (2007). Validation study of a Portuguese version of the Hospital Anxiety and Depression Scale. *Psychology, Health & Medicine* 12(2), 225-237. DOI: 10.1080/13548500500524088
34. Sawczuk T., Jones B., Scantlebury S., Weakley J., Read D. et al. (2018). Between-day reliability and usefulness of a fitness testing battery in youth sport athletes: reference data for practitioners. *Measurement in Physical Education and Exercise Science* 22(1), 11-18. DOI: 10.1080/1091367X.2017.1360304
35. Tanner R.K., Gore C.J. (eds) (2013). *Physiological tests for elite athletes*. 2nd ed. Champaign, IL: Human Kinetics.
36. Krstrup P., Mohr M., Amstrup T., Rysgaard T., Johansen J. et al. (2003). The Yo-Yo intermittent recovery test: physiological response, reliability, and validity. *Medicine & Science in Sports & Exercise* 35(4), 697-705. DOI: 10.1249/01.MSS.0000058441.94520.32

37. Henriques-Neto D., Minderico C., Peralta M., Marques A., Sardinha L.B. (2020). Test-retest reliability of physical fitness tests among young athletes: The FITescola® battery. *Clinical Physiology and Functional Imaging* 40(3), 173-182. DOI: 10.1111/cpf.12624
38. Massy-Westropp N.M., Gill T.K., Taylor A.W., Bohannon R.W., Hill C.L. (2011). Hand grip strength: age and gender stratified normative data in a population-based study. *BMC Research Notes* 4(1), 127. DOI: 10.1186/1756-0500-4-127
39. Biggar C., Larson A., DeBeliso M. (2022). *Establishing normative reference values for the Utah Seated Medicine Ball Throw Protocol in adolescents*. The Sport Journal. Retrieved 28 August, 2026 from: <https://thesportjournal.org/article/establishing-normative-reference-values-for-the-utah-seated-medicine-ball-throw-protocol-in-adolescents/>
40. Bento A., Loureiro V. (2018). High-intensity interval training: monitoring and effect between genders. *The Journal of Strength & Conditioning Research* 32(9), e42-e43. DOI: 10.1519/JSC.0000000000002820
41. Borg G. (1970). Perceived exertion as an indicator of somatic stress. *Scandinavian Journal of Rehabilitation Medicine* 2(2), 92-98.
42. Foster C. (1998). Monitoring training in athletes with reference to overtraining syndrome. *Medicine & Science in Sports & Exercise* 30(7), 1164-1168. DOI: 10.1097/00005768-199807000-00023
43. Castagna C., Impellizzeri F.M., Chaouachi A., Bordon C., Manzi V. (2011). Effect of training intensity distribution on aerobic fitness variables in elite soccer players: a case study. *The Journal of Strength & Conditioning Research* 25(1), 66-71. DOI: 10.1519/JSC.0b013e3181fef3d3
44. Foster C., Florhaug J.A., Franklin J., Gottschall L., Hrovatin L.A. et al. (2001). A new approach to monitoring exercise training. *The Journal of Strength and Conditioning Research* 15(1), 109-115. DOI: 10.1519/00124278-200102000-00019
45. Edwards S. (2010). *The heart rate monitor guidebook: To Heart Zones training*. 5th ed. Sacramento, CA: Heart Zones Publishing.
46. Portney L.G., Watkins M.P. (2015). *Foundations of clinical research: Applications to practice*. 3rd ed. Philadelphia, PA: F.A. Davis Company.
47. McRae G., Payne A., Zelt J.G.E., Scribbans T.D., Jung M.E. et al. (2012). Extremely low volume, whole-body aerobic-resistance training improves aerobic fitness and muscular endurance in females. *Applied Physiology, Nutrition, and Metabolism* 37(6), 1124-1131. DOI: 10.1139/h2012-093
48. Pahlavani H.A., Khozani M.N., Bahmanbeglou N.A., Zouhal H. (2024). Simultaneous effects of high-speed circuit training (HSCT) and high-speed interval training (HSIT) on physical fitness and lung volumes of males after coronavirus disease. *Journal of Bodywork and Movement Therapies* 40, 1828-1836. DOI: 10.1016/j.jbmt.2024.10.037
49. Batrakoulis A., Jamurtas A.Z., Tsimeas P., Poullos A., Perivoliotis K. et al. (2023). Hybrid-type, multicomponent interval training upregulates musculoskeletal fitness of adults with overweight and obesity in a volume-dependent manner: A 1-year dose-response randomised controlled trial. *European Journal of Sport Science* 23(3), 432-443. DOI: 10.1080/17461391.2021.2025434
50. Eather N., Morgan P.J., Lubans D.R. (2016). Improving health-related fitness in adolescents: the CrossFit Teens™ randomised controlled trial. *Journal of Sports Sciences* 34(3), 209-223. DOI: 10.1080/02640414.2015.1045925
51. Heinrich K.M., Becker C., Carlisle T., Gilmore K., Hauser J., Frye J. et al. (2015). High-intensity functional training improves functional movement and body composition among cancer survivors: a pilot study. *European Journal of Cancer Care* 24(6), 812-817. DOI: 10.1111/ecc.12338
52. Wang X., Soh K.G., Samsudin S., Deng N., Liu X. et al. (2023). Effects of high-intensity functional training on physical fitness and sport-specific performance among the athletes: a systematic review with meta-analysis. *PLOS ONE* 18(12), e0295531. DOI: 10.1371/journal.pone.0295531
53. Lu Y., Wiltshire H.D., Baker J.S., Wang Q. (2021). The effects of running compared with functional high-intensity interval training on body composition and aerobic fitness in female university students. *International Journal of Environmental Research and Public Health* 18(21), 11312. DOI: 10.3390/ijerph182111312
54. Bento A.F.P.d.S., Carrasco Páez L., Raimundo A.M.d.M. (2022). School-based high-intensity interval training programs for promoting physical activity and fitness in adolescents: A systematic review. *Journal of Teaching in Physical Education* 41(2), 288-300. DOI: 10.1123/jtpe.2020-0187
55. Wang X., Soh K.G., Samsudin S., Li L., Liu C. et al. (2025). Effects of high-intensity training on jumping performance among athletes: a systematic review with meta-analysis. *Scientific Reports* 15(1), 1763. DOI: 10.1038/s41598-024-83161-5
56. Helén J., Kyröläinen H., Ojanen T., Pihlainen K., Santtila M. et al. (2023). High-intensity functional training induces superior training adaptations compared with traditional military physical training. *The Journal of Strength & Conditioning Research* 37(12), 2477-2483. DOI: 10.1519/JSC.0000000000004559
57. Buendía-Romero Á., Hernández-Belmonte A., Franco-López F., Romero-Borrego E., Cava A.M. et al. (2023). A sensitive and practical evaluation to detect lower-limb strength changes in geriatrics: the isometric knee extension test. *Applied Sciences* 13(5), 2946. DOI: 10.3390/app13052946
58. Baxter S.C.D. (2021). *The effects of a 20-week HIFT circuit on cardiorespiratory fitness, functional fitness, muscle strength and body composition in recreationally active breast cancer survivors*. Master's thesis, University of Otago.
59. Teixeira R.V., Batista G.R., Mortatti A.L., Dantas P.M.S., Cabral B.G.d.A.T. (2020). Effects of six weeks of high-intensity functional training on physical performance in participants with different training volumes and frequencies. *International Journal of Environmental Research and Public Health* 17(17), 6058. DOI: 10.3390/ijerph17176058
60. Adami P.E., Rocchi J.E., Melke N., Macaluso A. (2021). *Physiological profile of high intensity functional training athletes*. Universidad de Alicante, Área de Educación Física y Deporte. Retrieved 28 August, 2026 from: <http://hdl.handle.net/10045/106833>
61. Chukhlantseva N., Cherednychenko I., Kemkina V. (2020). The influence of high-intensity functional training versus resistance training on the main physical fitness indicators in women aged 25-35 years. *TRENDS in Sport Sciences* 27(3), 157-165. DOI: 10.23829/TSS.2020.27.3-6
62. Posnakidis G., Aphamis G., Giannaki C.D., Mougios V., Aristotelous P. et al. (2022). High-intensity functional training improves cardiorespiratory fitness and neuromuscular performance without inflammation or muscle damage. *The Journal of Strength & Conditioning Research* 36(3), 615-623. DOI: 10.1519/JSC.00000000000003516

63. Wang Y., Jia N., Zhou Y., Fu L., Fan L. (2023). A comparison of the effects of remote coaching HIIT training and combined exercise training on the physical and mental health of university students. *Frontiers in Psychology* 14, 1182332. DOI: 10.3389/fpsyg.2023.1182332
64. Martland R., Mondelli V., Gaughran F., Stubbs B. (2020). Can high-intensity interval training improve physical and mental health outcomes? A meta-review of 33 systematic reviews across the lifespan. *Journal of Sports Sciences* 38(4), 430-469. DOI: 10.1080/02640414.2019.1706829
65. Goldfield G.S., Kenny G.P., Alberga A.S., Prud'homme D., Hadjiyannakis S. et al. (2015). Effects of aerobic training, resistance training, or both on psychological health in adolescents with obesity: The HEARTY randomized controlled trial. *Journal of Consulting and Clinical Psychology* 83(6), 1123-1135. DOI: 10.1037/ccp0000038
66. Fidalgo A., Farinatti P., Miranda H., Matos-Santos L., Willardson J., Monteiro W. (2023). Are self-selected intervals as effective as fixed intervals in controlling acute responses in high-intensity interval resistance training? *International Journal of Exercise Science* 16(4), 1205-1215. DOI: 10.70252/BOVS2537
67. Schaun G.Z., Alberton C.L. (2022). Using bodyweight as resistance can be a promising avenue to promote interval training: enjoyment comparisons to treadmill-based protocols. *Research Quarterly for Exercise and Sport* 93(1), 162-170. DOI: 10.1080/02701367.2020.1817293
68. Shaikh A.L., Al Salim Z.A., Al Rafati A.A., Ahsan M. (2025). Effect of different forms of high-intensity interval training on VO2max, strength, flexibility, and body fat percentage among middle-aged males. *Journal of Sports Medicine and Physical Fitness* 65(1), 37-50. DOI: 10.23736/S0022-4707.24.16121-X
69. Racil G., Zouhal H., Elmontassar W., Abderrahmane A.B., Sousa M.V.D. et al. (2016). Plyometric exercise combined with high-intensity interval training improves metabolic abnormalities in young obese females more so than interval training alone. *Applied Physiology, Nutrition, and Metabolism* 41(1), 103-109. DOI: 10.1139/apnm-2015-0384
70. Taylor J.L., Holland D.J., Spathis J.G., Beetham K.S., Wisløff U. et al. (2019). Guidelines for the delivery and monitoring of high intensity interval training in clinical populations. *Progress in Cardiovascular Diseases* 62(2), 140-146. DOI: 10.1016/j.pcad.2019.01.004
71. Arney B.E., Glover R., Fusco A., Cortis C., de Koning J.J. et al. (2019). Comparison of rating of perceived exertion scales during incremental and interval exercise. *Kinesiology* 51(2), 150-157. DOI: 10.26582/k.51.2.1
72. Duncombe S.L., Stylianou M., Price L., Walker J.L., Barker A.R. (2023). Making a HIIT: Methods for quantifying intensity in high-intensity interval training in schools and validity of session rating of perceived exertion. *Journal of Sports Sciences* 41(18), 1678-1686. DOI: 10.1080/02640414.2023.2291736
73. Santos A., Stork M.J., Locke S.R., Jung M.E. (2021). Psychological responses to HIIT and MICT over a 2-week progressive randomized trial among individuals at risk of type 2 diabetes. *Journal of Sports Sciences* 39(2), 170-182. DOI: 10.1080/02640414.2020.1809975

Submitted: May 15, 2026

Accepted: August 20, 2026