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**Research article**

# Combining HIIT with Small-Sided Soccer Games Enhances Cardiometabolic and Physical Fitness More Than Each Alone in Overweight Youth: A Randomized Controlled Study

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## Abstract

This study aimed to compare the effects of a combined high-intensity interval training (HIIT) and small-sided games (SSG) training program (SSG + HIIT) with training programs consisting solely of either HIIT or SSG on the cardiometabolic and physical fitness of sedentary, overweight youth. A randomized, parallel-controlled study design was employed, with interventions lasting six weeks (twice a week, with each work time lasting 12-16 minutes). Fifty-seven sedentary, overweight male youth participants (15.1 ± 0.8 years) were assessed twice on anthropometric measures, blood pressure, endurance (using the Multi-Stage Fitness Test, MSFT), muscle power (countermovement jump and broad jump), and change of direction ability (using the 5 - 0 - 5 COD test). The session's ratings of perceived exertion (RPE) and scores on the Physical Activity Enjoyment Scale (PACES) were also monitored. The HIIT group exhibited a significantly smaller waist circumference compared to the control group ($p$ = 0.041) after the intervention. The control group exhibited a significantly worst COD deficit compared to the SSG + HIIT ($p$ = 0.002), SSG ($p$ = 0.001) and HIIT ($p$ = 0.048) after the intervention. In the case of MSFT, the group exhibited a significantly smaller distance covered than SSG + HIIT ($p$ = 0.002), and SSG ($p$ = 0.005). Moreover, significant differences on RPE ($p < 0.001$) and PACES ($p < 0.001$) was found between groups. The SSG + HIIT or SSG are effective for improving COD and aerobic capacity, while being more enjoyable and less intense than HIIT alone. However, HIIT is more effective in reducing waist circumference. The research limitations include the short intervention duration, lack of control for diet and external factors, and the need for longer-term research.

**Key words:** Football, physical exercise, physical fitness, health, overweight.

## Introduction

Some evidence suggests that sedentary behavior and overweight (25 - 30 kg/m$^2$) together in youth may lead to potential health and physical negative consequences (Mitchell and Byun, 2014). Physical inactivity combined with excess weight heightens the risk of cardiovascular problems, such as high blood pressure, elevated cholesterol, and insulin resistance (Steinberger et al., 2009). This combination may also promote excessive fat storage, leading to inflammation and an increased risk of developing metabolic syndrome (Halpern et al., 2010). Furthermore, the lack of adequate physical activity associated with being overweight can result in low strength levels, which may negatively impact musculoskeletal health (Molnár and Livingstone, 2000). Finally, sedentary and overweight youth are, possibly, at a higher risk of experiencing anxiety, depression, and low self-esteem, with social stigma and biochemical imbalances playing contributing roles (Pont et al., 2017). Moreover, this issue may also lead to economic burdens, including increased healthcare costs (Lehnert et al., 2013). Therefore, addressing both inactivity and weight management is crucial for supporting the health and well-being of young people (Hills et al., 2007).

Given the significant health risks associated with sedentary behavior and overweight status in youth, effective and engaging exercise strategies, such as high-intensity interval training (HIIT) (Zhu et al., 2021), are needed. HIIT has been shown to offer significant benefits for cardiometabolic health and physical fitness, particularly among sedentary overweight youth (Martin-Smith et al., 2020). Research indicates that HIIT, which involves short bursts of intense exercise followed by recovery periods, can effectively improve cardiovascular fitness and insulin sensitivity (Cockcroft et al., 2019). Additionally, it has been shown to enhance body composition (Khammassi et al., 2018). A meta-analysis revealed that youth participating in HIIT programs exhibited marked reductions in body fat percentage and waist circumference (Zhu et al., 2021), alongside improvements in aerobic capacity (Martin-Smith et al., 2020). Moreover, HIIT has been associated with favorable changes in lipid profiles (da Silva et al., 2020). These adaptations are crucial for reducing the risk of developing metabolic syndrome and type 2 diabetes in overweight youth (Cao et al., 2021). Furthermore, the time-efficient nature of HIIT makes it an accessible option for this population.

While HIIT can be effective for improving fitness in overweight individuals, its intensity may lead to exercise intolerance, potentially leading to decreased motivation and adherence (Reljic et al., 2019). Research has shown that exercise enjoyment is a critical factor in maintaining long-term physical activity (Teixeira et al., 2012), and activities perceived as enjoyable can lead to greater engagement and improved health outcomes (Snuggs et al., 2023). Combining HIIT with more enjoyable activities, such as team sports, can provide a more engaging and less stressful alternative, while promoting cardiovascular health and improving adherence to exercise routines. Small-sided soccer

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games (SSG), which involve small formats of play (fewer players) and smaller fields, have been identified as a promising alternative to traditional running-based HIIT (Selmi et al., 2020). Studies (Cvetković et al., 2018) indicate that these games provide similar cardiovascular and metabolic benefits, such as improvements in aerobic fitness, or body composition while also promoting greater enjoyment (Ouertatani et al., 2022).

Although interesting, SSGs can suffer from heterogeneity in exercise stimulus (within and between participants), as their context is dependent on the match situation and may also vary according to the skill level and ability of participants (Clemente et al., 2022). For instance, changes in contextual factors (e.g., scoring status, varying competitive levels of opponents) may lead to dynamic shifts that influence behaviors/actions, thereby affecting the demands imposed by the game. While SSGs can facilitate continuous and intense physiological effort, certain critical locomotor demands -particularly the most intense ones, such as rapid accelerations or sprints- may be compromised due to the limited space and opportunities available (Dello Iacono et al., 2023). This limitation can hinder the targeting of other important physical components for youth populations, such as muscular power and change of direction (COD) (Clemente et al., 2021). In the context of soccer training, research has explored the effects of combining SSGs with HIIT, revealing promising benefits, including improvements in both endurance (Harrison et al., 2015) and muscular power (Paul et al., 2019). Combining regular HIIT with SSG can help overweight boys improve cardiovascular fitness and increase calorie burn through two effective training methods: one more individualized and less heterogeneous (HIIT) and the other more enjoyable yet still intense (SSG). This combination may ensure both effectiveness and enjoyment, which can enhance adherence. However, this approach has yet to be implemented in recreational or sedentary populations.

Exploring the effects of combining SSG and HIIT is particularly interesting. This combination can potentially merge the physiological benefits of both training methods with a more individualized and demanding locomotor stimulus offered by HIIT, all while maintaining the enjoyable aspects of SSG as a form of exercise. It is important to analyze whether the combined approach is as effective, or even more effective, than implementing SSG or HIIT alone. Such findings could influence public policy in schools and guide practitioners in designing effective interventions for sedentary, overweight populations. For instance, schools could implement regular programs as an additional resource for these populations, while minimizing exposure time to fit within regular schedules. These programs could have a combined effect by organizing small tournaments once a week and complementing them with more individualized training to the specific schedules and needs of each participant. Therefore, this study aimed to evaluate whether combining SSG and HIIT is more effective than either method alone in improving cardiometabolic health and physical fitness among sedentary, overweight youth.

## Methods

This report adheres to the CONSORT guidelines for presenting randomized study designs (Merkow et al., 2021). The study protocol, identified by code number [CDNU2024027], received approval from the Ethics Committee of [Chengdu Sport University]. Prior to participation, participants were fully informed about the study's aims and procedures. Voluntary informed consent was provided by the parents of the youth participants through signed consent forms. The study adhered to the ethical guidelines set forth in the Declaration of Helsinki, ensuring that all participation remained voluntary.

### Study design

The study design, a randomized parallel and controlled approach, compared three experimental groups (SSG + HIIT, SSG, and HIIT) with a control group that maintained their regular habits. The participants were evaluated at two different points (the week prior to the start of the intervention and the week following the final intervention session), with comparisons between groups made at baseline and following the intervention.

### Participants

The recruitment process involved contacting schools, parents, and youth populations through direct invitations at schools, as well as advertisements on social media and through mailing lists from the schools. The participants who expressed interest in joining the study were identified and subsequently assessed for their eligibility.

The inclusion criteria were defined as follows: (i) boys aged between 14 and 16 years; (ii) classified as overweight, with a body mass index ranging from 25 to 30 kg/m²; (iii) maintaining an adherence rate of over 80% throughout the intervention period; (iv) being assessed at both evaluation points; and (v) not participating in any other specific exercise program apart from the current one. The exclusion criteria included: (i) sustaining an injury during the intervention that resulted in missing more than two exercise sessions; (ii) starting a new physical exercise program during the course of the study; and (iii) exceeding the range of body mass index ranging from 25 to 30 kg/m² at the beginning of the study.

Out of an initial pool of 64 interested volunteers, 7 were excluded for not meeting the body mass index criteria required for inclusion in the intervention (4 were below 24 kg/m², and 3 exceeded 33 kg/m²). A flowchart describing the participants' progression through the study steps is presented in Figure 1.

### Interventions

The experimental groups were assigned to a 6-week training intervention, consisting of two sessions per week (Table 1). These sessions were part of a specialized exercise program designed to complement the regular physical education classes in the standard curriculum, which included three 45-minute weekly physical education classes. The interventions were conducted by three professional physical education and sport scientists, each with over three years of experience in prescribing physical exercise for youth.

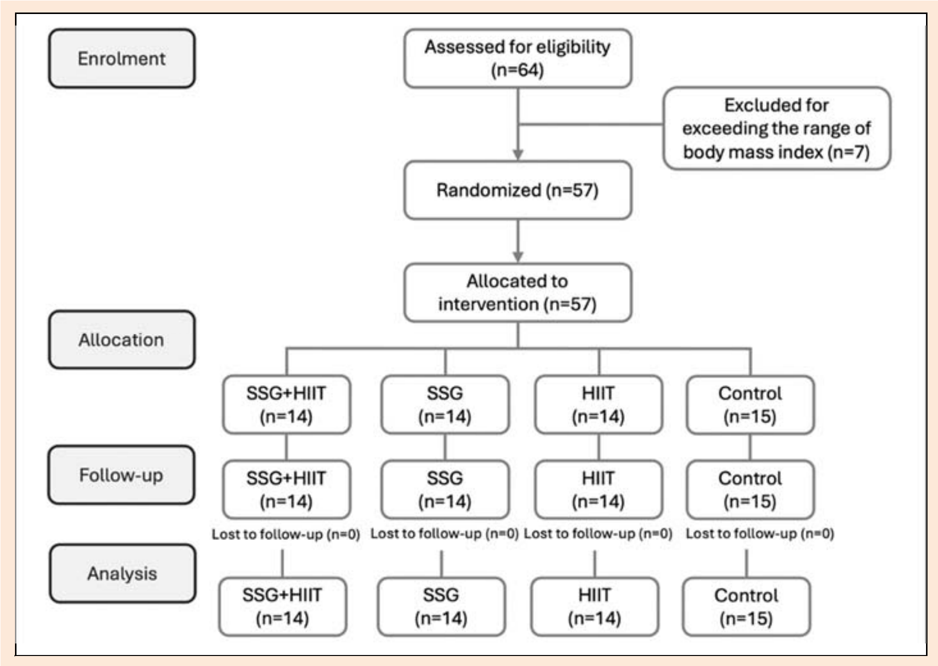


**Figure 1. Participant flowchart.**

**Table 1. Description of the training intervention plan over the 6-week period.**

| Week | Session | SSG+HIIT | SSG | HIIT |
|---|---|---|---|---|
| Week 1 | 1 | 2×3min/2 min rest - 3v3+1 (20×20m)<br>Rest 2 minutes<br>2×3 min of 15s work:15s rest/2 min rest - 90%:50% MAS | 4×3min/2 min rest - 3v3+1 (20×20m) | 4×3 min of 15s work:15s rest/2 min rest – 90%:50% MAS |
| | 2 | 2×3 min of 15s work:15s rest/2 min rest – 90%:50% MAS<br>Rest 2 minutes<br>2×3min/2 min rest - 3v3+1 (20×20m) | 4×3min/2 min rest - 3v3+1 (20×20m) | 4×3 min of 15s work:15s rest/2 min rest - 90%:50% MAS |
| Week 2 | 1 | 2×3min/2 min rest - 3v3+1 (20×20m)<br>Rest 2 minutes<br>2×3 min of 15s work:15s rest/2 min rest - 90%:50% MAS | 4×3min/2 min rest - 3v3+1 (20×20m) | 4×3 min of 15s work:15s rest/2 min rest - 90%:50% MAS |
| | 2 | 2×3 min of 15s work:15s rest/2 min rest – 90%:50% MAS<br>Rest 2 minutes<br>2×3min/2 min rest - 3v3+1 (20×20m) | 4×3min/2 min rest - 3v3+1 (20×20m) | 4×3 min of 15s work:15s rest/2 min rest - 90%:50% MAS |
| Week 3 | 1 | 2×3min/2 min rest - 3v3+1 (20×20m)<br>Rest 2 minutes<br>2×3 min of 15s work:15s rest/2 min rest - 90%:50% MAS | 4×3min/2 min rest - 3v3+1 (20×20m) | 4×3 min of 15s work:15s rest/2 min rest - 90%:50% MAS |
| | 2 | 2×3 min of 15s work:15s rest/2 min rest – 90%:50% MAS<br>Rest 2 minutes<br>2×3min/2 min rest - 3v3+1 (20×20m) | 4×3min/2 min rest - 3v3+1 (20×20m) | 4×3 min of 15s work:15s rest/2 min rest - 90%:50% MAS |
| Week 4 | 1 | 2×4 min of 15s work:15s rest/2 min rest – 90%:50% MAS<br>Rest 2 minutes<br>2×4min/2 min rest - 3v3+1 (20×20m) | 4×4min/2 min rest - 3v3+1 (20×20m) | 4×4 min of 15s work:15s rest/2 min rest - 90%:50% MAS |
| | 2 | 2×4min/2 min rest - 3v3+1 (20×20m)<br>Rest 2 minutes<br>2×4 min of 15s work:15s rest/2 min rest – 90%:50% MAS | 4×4min/2 min rest - 3v3+1 (20×20m) | 4×4 min of 15s work:15s rest/2 min rest - 90%:50% MAS |
| Week 5 | 1 | 2×4min/2 min rest - 3v3+1 (20×20m)<br>Rest 2 minutes<br>2×4 min of 15s work:15s rest/2 min rest – 90%:50% MAS | 4×4min/2 min rest - 3v3+1 (20×20m) | 4×4 min of 15s work:15s rest/2 min rest - 90%:50% MAS |
| | 2 | 2×4min/2 min rest - 3v3+1 (20×20m)<br>Rest 2 minutes<br>2×4 min of 15s work:15s rest/2 min rest – 90%:50% MAS | 4×4min/2 min rest - 3v3+1 (20×20m) | 4×4 min of 15s work:15s rest/2 min rest - 90%:50% MAS |
| Week 6 | 1 | 2×4min/2 min rest - 3v3+1 (20×20m)<br>Rest 2 minutes<br>2×4 min of 15s work:15s rest/2 min rest – 90%:50% MAS | 4×4min/2 min rest - 3v3+1 (20×20m) | 4×4 min of 15s work:15s rest/2 min rest - 90%:50% MAS |
| | 2 | 2×4min/2 min rest - 3v3+1 (20×20m)<br>Rest 2 minutes<br>2×4 min of 15s work:15s rest/2 min rest – HIIT | 4×4min/2 min rest - 3v3+1 (20×20m) | 4×4 min of 15s work:15s rest/2 min rest - 90%:50% MAS |

MAS: maximal aerobic speed; SSG+HIIT: combined small-sided games and high-intensity interval training; SSG: small-sided games; HIIT: high-intensity interval training.

The experimental groups followed similar programs, with the SSG + HIIT group performing exercises from both SSG and HIIT, though they spent half of their training time on each modality, combining both into the same session. To minimize the interference of exercise order, the SSG + HIIT group began the first session of the week with SSG and then moved on to HIIT, while the second session of the week followed the opposite sequence. Although evidence showed no influence of order (Rabbani et al., 2019; Arslan et al., 2021), we used this approach to keep participants engaged and maintain their commitment through variability. All the intervention sessions followed the same routine, with a 72-hour interval between each. Each session began with the same warm-up strategy: 5 minutes of jogging, 5 minutes of dynamic stretching for the lower limbs, and 5 minutes of balance and speed drills.

All experimental groups suffered an increase in training volume after the third week, with the duration of each set extended from the initial 3 minutes to 4 minutes, while the number of sets and the recovery time between sets remained the same. During the first to third weeks, each session included 12 minutes of active exercise per group, and from the fourth to the sixth weeks, the duration increased to 16 minutes per session.

The prescribed SSG was a 3v3 format, as it is often one of the most demanding exercises and is specifically fit to stimulate aerobic power. The participants were familiarized with these games through their physical education classes. The objective of the 3v3+1 was to score in a small 2x2 meter goal positioned at the endline of each team. The floater (the player supporting the attacking team) was rotated from set to set. The floater was allowed to play inside the field and actively participate in the attacking dynamics of the team by providing temporary numerical superiority. The games took place on an indoor court measuring 20x20 meters. Four balls were placed around the field to facilitate quicker ball repositioning. Ball replacements after the ball crossed the boundaries were made using the foot. Verbal encouragement was provided by the physical education teacher, using expressions such as "Go, go!", "Give your best!", and "Don't give up!" to help maintain participants' engagement and exercise intensity.

The HIIT training was conducted using a short-HIIT format, consisting of brief intervals of exercise at 90% of maximal aerobic speed (MAS), followed by 15 seconds of rest at 50% intensity. The MAS was defined as the highest running speed reached during the multistage fitness test. To simplify the exercise prescription, the court was divided into squares. Participants with higher MAS ran along the longer sides of the squares, while those with lower MAS ran along the shorter sides. The longer sides of the squares represented the 15-second running intervals, while the shorter sides were used for the 15-second rest periods. Participants were grouped according to their MAS to optimize the use of the available space. As with the SSG, verbal encouragement using similar expressions was provided to maintain higher engagement with the task.

The control group maintained their regular routines, attending two physical education classes of 40-45 minutes each week. They had the same number of sessions and duration of physical education as the participants in the intervention groups.

### Outcomes

The participants underwent two evaluations, one at baseline and another after the training intervention, with the evaluation conditions kept consistent. These assessments were carried out indoors during the afternoon, on the same weekdays for uniformity. The evaluation process began with collecting demographic and anthropometric data (height, body mass, waist circumference) and blood pressure evaluation, followed by a warm-up that included 5 minutes of jogging, 5 minutes of dynamic stretching for the lower limbs (leg swings, walking lunges, high knees, and butt kicks), and 5 minutes of balance and speed drills.

Following the warm-up, participants proceeded with the tests in a set sequence. The initial test assessed countermovement jump (CMJ), followed by the broad jump (BJ). Subsequently, participants' performance was evaluated in the 5-0-5 agility test. The final test conducted was the Multi-Stage Fitness Test (MSFT) to measure endurance. A 3-minute rest period was provided after each test, with an additional 3-minute rest between any repetitions within each assessment.

### Anthropometrics

In a standardized procedure, two skilled assessors, both with extensive experience in anthropometric assessments, began by measuring participants' height and body mass. Certified in physical education and sports sciences, the assessors had completed specialized training workshops and brought over three years of relevant experience to the task. For consistency, participants wore a T-shirt and shorts, without socks, during the measurements. To obtain accurate height measurements, participants stood with their backs against the height scale, looking forward to align the Frankfort Plane. Positioned in front of the participant, the assessor adjusted the stadiometer marker (ADE MZ10042, ADE, Germany) accordingly.

For body mass measurement, participants stood at the center of an electronic flat scale (SECA Model 813, Germany), facing forward. Waist circumference was then measured with participants standing upright, feet together, at the midpoint between the iliac crest and lower ribs. Using a non-elastic measuring tape (Lufkin W606PM, Mexico) wrapped around the waist parallel to the floor, the assessor ensured a snug but comfortable fit. Measurements were taken at the end of a regular exhalation, and the average of two readings was recorded.

### Blood pressure measurements

In the supine position, blood pressure was recorded for each arm consecutively, and the average of these readings was calculated to determine systolic (BPs) and diastolic (BPd) values. A validated (Peprah et al., 2023) automated upper-arm blood pressure monitor (Omron Healthcare, model BP7450) was used for the measurements.

### Countermovement jump (CMJ)

For the CMJ, participants were instructed to start in a squat-jump position with knees bent at a 90° angle and feet placed shoulder-width apart, with hands positioned on their hips. The goal was to jump for maximum height while keeping hands on the hips to avoid arm assistance.

Jump height was measured using the My Jump 2 app on an iPhone X, chosen for its established validity and reliability in assessing jump (Bogataj et al., 2020). Each participant performed two attempts, with a 2-minute rest interval between attempts. The average vertical jump (in centimeters) recorded were used for data analysis.

### Broad jump (BJ)

For the standing BJ, participants began at the start line, aiming to jump as far forward as possible. They were required to maintain hands on hips throughout the movement, and arm swinging was not allowed. A successful jump required a stable, two-foot landing without any additional movements to correct balance.

The My Jump 2 app on an iPhone X was used to measure jump distance, selected for its proven accuracy and reliability in jump assessment (Bogataj et al., 2020). Each participant completed two attempts, with a 2-minute rest between each. Each participant performed two attempts, with a 2-minute rest interval between attempts. The average distance of the horizontal jumps (in centimeters) was calculated and used for data analysis.

### 5-0-5 Change-of-direction (COD)

The 5-0-5 change-of-direction (COD) test in its original format was utilized for this study. Participants started in a split stance, with their dominant leg positioned in front. They first accelerated over a 10-meter stretch, after which they were timed for the initial 5 meters, the 180° change of direction, and the final 5-meter return (Ryan et al., 2022). The time taken for the two 5-meter segments was recorded as the COD time. This time was then subtracted from the total 10-meter sprint time to determine the COD deficit, which is considered a more accurate representation of an athlete's COD ability (Nimphius et al., 2016). This approach accounts for the fact that COD performance is significantly impacted by linear sprint speed (Sayers, 2014).

Participants were instructed to use the same leg for the 180° COD throughout both trials. The COD time was measured with a validated and reliable mobile application (COD timer) using iPhone X. A previous study showed that this mobile application provided valid and reliable measurements, comparable to those obtained using timing gates (Chen et al., 2021). Each player performed two trials, separated by a 3-minute rest period. The average COD deficit (in seconds) was calculated and used for data analysis.

### Multi-Stage Fitness Test (MSFT)

Participants completed the 20-meter shuttle run test following the standardized protocol from a previous study (Menezes Júnior et al., 2019). This test required running back and forth between two lines set 20 meters apart, with a pivot at a midpoint between the lines. The MSFT starts at a speed of 8.5 km/h. With each level, the speed increases by 0.5 km/h. Participants were permitted to pivot and resume running within the marked boundaries rather than fully crossing the line before each turn.

The test ended under two conditions: either the participant failed to reach the line after two consecutive beeps, or they twice neglected to wait for the beep before turning. The outcome measure was the total distance each participant covered during the shuttle run.

### Monitoring the training interventions

The 6 - 20 Borg's Rating of Perceived Effort (RPE) scale was used to assess the participants' perceived effort during the intervention sessions (Borg, 1998). The scale was first introduced to the participants to ensure they were familiar with it. During each session, participants completed the scale 15 minutes after the session ended. To minimize bias from peer influence, responses were collected individually, ensuring participants did not hear or see the scores of their colleagues. The researchers recorded the RPE scores. In addition, the Physical Activity Enjoyment Scale (PACES) (Moore et al., 2009) was administered at the end of each session to evaluate the participants' level of enjoyment throughout the intervention. The PACES scale was included to monitor participants' enjoyment during interventions because it provides a reliable, validated measure of subjective enjoyment, which is crucial for understanding motivation and long-term engagement in physical activities (Moore et al., 2009). The PACES consists of 18 items, each rated on a 7-point scale ranging from 1 to 7. Eleven of these items are reverse-scored. The overall physical activity enjoyment score was calculated by summing the scores for each item, resulting in a possible total score ranging from 18 to 126.

### Sample size

The sample size was determined using G*Power software (version 3.1.9, Universität Düsseldorf, Germany), which recommended a total of 44 participants to achieve a statistical power of 0.85 and a significance level of 0.05 for the F tests, specifically targeting the repeated measures ANOVA for within-between interactions. This calculation was based on an effect size of 0.278, derived from the partial eta square ($\eta_p^2$) of 0.072 observed in a study which tested the effects of SSG in high school children (Trajković et al., 2020).

### Randomization

The randomization process was supervised by a researcher who was not involved in the subsequent assessments, ensuring the blinding procedure was upheld. Participants were randomly assigned to groups using a 1:1 allocation ratio through a simple randomization method. Opaque envelopes were provided to the participants prior to their initial assessments, ensuring unbiased allocation.

### Blinding

Evaluations were conducted by independent researchers who were unaware of group assignments or the specifics of the intervention. Additionally, the registration forms only included identification numbers to prevent researchers from memorizing participants or associating them with specific groups, thereby ensuring blindness during the evaluation. In contrast, the participants and teachers were informed about the training protocols being implemented.

### Statistical methods

To evaluate the normality of the sample, the Kolmogorov-Smirnov test was applied, which produced p-values greater than 0.05. Levene's test was then conducted to assess the homogeneity of variances, also resulting in p-values above 0.05. A mixed ANOVA was performed to analyze the interaction between time and group. Effect sizes were calculated using $\eta_p^2$ and Cohen's d for comparisons between pre- and post-intervention measurements. Effect sizes were categorized according to the thresholds outlined by Hopkins et al (Hopkins et al., 2009): small (≥ 0.10), moderate (≥ 0.30), large (≥ 1.2), and very large (≥ 2.0). Post-hoc analyses were conducted using the Bonferroni test. A one-way ANOVA was used to compare the RPE and PACES scores across intervention sessions between the different intervention groups. The statistical analysis was carried out using JASP software (version 0.18.3, University of Amsterdam, The Netherlands), with a significance level set at $p < 0.05$.

## Results

The study included fifty-seven overweight, sedentary boys. The average age of the participants was 15.1 years (±0.8), with an average height of 166.6 cm (±5.1), body mass of 78.0 kg (±5.3), and a body mass index (BMI) of 28.1 kg/m² (±1.0). Detailed characteristics of the groups are presented in Table 2.

Significant interactions (time*group) were observed in body mass ($F$ = 41.527; $p$ < 0.001; $\eta_p^2$ = 0.857), body mass index ($F$ = 45.145; $p$ < 0.001; $\eta_p^2$ = 0.719), waist circumference ($F$ = 37.182; $p$ < 0.001; $\eta_p^2$ = 0.678), systolic blood pressure ($F$ = 5.224; $p$ = 0.003; $\eta_p^2$ = 0.228), and diastolic blood pressure ($F$ = 11.497; $p$ < 0.001; $\eta_p^2$ = 0.394).

No significant differences were observed between the groups at baseline for body mass ($F$ = 0.671; $p$ = 0.573; $\eta_p^2$ = 0.037), body mass index ($F$ = 0.432; $p$ = 0.731; $\eta_p^2$ = 0.024), waist circumference ($F$ = 0.628; $p$ = 0.600; $\eta_p^2$ = 0.034), systolic blood pressure ($F$ = 1.019; $p$ = 0.392; $\eta_p^2$= 0.055), and diastolic blood pressure ($F$ = 2.138; $p$=0.106; $\eta_p^2$ = 0.108).

No significant differences were observed between the groups at post-intervention for body mass ($F$ = 2.403; $p$ = 0.078; $\eta_p^2$ = 0.120), body mass index ($F$ = 1.730; $p$ = 0.172; $\eta_p^2$= 0.089), systolic blood pressure ($F$ = 2.121; $p$ = 0.109; $\eta_p^2$ = 0.107), and diastolic blood pressure ($F$ = 0.649; 0.587; $\eta_p^2$= 0.035). However, significant differences were observed between the groups at post-intervention for waist circumference ($F$ = 3.428; $p$ = 0.023; $\eta_p^2$= 0.163). Specifically, the HIIT group exhibited a significantly smaller waist circumference compared to the control group (mean difference: 3.671 cm; $p$ = 0.041; $d$ = -1.018, moderate effect size) after the intervention. Figure 2 shows the mean differences between post- and pre-intervention for the anthropometric and blood pressure variables.

**Table 2. Age, anthropometric and blood pressure baseline data for the participants of this study.**

| | SSG+HIIT (n = 14) | SSG (n = 14) | HIIT (n = 14) | Control (n = 15) |
|---|---|---|---|---|
| **Age (years)** | 15.1 ± 0.8 | 15.1 ± 0.8 | 15.1 ± 0.8 | 15.1 ± 0.7 |
| **Height (cm)** | 166.6 ± 6.5 | 165.4 ± 5.1 | 165.9 ± 4.3 | 168.5 ± 4.2 |
| **Body mass (kg)** | 78.1 ± 6.6 | 77.4 ± 5.2 | 76.8 ± 5.0 | 79.5 ± 4.4 |
| **Body mass index (kg/m²)** | 28.1 ± 0.9 | 28.3 ± 1.0 | 27.9 ± 1.2 | 28.0 ± 0.9 |
| **Waist circumference (cm)** | 86.5 ± 2.7 | 87.7 ± 3.2 | 86.4 ± 3.5 | 86.3 ± 3.4 |
| **Systolic blood pressure (mmHg)** | 136.6 ± 5.1 | 132.8 ± 5.4 | 134.4 ± 7.3 | 134.0 ± 5.3 |
| **Diastolic blood pressure (mmHg)** | 86.7 ± 6.1 | 83.8 ± 4.8 | 85.1 ± 6.3 | 81.7 ± 4.6 |

SSG+HIIT: combined small-sided games and high-intensity interval training; SSG: small-sided games; HIIT: high-intensity interval training.

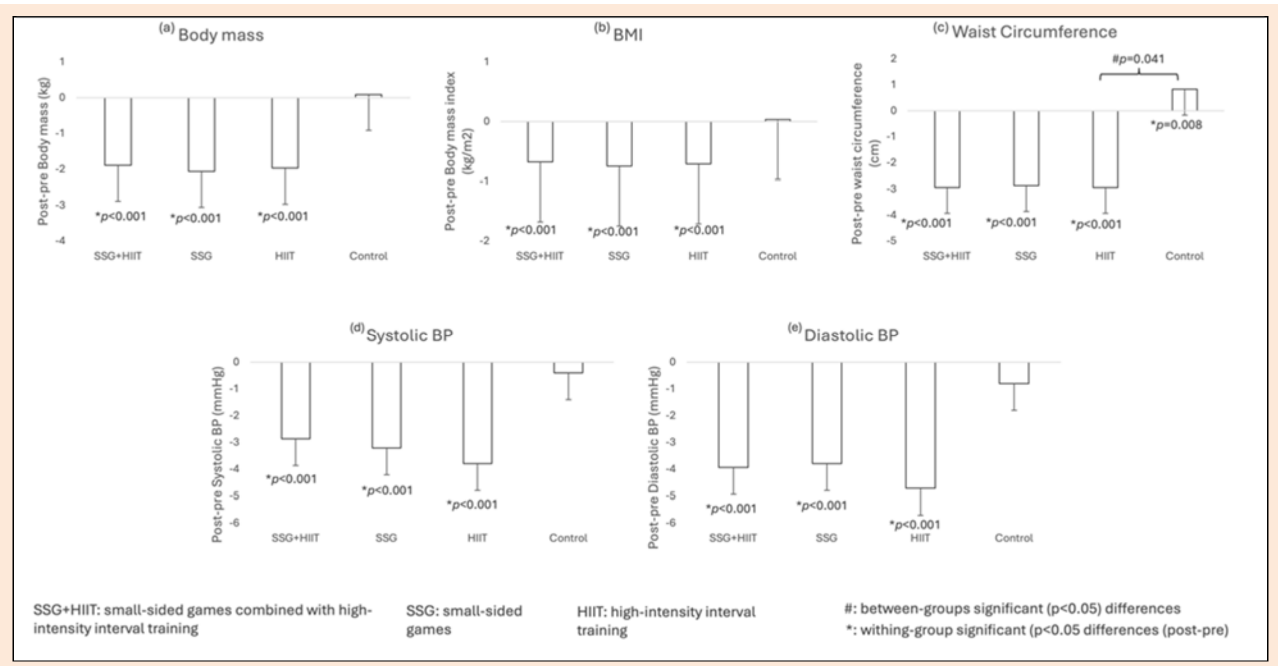


**Figure 2. Mean difference (post-pre) in the (a) body mass; (b) body mass index (BMI); (c) waist circumference; (d) systolic blood pressure (BP); and (e) diastolic BP.**

Significant interactions (time*group) were observed in CMJ ($F$ = 21.407; $p$ < 0.001; $\eta_p^2$= 0.548), BJ ($F$ = 5.945; $p$ = 0.001; $\eta_p^2$= 0.252), COD deficit ($F$ = 73.516; $p$ < 0.001; $\eta_p^2$ = 0.806), and MSFT ($F$ = 122.916; $p$ < 0.001; $\eta_p^2$ = 0.874). No significant differences were observed between the groups at baseline for CMJ ($F$ = 0.554; $p$ = 0.648; $\eta_p^2$= 0.030), BJ ($F$ = 0.365; $p$ = 0.778; $\eta_p^2$ = 0.020), COD deficit ($F$ = 0.827; $p$ = 0.485; $\eta_p^2$ = 0.045), and MSFT ($F$ = 0.101; $p$ = 0.959; $\eta_p^2$ = 0.006).

No significant differences were observed between the groups at post-intervention for CMJ ($F$ = 2.516; $p$ = 0.068; $\eta_p^2$= 0.125), and BJ ($F$ = 1.456; $p$ = 0.237; $\eta_p^2$= 0.076). However, significant differences were observed between the groups at post-intervention for COD deficit ($F$ = 6.952; $p$ < 0.001; $\eta_p^2$ = 0.282) and MSFT ($F$ = 6.171; $p$ = 0.001; $\eta_p^2$ = 0.259). Specifically, the control group exhibited a significantly worst COD deficit compared to the SSG + HIIT (mean difference: 0.221s; $p$ = 0.002; $d$ =1.375, large effect size), SSG (mean difference: 0.222s; $p$ = 0.001; $d$ =1.149, large effect size) and HIIT (mean difference: 0.155s; $p$ = 0.048; $d$=1.032, moderate effect size) after the intervention. In the case of MSFT, the group exhibited a significantly smaller distance covered than SSG+HIIT (mean difference: 166.5 m; $p$ = 0.002; $d$ = 1.560, large effect size), and SSG (mean difference: 155.1 m; $p$ = 0.005; $d$ = 1.556, large effect size) (Table 3).

One-way ANOVA revealed significant differences on RPE ($F$ = 12.013; $p$ < 0.001; $\eta^2$ = 0.421) and PACES ($F$ = 61.043; $p$ < 0.001; $\eta^2$ = 0.787) between groups (Figure 3). HIIT was perceived to be significantly more intense in comparison to SSG+HIIT ($p$ = 0.005; $d$ = 1.346, large effect size) and SSG ($p$ < 0.001; $d$ = 1.874, large effect size). Moreover, HIIT was perceived to be significantly less enjoyable than SSG+HIIT ($p$ < 0.001; $d$ = 3.492, very large effect size) and SSG ($p$ < 0.001; $d$ = 5.930, very large effect size).

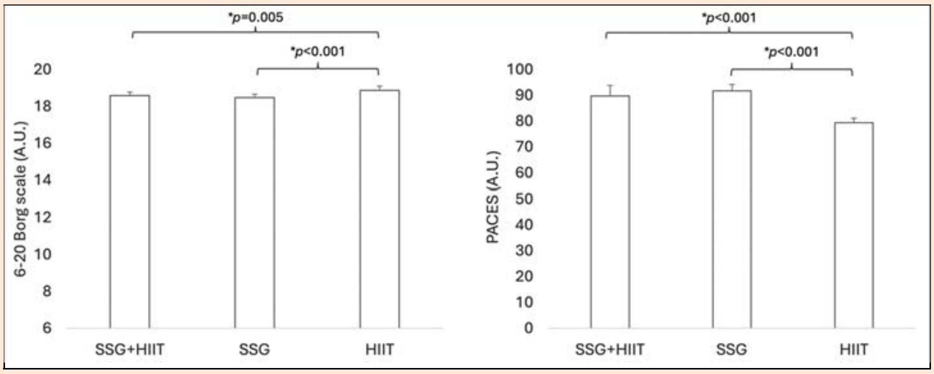


**Figure 3. Mean of rating of perceived exertion (6 - 20 Borg scale) and Physical Activity Enjoyment Scale (PACES) scores over the intervention.** SSG+HIIT: combined small-sided games and high-intensity interval training; SSG: small-sided games; HIIT: high-intensity interval training; *: significantly different between groups (p < 0.05).

**Table 3. Mean and standard deviation (SD) of baseline and post-intervention physical fitness values for four groups.**

| | SSG+HIIT (n = 14) | SSG (n = 14) | HIIT (n = 14) | Control (n = 15) |
|---|---|---|---|---|
| **CMJ (cm)** | | | | |
| Baseline | 22.6 ± 2.1 | 22.9 ± 2.3 | 22.7 ± 2.3 | 21.9 ± 1.5 |
| Post-intervention | 23.2 ± 1.9 | 23.4 ± 2.2 | 23.3 ± 2.1 | 21.7 ± 1.5 |
| p-value and ES (post-pre) | *$p$ < 0.001; $d$ = 0.300 | *$p$ < 0.001; $d$ = 0.222 | *$p$ < 0.001; $d$ = 0.273 | *$p$ = 0.029; $d$ = -0.133 |
| **BJ (cm)** | | | | |
| Baseline | 148.9 ± 7.9 | 146.7 ± 7.2 | 149.4 ± 7.2 | 147.9 ± 6.5 |
| Post-intervention | 152.0 ± 7.3 | 150.4 ± 8.3 | 153.2 ± 8.7 | 147.5 ± 6.7 |
| p-value and ES (post-pre) | *$p$ < 0.001; $d$ = 0.408 | *$p$ < 0.001; $d$ = 0.477 | *$p$ < 0.001; $d$ = 0.478 | $p$ = 0.626; $d$ = -0.061 |
| **5-0-5 COD deficit (s)** | | | | |
| Baseline | 0.78 ± 0.15 | 0.76 ± 0.15 | 0.82 ± 0.17 | 0.84 ± 0.15 |
| Post-intervention | 0.62 ± 0.16[¶] | 0.62 ± 0.15[¶] | 0.68 ± 0.15[¶] | 0.84 ± 0.16[#,@,$] |
| p-value and ES (post-pre) | *$p$ < 0.001; $d$ = -1.032 | *$p$ < 0.001; $d$ = -0.933 | *$p$ < 0.001; $d$ = -0.875 | $p$ = 0.921; $d$ = 0.000 |
| **MSFT (m)** | | | | |
| Baseline | 572.1 ± 131.4 | 553.6 ± 118.2 | 557.9 ± 147.7 | 548.0 ± 88.1 |
| Post-intervention | 687.9 ± 133.8[¶] | 676.4 ± 119.5[¶] | 637.9 ± 130.8 | 521.3 ± 79.8[#,@] |
| p-value and ES (post-pre) | *$p$ < 0.001; $d$ = 0.873 | *$p$ < 0.001; $d$ = 1.033 | *$p$ < 0.001; $d$ = 0.575 | *$p$ < 0.001; $d$ = -0.318 |

ES: effect size; SSG+HIIT: combined small-sided games and high-intensity interval training; SSG: small-sided games; HIIT: high-intensity interval training; CMJ: countermovement jump; BJ: broad jump; COD: change-of-direction; MSFT: multistage fitness test; *: significant within-group differences at p<0.05; #: significant (p<0.05) different from SSG+HIIT; @: significant (p<0.05) different from SSG; $: significant (p<0.05) different from the HIIT; ¶: significant different (p<0.05) from the control group.

## Discussion

The current experimental study found that both SSG + HIIT and SSG alone were significantly effective in improving COD ability and aerobic capacity in sedentary, overweight boys. Although HIIT alone did not show significant advantages over the control group, it was still effective in developing COD ability. HIIT was the only intervention that led to a significant reduction in waist circumference. Overall, none of the interventions had a significant effect on anthropometric measures such as body mass or body mass index, nor on blood pressure or muscle power, with outcomes in these areas not differing substantially from those in the control group. Our study also found that HIIT was perceived as significantly more intense and less enjoyable compared to both SSG + HIIT and SSG.

The impact on aerobic capacity, measured through the MSFT, revealed interesting and unexpected findings. Both SSG+HIIT and SSG alone were significantly effective in improving overall capacity, showing substantial differences from the control group after six weeks of training. In contrast, while HIIT led to significant improvements within its own group, these gains were not significantly different from those of the control group. A previous study by Cvetković et al. (2018) found that both SSG and HIIT are similarly effective in enhancing the aerobic capacity of overweight youth. Our results reveal that, although no significant differences were found between SSG + HIIT, SSG, and HIIT post-intervention, HIIT did not show a significant improvement compared to the control group, whereas both SSG+HIIT and SSG did. SSGs inherently incorporate continuous movement with variable intensities, which stimulates cardiovascular adaptations by enhancing intense heart rate and improving oxygen delivery (Zouhal et al., 2020). The unpredictable nature of SSGs also recruits a wide range of muscular participation, promoting both aerobic and anaerobic energy systems (Delextrat et al., 2018). On the other hand, HIIT triggers a rapid increase in heart rate, challenging the cardiorespiratory system to adapt to high-intensity bursts followed by brief recovery periods (Torma et al., 2019). This combination enhances the body's capacity to utilize oxygen efficiently and increases mitochondrial density (Batterson et al., 2023), ultimately improving overall aerobic fitness. However, the lack of significant difference between HIIT alone and the control group in your study may be explained by the HIIT type sessions (short intervals), since while this short duration of intense work can improve power output, muscular endurance, and anaerobic capacity (Stöggl and Björklund, 2017), it may not provide enough sustained cardiovascular stress to drive significant adaptations in aerobic fitness. SSGs can complement HIIT efforts by promoting a more sustained aerobic workload with dynamic movement patterns, namely using long HIIT type.

Regarding the impact of the interventions on COD ability, all three interventions showed a significantly positive effect compared to the control group, with each intervention having a similarly favorable impact. Previous studies in athletes suggest that SSG may enhance COD ability (Chaouachi et al., 2014) by fostering quicker decision-making and improved maneuvering skills (Young and Rogers, 2014). SSG inherently involves unpredictable and multidirectional movements, demanding rapid adjustments in acceleration, deceleration, and directional shifts (Mota et al., 2022). This unpredictability may involve greater neuromuscular activity associated with agility and reactive strength (Hammami et al., 2018a). On the other hand, HIIT, which frequently incorporates COD movements, may also improve COD ability by requiring repeated acceleration and deceleration (Hader et al., 2014). Through high-intensity, repetitive bursts of activity (such as those in short HIIT sessions), fast-twitch muscle fibers responsible for explosive movements may be effectively targeted (Kohn et al., 2011). This type of training may improve the reactivity of the stretch-shortening cycle, which enhances the efficiency of eccentric and concentric contractions required for rapid directional changes (García-Pinillos et al., 2016). However, future studies are recommended to analyze the potential impact of the number of CODs in HIIT, particularly because HIIT can be performed in different formats, with varying intensities and turns.

Regarding the impact of the training interventions on muscle power, as measured by the CMJ and BJ tests, no significant differences were observed compared to the control group. Both CMJ and BJ performance rely on explosive muscular strength, particularly in the lower limbs (Jakobsen et al., 2012). For overweight and sedentary youth, these muscle groups may not be sufficiently conditioned to generate the power required for improvements in jump performance. Additionally, overweight individuals may experience impaired force transfer during explosive movements (Riddiford-Harland et al., 2006), which can only be improved through targeted strength training. As a result, the absence of focused power training likely explains why neither SSGs nor running HIIT led to significant improvements in CMJ or broad jump performance in this population.

Considering the impact of the training interventions on anthropometrics, significant improvements were only observed in waist circumference following HIIT, while SSG + HIIT and SSG did not show significant effects. Furthermore, none of the training protocols (SSG + HIIT, SSG, or HIIT) were effective in reducing body mass or body mass index. HIIT has been shown to be particularly effective in reducing visceral fat and improving abdominal fat distribution (Maillard et al., 2018), which could explain the significant reduction in waist circumference observed in the HIIT group. In contrast, SSG and the combination of SSG + HIIT may have provided insufficient intensity or volume to significantly affect fat loss or body mass, similarly with a previous study testing the impact of SSG in body composition (Hammami et al., 2018b). Furthermore, body mass and BMI are influenced by both fat loss and lean mass changes, and these interventions may not have been of sufficient intensity or duration to significantly alter overall body mass or BMI in overweight, sedentary youth. It is possible that a more prolonged, or high-volume intervention focused on caloric expenditure, along with dietary control, might be needed to see significant reductions in body mass or BMI.

Furthermore, none of the three interventions had a significant impact on blood pressure measures, with no significant differences observed compared to the control group. Blood pressure regulation involves complex interactions between cardiovascular fitness, autonomic control, and vascular health (Persson, 1996), which may require longer periods to produce measurable reductions. Additionally, the participants in this study were sedentary, overweight youth, a population that may not exhibit as pronounced a response in blood pressure to short-term interventions as older or more hypertensive individuals.

One factor that may encourage practitioners to use

SSG is the experience of playing a game, which can engage participants more deeply in the activity, fostering a sense of teamwork and motivation. During the training sessions, it was observed that HIIT was perceived as significantly more intense and less enjoyable compared to the SSG + HIIT and SSG groups. Our results confirm previous studies that compare SSG with HIIT (Los Arcos et al., 2015; Ouertatani et al., 2022). The element of play and competition inherent in SSG can increase intrinsic motivation, enhance social engagement, and reduce the perception of effort, making the activity more enjoyable despite the physical demands (Selmi et al., 2020). The sense of teamwork and the opportunity to engage in skill-based tasks may also contribute to a more positive psychological experience, which may explain why participants in SSG-based groups reported greater enjoyment (Ridwan et al., 2022). Despite these findings, a more qualitative analysis could add value, such as interviewing participants to identify the factors that explain why HIIT is perceived as less enjoyable.

While this study provides interesting findings for the use of SSG + HIIT in overweight youth populations, some limitations must be considered. First, the duration of the intervention (six weeks) may not have been sufficient to elicit significant changes in certain outcomes, such as body mass, body mass index, or blood pressure, primarily because these changes depend on a complex combination of physiological adaptations (e.g., fat oxidation, muscle hypertrophy, and vascular function). Longer intervention periods or higher training volumes might be required to observe substantial changes in these parameters, particularly in overweight populations. Moreover, the lack of a control for dietary intake or other external factors (as general physical activity levels) could be relevant to isolate better the findings. Future research could explore longer-term training effects, assess the combined impact of exercise and dietary interventions on body composition, and incorporate more specific assessments of muscle power to better understand the underlying mechanisms of fitness improvements in this population. For instance, using dietary diaries could help analyze whether modifications in lifestyle and diet (e.g., macronutrient balance) affect the patterns of adaptations.

Despite the limitations, the findings of this study have important implications for community-based programs and practitioners working with sedentary, overweight youth. Both SSG+HIIT and SSG alone were effective in improving COD ability and aerobic capacity, highlighting the potential of incorporating game-based training into youth fitness interventions. The positive effects of SSG suggest that activities that are both physically engaging and enjoyable, like SSGs, could be an effective alternative to traditional, more structured exercise programs, helping to increase youth participation and long-term adherence to physical activity. The fact that HIIT led to a significant reduction in waist circumference further supports its role in addressing abdominal fat in overweight populations. Practitioners could consider use combined modalities as SSG + HIIT into youth fitness regimens, particularly to benefit both body composition and physical fitness. Moreover, the enjoyment in SSG emphasize the importance of fostering positive emotional experiences in physical activity, which can contribute to greater motivation and engagement.

## Conclusion

Our study suggests that both SSG combined with HIIT and SSG alone were effective in improving COD ability and aerobic capacity in sedentary, overweight boys. Both interventions yielded significant improvements in these measures compared to the control group, with SSG also showing substantial improvements in aerobic capacity. While HIIT alone was effective in improving COD ability and led to a significant reduction in waist circumference, it did not outperform the control group in terms of aerobic fitness. Neither HIIT, SSG, nor their combination resulted in significant changes in body mass, body mass index, blood pressure, or muscle power, suggesting that the interventions were not of sufficient to drive changes in these measures. The perception of HIIT as more intense and less enjoyable compared to SSG suggests that the enjoyment and social aspects of SSG may enhance engagement and adherence in youth physical activity programs. As a limitation, this study examined the impact over a relatively short period and did not include a combined approach with dietary or lifestyle modifications. Future research should focus on integrating these factors and extending the duration of studies to identify thresholds or plateaus in the adaptations. Despite the limitations, these findings emphasize the value of incorporating game-based interventions like SSG, which offer both physical benefits and greater enjoyment, potentially fostering long-term participation in physical activity among sedentary youth in the regular HIIT programs. Educators and professionals are encouraged to incorporate SSGs in the form of tournaments, potentially integrated with "teams" to engage participants, while also offering more individualized options to better fit participants' schedules.

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## Key points

- Combining HIIT with small-sided soccer games (SSG+HIIT) enhances aerobic capacity, change-of-direction ability, and exercise enjoyment more effectively than either HIIT or SSG alone in overweight youth.
- The SSG+HIIT approach offers a balanced training method that is both effective and enjoyable, providing an innovative solution for improving fitness in sedentary youth populations.

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