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Research article

Comparative Effects Of 1V1 Vs 3V3 Small-Sided Basketball Training On Body Anthropometric-Related Outcomes And Physical Fitness In Sedentary Female College Students: An 8-Week Randomized Controlled Trial

Lu Li[1], Xinjie Han [1], Jiawei Chen [2], Qingpan Wen [1], Gustavo De Conti Teixeira Costa [3], Robert Trybulski [4,5] and Filipe Manuel Clemente [1,6,7]✉

[1] Department of Biomechanics and Sport Engineering, Gdansk University of Physical Education and Sport, Gdansk, Poland; [2] Hunan Mechanical and Electrical Vocational Technical College; [3] Physical Education Department, Federal University of Goiás, Goiás, Goiânia, Brazil; [4] Faculty of Medicine, Katowice Business University, Katowice, Poland; [5] Provita Żory Medical Center, Żory, Poland; [6] Applied Research Institute (i2A), Polytechnic University of Coimbra, Coimbra, Portugal; [7] Sport Physical Activity and Health Research & Innovation Center, Coimbra, Portugal

Abstract

Objective: This randomized controlled trial compared the effects of 1v1 and 3v3 basketball small-sided games (SSGs) on body anthropometric-related outcomes and physical fitness in sedentary female college students. Methods: Sixty-three sedentary female university students aged 18 - 21 years were randomized to 1v1 SSGs (n = 21), 3v3 SSGs (n = 21), or a non-training control group (n = 21) for 8 weeks. Training was performed three times per week, with each 60-min session including 40 min of SSG play. Outcomes were assessed at baseline, week 4, and week 8. All randomized participants completed the scheduled assessments, with no missing outcome cases. Adherence was 94.5% in the 1v1 group and 92.8% in the 3v3 group. The primary outcome was 20-m multistage fitness test distance. Secondary outcomes included body mass, body mass index, waist circumference, hip circumference, waist-to-hip ratio, the sum of skinfold thicknesses, handgrip strength, vertical jump height, and standing long jump distance. Linear mixed-effects models including group, time, and group × time were used to estimate longitudinal intervention effects. Results: The primary outcome improved more in both intervention groups than in the control group. The 20-m multistage fitness test distance increased by 29.1% in the 1v1 group and 35.3% in the 3v3 group, compared with 1.1% in the control group; the model-estimated differences in baseline-to-week 8 change versus control were 120.95 m for 1v1 and 151.43 m for 3v3, with both Holm-adjusted p values < 0.001. Body mass decreased by 6.8% in the 1v1 group and 8.2% in the 3v3 group, compared with 0.8% in the control group. The corresponding differences in baseline-to-week 8 change versus control were -3.45 kg for 1v1 and -4.18 kg for 3v3, both with Holm-adjusted p values < 0.001. The sum of skinfold thicknesses decreased by 10.6% in the 1v1 group and 12.2% in the 3v3 group, compared with 0.4% in the control group (p values < 0.001). Secondary fitness outcomes also improved more in the intervention groups than in the control group, including handgrip strength, vertical jump height, and standing long jump distance. The 3v3 format showed larger exploratory gains than 1v1 in vertical jump height and standing long jump distance, whereas direct between-format differences for multistage fitness test distance and handgrip strength were not statistically significant. Conclusions: Eight weeks of recreational basketball SSGs improved cardiorespiratory fitness, several adiposity-related indicators, and neuromuscular fitness in sedentary female college students. These findings support basketball SSGs as a reasonable university-based exercise strategy, although between-format comparisons should be interpreted cautiously because they were exploratory. Future studies should test these formats in larger multicenter samples, include longer-term follow-up, and incorporate dietary/free-living activity monitoring and direct training-load measures to clarify sustainability, mechanisms, and format-specific effects.

Key words: aerobic capacity, neuromuscular adaptation, exercise intensity, health.

Introduction

Rising rates of overweight/obesity and declining physical health among university students have been reported in China, mirroring broader concerns about youth health (Department of Physical and Arts Education Ministry of, 2021). This matters because regular physical activity reduces risk for chronic conditions including hypertension, cardiovascular disease, type 2 diabetes, and obesity (Trajković et al., 2020). However, lifestyle shifts in young adults have increased sedentary time and worsened health indicators, with inactivity linked to poorer cardiometabolic profiles and adverse psychosocial outcomes (Biddle and Asare, 2011; Carson et al., 2016; Mitchell et al., 2013; Villa-González et al., 2023). In this population, health-related fitness should be understood as a multidimensional construct rather than a single performance attribute. Cardiorespiratory fitness reflects the capacity to sustain dynamic whole-body exercise through integrated cardiovascular, respiratory, and muscular function and is strongly relevant to cardiometabolic health (de Souza et al., 2025; Dimitros et al., 2021; O'Grady et al., 2020; Stojanoví et al., 2021). Neuromuscular fitness includes muscular strength and explosive power, which are commonly represented in field settings by handgrip strength and jump performance (de Souza et al., 2025; Dimitros et al., 2021; O'Grady et al., 2020; Stojanoví et al., 2021). Anthropometric/adiposity-related outcomes, including body mass, body mass index, waist circumference, waist-to-hip ratio, and skinfold thickness, provide practical field indicators of body-size and fat-distribution changes.

Basketball is widely practiced and functions as an intermittent, high-intensity activity that alternates anaerobic actions (e.g., sprints, jumps, physical contests) with lower-intensity recovery phases (Mikić et al., 2021). In this context, small-sided basketball games (SSGs) have

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attracted attention as an efficient, enjoyable training mode capable of stimulating multiple fitness components while supporting adherence, an important consideration for previously inactive participants (de Souza et al., 2025; Dimitros et al., 2021; Kunz et al., 2019; O'Grady et al., 2020; Stojanoví et al., 2021; Xu et al., 2024). SSGs are modified game formats in which structural constraints such as player number, playing area, bout duration, recovery duration, rules, and scoring conditions are manipulated to regulate the physiological, perceptual, technical, and tactical demands of training (Clemente et al., 2021a). In this context, internal load refers to the participant's psychophysiological response to the exercise stimulus, commonly represented by heart rate and perceived exertion, whereas external load refers to the work performed, such as distance covered, accelerations, decelerations, jumps, or technical actions (McLaren et al., 2018). Because game-based exercise combines physiological loading with sport-specific interaction, it may be particularly suitable for sedentary university students who require engaging alternatives to traditional conditioning.

Across recreational and experimental contexts, SSG-based interventions have been associated with improvements in aerobic fitness and other performance markers, often with favorable motivational responses compared with traditional conditioning (de Souza et al., 2025; Dimitros et al., 2021; O'Grady et al., 2020; Stojanoví et al., 2021). For sedentary participants, this is relevant because the same training format can simultaneously expose individuals to repeated vigorous cardiovascular stimuli, lower-limb power actions, coordination demands, and social interaction. Evidence from SSGs and related team-sport interventions also supports favorable changes in adiposity-related indicators, including body mass, body mass index, waist measures, and skinfold-based outcomes, although the magnitude of change depends on training dose, participant phenotype, and control of diet and non-intervention physical activity (Ekkekakis et al., 2011; Milanović et al., 2015; Ntoumanis et al., 2021; Reiner et al., 2013; Xu et al., 2024). These physiological benefits may be reinforced by psychosocial mechanisms (e.g., enjoyment, self-efficacy, social connectedness) that are particularly relevant for sustaining activity in novice and female exercisers(Ekkekakis et al., 2011; Ntoumanis et al., 2021; Reiner et al., 2013).

An important advantage of SSGs is that training load is highly adjustable through task constraints (e.g., player number, court size, bout duration, and rules), which directly alters internal and external demands(Milanović et al., 2015). Player number is particularly relevant because it changes the density of individual involvement. In a 1v1 format, each participant is continuously involved in attacking, defending, ball handling, and physical contests, whereas in a 3v3 format the effort is distributed across more players and may involve different patterns of off-ball movement, cooperation, spacing, and transition play profiles (Clemente et al., 2021a; Halouani et al., 2017; Halouani et al., 2014). Smaller formats such as 1v1 typically increase individual involvement and can elicit higher cardiovascular and perceptual loads, whereas larger formats distribute effort more evenly and may change movement and recovery profiles (Clemente et al., 2021b; Halouani et al., 2017; Halouani et al., 2014). These format-dependent differences provide a clear rationale for comparing specific basketball SSG configurations when designing exercise interventions for sedentary students.

However, the available basketball SSG literature has focused mainly on acute physiological, perceptual, technical-tactical, or workload responses, and on comparisons between SSGs and other conditioning approaches, rather than on chronic randomized comparisons of 1v1 versus 3v3 basketball SSG training in sedentary female college students (O'Grady et al., 2020; de Souza et al., 2025). This leaves an important practical question for university-based exercise promotion which is whether basketball SSG formats that differ in player number, but are matched for training frequency, duration, recovery structure, and relative playing area, produce favorable changes in health-related fitness compared with non-training control conditions, and whether any format-specific signals emerge across the outcomes. Accordingly, the present study examined the effects of an 8-week 1v1 versus 3v3 basketball SSGs program on anthropometric-related outcomes and physical fitness in sedentary female college students. We hypothesized that both 1v1 and 3v3 SSG training would improve the primary cardiorespiratory fitness outcome compared with a non-training control condition. Secondary anthropometric and neuromuscular outcomes were examined to characterize broader intervention-related adaptations, whereas direct 1v1-versus-3v3 comparisons were interpreted cautiously as exploratory format-comparison evidence (Xu et al., 2024).

Methods

Experimental design

The experiment was conducted in accordance with the CONSORT guidelines for randomized controlled trials and used an 8-week parallel-group randomized controlled design. Participants were allocated in a 1:1:1 ratio to one of three groups: a 1v1 SSG intervention, a 3v3 SSG intervention, or a control group that maintained usual lifestyle habits. Outcomes were assessed at baseline, mid-intervention (week 4), and post-intervention (week 8). No dietary intervention was prescribed. A schematic overview of participant screening, randomization, intervention allocation, training exposure, monitoring procedures, and assessment time points is presented in Figure 1.

Female university students aged 18 - 21 years with a sedentary lifestyle were recruited via open advertisement. Seventy-two volunteers were screened; sixty-three met the eligibility criteria and were enrolled. Prior to the start of training, all participants attended a standardized 2-hour familiarization session covering procedures, safety, and correct performance of the tests and training activities.

Randomization was performed before the intervention using a computer-generated random sequence with equal allocation (1:1:1), ensuring that each participant had the same probability of assignment to any group.

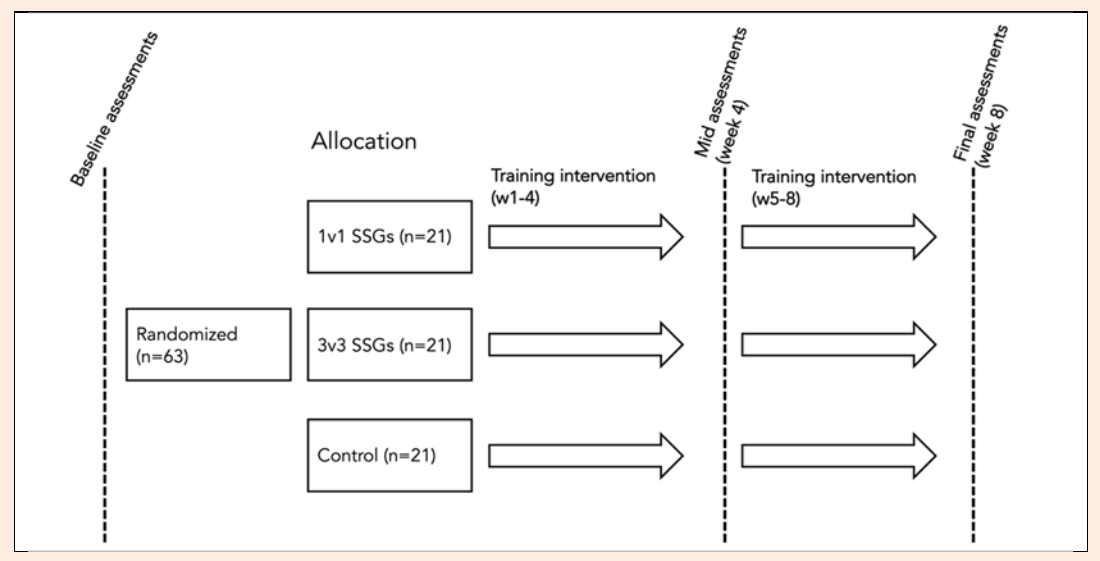

Figure 1. Study design. SSGs: small-sided games.

Allocation concealment was maintained using sequentially numbered, opaque, sealed envelopes prepared by an independent researcher not involved in recruitment, testing, or training delivery. After baseline testing, the next envelope in sequence was opened to reveal group assignment. This procedure prevented foreknowledge of allocation and minimized selection bias. During the week before the intervention, participants completed baseline assessments including height, body mass, skinfold thickness, waist and hip circumferences, standing long jump, vertical jump, bilateral handgrip strength, and the 20-m shuttle run. During the intervention, both training groups completed three 60-min sessions per week. Each session comprised a 10-min warm-up, 40-min SSG play, and a 10-min cool-down. Heart rate was continuously monitored throughout each session to quantify internal training load.

The confirmatory component tested whether each basketball SSGs intervention produced a greater improvement than the control condition in the primary outcome, 20-m multistage fitness test distance, from baseline to week 8. This outcome was selected as the primary endpoint because it represented the principal cardiorespiratory fitness adaptation expected from the intervention and was aligned with the aerobic-fitness basis used for the sample-size calculation. The primary intervention contrasts were 1v1 SSG versus control and 3v3 SSG versus control for the model-estimated baseline-to-week 8 change in 20-m multistage fitness test distance.

Secondary outcomes were grouped into two outcome domains. The anthropometric and body-composition domain comprised body mass, body mass index, waist circumference, hip circumference, waist-to-hip ratio, and the sum of skinfold thicknesses. The secondary physical-fitness domain comprised left-hand handgrip strength, right-hand handgrip strength, vertical jump height, and standing long jump distance. These secondary analyses were considered supportive and were used to characterize the intervention-related adaptations. Direct comparisons between the two active intervention formats, 1v1 SSG versus 3v3 SSG, were treated as exploratory format-comparison analyses. Exercise-load variables were analyzed descriptively as intervention measures and were not treated as efficacy outcomes.

Participants

Sample size was calculated a priori using G*Power 3.1 (version 3.1.9.4; Düsseldorf, Germany). The calculation was based on the primary measure, 20-m multistage fitness test distance, because this outcome represented the principal cardiorespiratory fitness adaptation expected from the intervention. The target effect was the intervention-versus-control difference in baseline-to-week 8 change for each active SSG condition compared with the non-training control condition. The a priori calculation used a standardized mean-difference approximation for the primary intervention-versus-control contrast. A large expected effect size was assumed (Cohen's d = 0.80), consistent with prior evidence of aerobic-fitness improvements after recreational SSG interventions in sedentary adults (Krustrup et al., 2010). With a two-sided α level of 0.05 and 80% power, the minimum required sample was estimated at 52 participants. To protect against attrition and preserve balanced allocation across the three randomized groups, 63 participants were recruited and allocated equally to 1v1 SSGs, 3v3 SSGs, or control (n = 21 per group).

This sample-size calculation was intended to support the primary intervention-versus-control inference for the cardiorespiratory fitness. It was not designed to provide independent confirmatory power for all secondary anthropometric and neuromuscular outcomes, nor for direct 1v1-versus-3v3 format comparisons. Accordingly, secondary outcomes were interpreted as supportive, and direct comparisons between active training formats were treated as exploratory.

Participants were recruited via open advertisement and screened for eligibility before baseline testing. Inclusion criteria were: (i) female university student; (ii) age 18 - 21 years; (iii) self-reported sedentary status, operationally defined as no regular structured exercise training during the preceding six months; (iv) no history of systematic basketball training and no current or previous participation in competitive or club basketball; (v) medical suitability for vigorous physical activity based on standard health screening and self-report; and (vi) willingness and availability to attend baseline, week-4, and week-8 assessments and the three weekly training sessions if allocated to an intervention group.

Exclusion criteria were: (i) cardiovascular, metabolic, respiratory, neurological, or musculoskeletal disease, condition, or injury that could contraindicate vigorous intermittent exercise; (ii) current participation in structured exercise training or organized sport, because this would conflict with the sedentary eligibility criterion and could confound training responses; (iii) previous systematic basketball training or competitive/club basketball experience, because prior skill and training exposure could influence baseline performance and intervention load; (iv) use of medications known to affect cardiovascular responses, metabolism, or body composition, including beta-blockers or systemic corticosteroids; (v) pregnancy; and (vi) anticipated inability to complete the scheduled assessments or comply with the training schedule. These criteria were applied to protect participant safety, minimize confounding due to prior training status or pharmacological influences, and reduce avoidable non-adherence.

In total, 72 volunteers were screened. Individuals were excluded primarily because they did not meet the sedentary criterion (n = 2), had a history of organized basketball training (n = 2), reported medical or musculoskeletal limitations incompatible with vigorous exercise(n = 2), or withdrew before baseline testing due to scheduling constraints(n = 3). After final screening and pre-intervention withdrawals, 63 participants were enrolled and randomized in a 1:1:1 ratio to a 1v1 SSG group (n = 21), a 3v3 SSG group (n = 21), or a control group (n = 21), as summarized in Figure 2. The baseline participant characteristics are presented descriptively in Table 1. No baseline significance tests were performed between randomized groups. To enhance representativeness within the university context, participants were recruited from multiple academic majors, and all included participants were sedentary and had not previously undertaken a systematic exercise program. The table 1 describes the main demographic characteristics per group.

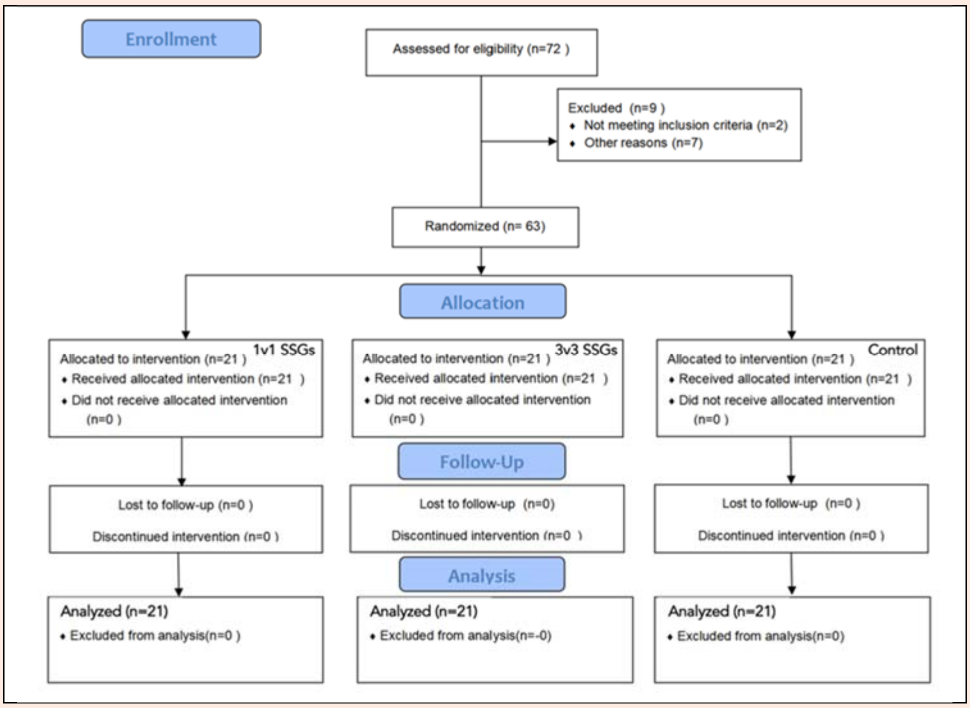

Figure 2. Participants flow diagram. SSGs: small-sided games.

Table 1. Baseline descriptive values by randomized group.

Outcome	1v1 SSG (n = 21)	3v3 SSG (n = 21)	Control (n = 21)
Age (years)	19.51 ± 0.44	19.44 ± 0.85	19.43 ± 0.50
Height (cm)	162.2 ± 5.8	163.5 ± 6.3	160.2 ± 4.8
Body mass (kg)	56.76 ± 6.36	56.43 ± 6.81	56.48 ± 5.29
Body mass index (kg/m2)	21.57 ± 2.75	21.10 ± 2.76	22.00 ± 1.73
Waist circumference (cm)	81.14 ± 5.26	81.05 ± 4.24	80.86 ± 2.78
Hip circumference (cm)	99.24 ± 3.43	98.95 ± 5.07	98.05 ± 4.15
Waist-to-hip ratio (A.U.)	0.818 ± 0.044	0.820 ± 0.030	0.818 ± 0.025
Sum of skinfold thicknesses (mm)	96.90 ± 15.78	96.37 ± 15.82	97.15 ± 6.29
20-m multistage fitness test distance (m)	432.38 ± 92.41	442.86 ± 88.61	436.19 ± 60.21
Left-hand handgrip strength (kg)	12.76 ± 5.17	13.33 ± 5.08	11.24 ± 5.12
Right-hand handgrip strength (kg)	12.57 ± 4.80	12.62 ± 4.38	11.38 ± 3.99
Vertical jump height (cm)	25.14 ± 4.46	27.11 ± 5.04	26.03 ± 2.85
Standing long jump distance (cm)	160.67 ± 14.78	163.81 ± 20.40	158.48 ± 9.85

Values are mean ± standard deviation. SSG = small-sided games.

This study was reviewed and approved by the institutional ethics review body of Hunan Mechanical and Electrical Polytechnic (Ethical Review Approval Form; application date 27 May 2024; Luncheon Research Grants No. 2024011). All procedures were conducted in accordance with the principles of the Declaration of Helsinki and relevant institutional regulations. Prior to participation, eligible students received a detailed explanation of the study aims, testing and training procedures, potential risks and benefits, and data handling, and provided written informed consent. Participation was voluntary, and individuals were informed that they could withdraw at any time without penalty or academic consequence.

Training interventions

The training intervention was delivered three times per week for 8 weeks, resulting in 24 planned sessions per intervention arm. Each session lasted 60 min and consisted of a standardized 10-min warm-up, a 40-min SSG training block, and a 10-min cool-down. To ensure that the comparison between 1v1 and 3v3 reflected the effect of player-number format rather than unequal training dose, the two intervention arms were matched for session frequency, total session duration, SSG block duration, active playing time, passive recovery time, and progression across the 8-week intervention. The 40-min SSG block comprised four 8-min playing bouts separated by three 2-min passive recovery intervals, plus 2 min allocated to standardized bout transition and hydration. Thus, each session provided 32 min of active SSGs exposure and 6 min of passive recovery within the SSG block. Across the 24 planned sessions, the intended active SSGs exposure was 768 min per participant in each intervention arm.

Task constraints were standardized within each phase and matched between arms wherever possible. The 1v1 and 3v3 formats were played on courts scaled to preserve the same relative playing area per player. During weeks 1 - 4, the 1v1 format was played on a 7 × 10 m court with two players, corresponding to 35 m^2 per player, whereas the 3v3 format was played on a 14 × 15 m half-court with six players, also corresponding to 35 m^2 per player. During weeks 5 - 8, the playing space was increased to progress locomotor demands while preserving area-per-player equivalence: the 1v1 format was played on a 10 × 14 m court with two players, corresponding to 70 m^2 per player, and the 3v3 format was played on a 28 × 15 m full court with six players, also corresponding to 70 m^2 per player. Therefore, the active formats differed in player number and tactical interaction structure but not in relative playing area.

Rules, coach behavior, and feedback were standardized to minimize differential motivational or instructional bias. All sessions were supervised by the same coaching team using a written session script. Coaches provided instructions, timekeeping, and standardized neutral encouragement, but no individualized technical feedback that could preferentially affect one group. The same ball size, basket height, scoring system, bout timing, recovery timing, hydration access, and warm-up/cool-down procedures were used in both intervention arms. Format-specific tactical rules were retained only where required to preserve the intended ecological structure of the 1v1 or 3v3 format. Attendance was recorded at each session, and heart rate and session rating of perceived exertion (RPE) were collected to characterize internal load and intervention intensity rather than to define efficacy outcomes.

Exercise intensity was monitored to document the implementation and to confirm that the SSG formats elicited the intended training stimulus. Heart rate (HR) was recorded continuously at 1 Hz using Polar RS400 telemetry (Polar Electro, Kempele, Finland), a chest-strap system that has been used as a criterion comparator in validation studies of wearable HR monitors during walking and running exercise (Stahl et al., 2016). RPE was obtained using the Borg CR10 scale approximately 20 min after each session, consistent with the session-RPE approach for quantifying internal training load in intermittent and non-steady-state exercise (Foster et al., 2001). HR and RPE were used descriptively to characterize internal load (cardiovascular strain and perceived effort) and were not entered as covariates or predictors in the primary efficacy models. This combined monitoring approach captured both physiological and perceptual responses to the sessions, providing contextual evidence that the prescribed SSG training was implemented as planned, while the standardized cool-down supported recovery and helped maintain consistent session timing.

Adverse events were monitored throughout the intervention and assessment period by the coaching and testing staff. For this purpose, an adverse event was defined as any injury, illness, symptom, or other untoward occurrence during supervised training or testing, whether or not it required medical care, training modification, or withdrawal.

Participants in the control group did not receive any structured exercise program and were instructed to maintain their usual daily routines throughout the 8-week period. They attended the same assessment sessions as the intervention groups at baseline, week 4, and week 8, but did not participate in supervised training.

Measurement procedures

All outcome measurements were collected at baseline, week 4, and week 8 using standardized procedures to maximize reliability and comparability across time points. To control for acute fatigue and circadian variability, assessments were performed in the morning, on the same day of the week for each participant whenever feasible, and scheduled after at least 48 h without structured exercise. Baseline, week 4, and week 8 assessments were conducted under comparable conditions, including the same facility, testing personnel, equipment, and test order. Assessments took place in the indoor testing room with air-conditioning controlled via an AVACH system, maintaining a stable ambient temperature of 21°C and relative humidity of 55% throughout all testing sessions.

Testing followed a fixed sequence designed to minimize fatigue-related bias and carryover effects. Anthropometric assessments were performed first. Body mass and height were measured using a calibrated digital scale and stadiometer, and body mass index (BMI) was calculated as mass (kg) divided by height squared (m^2). Waist circumference (WC) and hip circumference (HC) were then measured with a flexible tape at standardized anatomical landmarks, and waist-to-hip ratio (WHR) was computed accordingly(Ross et al., 2020).

After anthropometry, participants completed physical fitness tests in an order prioritizing neuromuscular performance before metabolically demanding tasks, preserving maximal-effort quality and reducing systematic underestimation due to accumulating fatigue. Following a standardized dynamic warm-up (5 min jogging and 5 min active stretching), lower-limb power was assessed using the vertical jump (VJ) followed by the standing long jump (SLJ). Multiple trials were performed for each test, with 90 s rest between repeated attempts and 3 min between test types to support recovery and maintain peak output.

Cardiorespiratory endurance was assessed last using the 20-m Multistage Fitness Test (MSFT). A minimum of 5 min passive recovery was provided between the final lower-limb power test and the MSFT, during which participants were rehydrated and reminded of standardized pacing and termination criteria. All assessments were administered by trained assessors using standardized instructions and monitoring procedures to ensure participant safety and consistency across time points.

Anthropometric assessment

Anthropometric assessments were performed according to standardized procedures to maximize measurement precision and between-timepoint comparability. Standing height was measured barefoot using a portable stadiometer (SECA 213, Hamburg, Germany; nearest 0.1 cm), with participants positioned upright (heels together, arms relaxed at the sides), head oriented in the Frankfort plane, and the stadiometer headboard lowered to compress the hair lightly. Body mass was measured using a calibrated electronic scale (SECA 760, Hamburg, Germany; nearest 0.1 kg) with participants wearing light athletic clothing and no shoes; the scale was zeroed before each measurement and placed on a stable, level surface.

Waist and hip circumferences were measured using a non-elastic tape (Lufkin W606PM, Mexico) with the tape kept horizontal and snug but not compressing the skin. Waist circumference was measured at the midpoint between the inferior margin of the last palpable rib and the top of the iliac crest, and hip circumference at the level of the maximum protuberance of the buttocks; both were taken at the end of a normal expiration and recorded to the nearest 0.1 cm. Because waist circumference is a relevant anthropometric marker only when measured using standardized procedures, all circumference assessments were performed by trained assessors using duplicate measurements, with a third measurement obtained when duplicate values differed by more than 0.5 cm.

Skinfold thickness was assessed on the right side of the body using a Lange skinfold caliper (Beta Technology Inc., Cambridge, MD; nearest 0.1 mm) at five sites (subscapular, triceps, biceps, suprailiac, and thigh) in accordance with standardized anatomical landmarking and fold orientation. Each site was measured at least twice in rotational order to minimize tissue compression effects. If duplicate readings differed by > 2 mm, a third measurement was obtained, and the mean of the two closest values was used. The sum of skinfolds was used as an index of subcutaneous adiposity. The sum of skinfold thicknesses was retained as the field-based adiposity indicator.

Handgrip maximal strength (HG)

Handgrip strength of the dominant and non-dominant hands was assessed using a digital dynamometer (TKK 5101 Grip-D, Takei, Tokyo, Japan) following standardized testing posture and timing. The handle was adjusted to hand size so that the second phalanx of the fingers formed an approximate right angle during gripping. Participants stood upright with the tested arm alongside the body (not touching the trunk), shoulder adducted and neutrally rotated, elbow fully extended (or comfortably extended), and wrist in a neutral position. They were instructed to squeeze maximally for 3 seconds without trunk lean or arm swing. Three maximal trials were performed per hand with ≥ 60 s rest between trials, alternating hands to limit fatigue, and the highest value was retained for analysis. This standardized approach was used because handgrip values are sensitive to protocol variation, including device type, posture, elbow position, number of trials, and whether the maximum or mean trial value is analyzed (Roberts et al., 2011).

Standing Long Jump (SLJ)

The standing long jump (SLJ) is a field test of horizontal lower-limb explosive power and is appropriate for sedentary participants because it is simple to administer and does not require specialized equipment. In accordance with standardized procedures, participants stood behind a clearly marked take-off line with feet approximately shoulder-width apart and performed a maximal two-foot take-off jump using a self-selected countermovement and coordinated arm swing. Landing was required on both feet without falling backward. If balance was lost or the participant stepped behind the landing point, the attempt was repeated.

Jump distance was recorded to the nearest 1 cm as the horizontal distance from the take-off line to the rearmost heel contact on landing, which is the conventional scoring method used to reduce overestimation when asymmetrical landings occur. The standing long jump was retained as a field-based measure of horizontal lower-limb explosive performance because recent adult evidence supports its criterion-related validity and reliability for evaluating lower-body explosive muscular strength (Marin-Jimenez et al., 2024). In the present context, standing long jump was selected because it complements vertical jump testing by capturing horizontal force-production capacity relevant to accelerations, decelerations, and transitions (Aslan, 2013).

Vertical Jump (VJ)

The vertical jump (VJ) was assessed using a standardized countermovement jump (CMJ) protocol as a field-based indicator of lower-limb explosive power and neuromuscular function. Participants began from an upright stance with hands fixed on the hips to eliminate arm-swing contribution and improve between-trial comparability. They performed a rapid downward countermovement to approximately 90° knee flexion depth (standardized by instruction), immediately followed by a maximal vertical take-off, and landed bilaterally with controlled balance. Jump height was calculated from flight time recorded with the My Jump 2 smartphone application, using standardized video-capture procedures, consistent camera placement, and frame-by-frame identification of take-off and landing. My Jump 2 validation studies support its use for vertical-jump assessment, while earlier smartphone-based My Jump validation work showed strong agreement with force-platform estimates of CMJ height when standardized procedures were used (Balsalobre-Fernández et al., 2015; Peng et al., 2024). In the present study, CMJ was included as an outcome to detect neuromuscular adaptations induced by basketball SSGs training, given the repeated demands for jumping, landing, and rapid force production inherent to SSG play.

Multistage Fitness Test (20mMFT)

The 20-m Multistage Fitness Test (20mMFT) was used as a standardized field-based assessment of cardiorespiratory fitness. Participants ran back and forth between two lines set 20 m apart, synchronizing their pace with an audio signal that increased in frequency in a stepwise manner, thereby progressively raising the required running speed. The test was terminated when a participant failed to reach the line in time on two consecutive occasions (or voluntarily stopped due to exhaustion), and total performance was recorded as the final completed stage/shuttle (and corresponding total distance).

This protocol was developed by Léger and colleagues (1982) as a field-based test to estimate maximal aerobic capacity, with early validation work showing strong test-retest reliability and associations with maximal oxygen uptake (VO_2max). More recent synthesis indicates that the 20-m shuttle-run performance score has moderate-to-high criterion-related validity for estimating cardiorespiratory fitness, while emphasizing that it remains an estimate rather than a direct laboratory measure of VO_2max (Mayorga-Vega et al., 2015).

Statistical analysis

All analyses were conducted after verification of variable coding, group labels, measurement units, and the longitudinal structure of the supplied datasets. The analyzable outcome datasets contained three randomized groups, corresponding to 1v1 SSG, 3v3 SSGs, and a non-training control condition, with measurements at baseline, week 4, and week 8. Rows containing no participant-level information were excluded before analysis. Descriptive statistics were calculated as mean ± standard deviation for continuous outcomes. Baseline values were summarized descriptively only; no null-hypothesis tests were used to assess baseline equivalence between randomized groups.

The primary inferential analysis used a linear mixed-effects model for each outcome, including fixed effects for group, time, and the group × time interaction, with participant specified as a random intercept to account for repeated observations. Time was modeled as a categorical factor with three levels (baseline, week 4, and week 8), thereby avoiding any assumption of a linear time trend. The primary intervention contrasts were the model-estimated differences in change from baseline to week 8 between each intervention group and the control group. The 3v3 versus 1v1 difference in change was treated as a secondary format-comparison contrast. Baseline values were not entered as covariates because baseline was included as an observed level of the repeated-measures factor. Accordingly, sphericity testing and Mauchly-type corrections were not used, as these procedures are not relevant to the selected mixed-model specification.

Model estimates are reported as difference-in-differences for baseline-to-week 8 change with 95% confidence intervals. For descriptive interpretation, percentage change was calculated as [(week 8 - baseline) / baseline] × 100 using group means. Standardized between-group effects were calculated as Hedges' g for the difference in baseline-to-week 8 change between each intervention group and the control group, with approximate 95% confidence intervals. The primary outcome was 20-m multistage fitness test distance, and Holm adjustment was applied to the two planned primary contrasts comparing each intervention group with the control group. For secondary outcomes, Holm-adjusted p values were calculated separately within the anthropometric/body-composition family and the secondary physical-fitness family. Direct comparisons between 1v1 SSG and 3v3 SSG were considered exploratory and were interpreted as hypothesis-generating. Statistical significance for the confirmatory primary analysis was set at two-sided $p < 0.05$ after Holm adjustment. Secondary analyses were interpreted as supportive, with emphasis placed on effect estimates, 95% confidence intervals, adjusted p values, and consistency across related outcomes rather than isolated nominal p values. Exercise-load variables, including heart rate and session rating of perceived exertion, were summarized descriptively because they were used to characterize intervention rather than as efficacy outcomes. Analyses were performed using SPSS (version 23.0, IBM, USA) and JASP (version 0.13).

Results

The study included 63 randomized participants, with 21 allocated to 1v1 SSG, 21 to 3v3 SSG, and 21 to the control group. Baseline outcome values are presented descriptively in Table 1. Adherence rates, calculated based on the total number of planned sessions, were 94.5% in the 1v1 group and 92.8% in the 3v3 group. No missing cases were observed in either the experimental or control groups at any evaluation time point. No adverse events, illness episodes, or injuries were registered during the intervention or assessment period.

The primary outcome was 20-m multistage fitness test distance. In the primary mixed-model analysis, both intervention groups demonstrated greater baseline-to-week 8 improvements in 20-m multistage fitness test distance than the control group after multiplicity adjustment. The 1v1 SSG group increased from 432.38 ± 92.41 m at baseline to 558.10 ± 131.13 m at week 8, whereas the 3v3 SSG group increased from 442.86 ± 88.61 m to 599.05 ± 167.15 m; the control group changed from 436.19 ± 60.21 m to 440.95 ± 55.67 m. The model-estimated difference in change versus control was 120.95 m for 1v1 SSG and 151.43 m for 3v3 SSG, with both Holm-adjusted p values < 0.001. Secondary analyses supported favorable intervention-related changes across anthropometric, body-composition, and neuromuscular-fitness outcomes, whereas direct comparisons between 1v1 and 3v3 were interpreted as exploratory evidence of possible format-specific adaptation tendencies.

Training exposure was successfully implemented in both intervention arms. Across all participant-session observations, mean heart rate was 178.33 ± 2.13 beats/min in the 1v1 group and 177.49 ± 2.02 beats/min in the 3v3 group. Mean session RPE was 8.45 ± 0.86 arbitrary units in the 1v1 group and 7.88 ± 0.93 arbitrary units in the 3v3 group, indicating consistently high perceived exercise intensity (Table 2).

Anthropometric outcomes are summarized in Figure 3 and Table 3. The group × time interaction was statistically significant for all anthropometric outcomes. From baseline to week 8, body mass decreased by 6.8% in the 1v1 group and 8.2% in the 3v3 group, compared with 0.8% in the control group. The corresponding model-estimated differences in baseline-to-week 8 change versus control were -3.45 kg for 1v1 and -4.18 kg for 3v3, both with Holm-adjusted $p < 0.001$. The 3v3 group showed a larger body-mass reduction than the 1v1 group,

Table 2. Exercise-load characterization across the 24 training sessions.

Protocol component	1v1 SSG	3v3 SSG
Intervention duration	8 weeks	8 weeks
Session frequency	3 sessions/week	3 sessions/week
Planned total sessions	24 sessions	24 sessions
Session structure	10-min warm-up, 40-min SSG block, 10-min cool-down	10-min warm-up, 40-min SSG block, 10-min cool-down
SSG block structure	4 x 8-min bouts with 2-min passive recovery between bouts and 2 min for transition/hydration	4 x 8-min bouts with 2-min passive recovery between bouts and 2 min for transition/hydration
Active SSG time/session	32 min	32 min
Passive recovery/session within SSG block	6 min	6 min
Total intended active SSG exposure	768 min	768 min
Weeks 1 - 4 playing area	7 x 10 m; two players; 35 m2/player	14 x 15 m; six players; 35 m2/player
Weeks 5 - 8 playing area	10 x 14 m; two players; 70 m2/player	28 x 15 m; six players; 70 m2/player
Ball, basket, and scoring	Same ball size, standard basket height, standard scoring	Same ball size, standard basket height, standard scoring
Coach encouragement	Neutral encouragement	Neutral encouragement
Permitted coaching	Safety, timekeeping, rules, and standardized reminders only	Safety, timekeeping, rules, and standardized reminders only
Primary format difference	Individual 1v1 attacking/defending interactions	Cooperative/oppositional 3v3 attacking/ defending interactions
Heart rate (beats/min)	178.33 ± 2.13 [range: 172 to 185]	177.49 ± 2.02 [range: 172 to 184]
RPE (A.U.)	8.45 ± 0.86 [range 5 to 10]	7.88 ± 0.93 [range: 6 to 10]

Values of heart rate and RPE are based on all available participant-session observations from the intervention groups. RPE = rating of perceived exertion; AU = arbitrary units. The control group did not complete training sessions and is therefore not included.

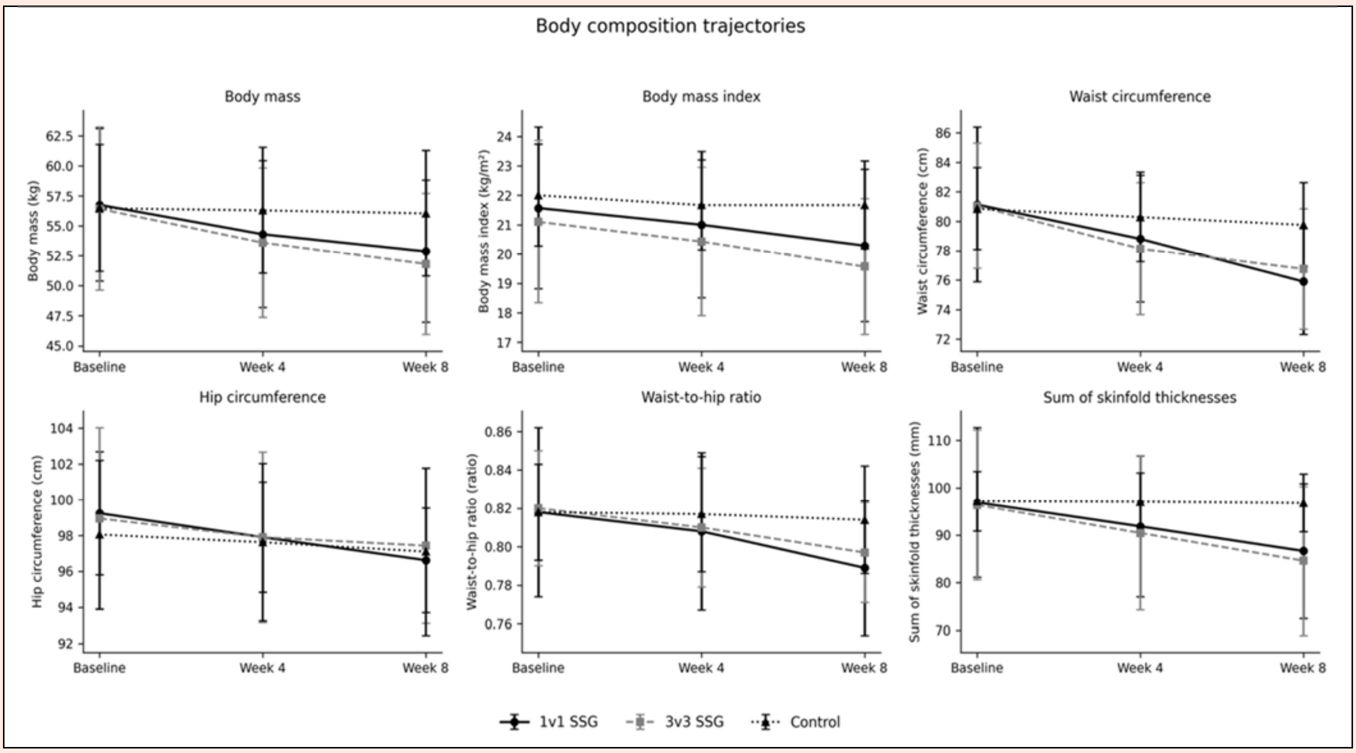

Figure 3. Body-composition and anthropometric trajectories from baseline to week 8. Values are group means with 95% confidence intervals. SSG = small-sided games.

but the exploratory active-format comparison was not statistically significant (difference in change, -0.73 kg; 95% CI, -1.64 to 0.18; p = 0.113).

The sum of skinfold thicknesses decreased by 10.6% in the 1v1 group and 12.2% in the 3v3 group, compared with 0.4% in the control group. The corresponding model-estimated differences in baseline-to-week 8 change versus control were -9.90 mm for 1v1 and -11.42 mm for 3v3, both with Holm-adjusted p < 0.001. The exploratory format comparison for the sum of skinfold thicknesses was not statistically significant (difference in change, -1.52 mm; 95% CI, -3.77 to 0.73; p = 0.180). Body mass index, waist circumference, waist-to-hip ratio, and skinfold thickness also decreased more in both intervention groups than in the control group. Hip circumference decreased more in the 1v1 group than in the control group, whereas the 3v3 versus control contrast for hip circumference was not statistically significant after modeling (difference in change, -0.57 cm; 95% CI, -1.36 to 0.22; p = 0.155). Thus, the corrected analysis does not support a statement that all anthropometric intervention-versus-control comparisons were significant at p < 0.001.

Physical fitness outcomes are summarized in Figure 4 and Table 4. The group × time interaction was statistically significant for all physical fitness outcomes. The 20-m multistage fitness test distance increased by 29.1% in the 1v1 group and 35.3% in the 3v3 group, compared with 1.1% in the control group. The model-estimated differences in change versus control were 120.95 m for 1v1 and 151.43 m for 3v3, both with Holm-adjusted p < 0.001. The direct 3v3 versus 1v1 contrast was not statistically significant for multistage fitness test distance (difference in change, 30.48 m; 95% CI, -9.09 to 70.05; p = 0.131).

Both intervention formats also improved left- and right-hand handgrip strength relative to control, with large standardized effects and no statistically significant difference between 1v1 and 3v3. Vertical jump height increased by 11.0% in 1v1 and 14.1% in 3v3, compared with 1.5% in control; both intervention-versus-control contrasts remained significant after Holm adjustment. The 3v3 group also showed a larger increase than the 1v1 group in vertical jump height (difference in change, 1.05 cm; 95% CI, 0.05 to 2.05; p = 0.039). Standing long jump distance increased by 3.3% in 1v1 and 5.3% in 3v3, compared with 1.6% in control; both intervention-versus-control contrasts were significant, and the 3v3 increase exceeded the 1v1 increase (difference in change, 3.29 cm; 95% CI, 1.49 to 5.08; p < 0.001).

Table 3. Body-composition and anthropometric outcomes from baseline to week 8.

Outcome	Group	Baseline	Week 4	Week 8	Δ%	Difference in change vs control (95% CI)	p	Holm p	Hedges g (95% CI)	Group × time p
Body mass (kg)	1v1 SSG	56.76 ± 6.36	54.31 ± 6.13	52.88 ± 5.92	-6.8	-3.45 (-4.25 to -2.65)	< 0.001	< 0.001	-2.64 (-3.46 to -1.81)	< 0.001
	3v3 SSG	56.43 ± 6.81	53.61 ± 6.23	51.82 ± 5.89	-8.2	-4.18 (-4.94 to -3.42)	< 0.001	< 0.001	-3.37 (-4.32 to -2.43)	
	Control	56.48 ± 5.29	56.30 ± 5.25	56.05 ± 5.22	-0.8					
Body mass index (kg/m^2)	1v1 SSG	21.57 ± 2.75	21.00 ± 2.49	20.29 ± 2.59	-6.0	-0.95 (-1.37 to -0.53)	< 0.001	< 0.001	-1.14 (-1.79 to -0.48)	< 0.001
	3v3 SSG	21.10 ± 2.76	20.43 ± 2.52	19.57 ± 2.31	-7.2	-1.19 (-1.61 to -0.77)	< 0.001	< 0.001	-1.45 (-2.13 to -0.77)	
	Control	22.00 ± 1.73	21.67 ± 1.53	21.67 ± 1.49	-1.5					
Waist circumference (cm)	1v1 SSG	81.14 ± 5.26	78.81 ± 4.31	75.90 ± 3.60	-6.5	-4.14 (-5.45 to -2.83)	< 0.001	< 0.001	-1.95 (-2.69 to -1.21)	< 0.001
	3v3 SSG	81.05 ± 4.24	78.14 ± 4.49	76.76 ± 4.10	-5.3	-3.19 (-4.50 to -1.88)	< 0.001	< 0.001	-1.14 (-1.79 to -0.48)	
	Control	80.86 ± 2.78	80.29 ± 3.04	79.76 ± 2.86	-1.4					
Hip circumference (cm)	1v1 SSG	99.24 ± 3.43	97.90 ± 3.08	96.62 ± 2.91	-2.6	-1.67 (-2.45 to -0.88)	< 0.001	< 0.001	-0.93 (-1.57 to -0.29)	< 0.001
	3v3 SSG	98.95 ± 5.07	97.90 ± 4.76	97.43 ± 4.32	-1.5	-0.57 (-1.36 to 0.22)	0.155	0.155	-0.39 (-1.00 to 0.22)	
	Control	98.05 ± 4.15	97.62 ± 4.39	97.10 ± 4.66	-1.0					
Waist-to-hip ratio (A.U.)	1v1 SSG	0.818 ± 0.044	0.808 ± 0.041	0.789 ± 0.035	-3.4	-0.024 (-0.033 to -0.015)	< 0.001	< 0.001	-1.27 (-1.93 to -0.60)	< 0.001
	3v3 SSG	0.820 ± 0.030	0.810 ± 0.031	0.797 ± 0.026	-2.8	-0.019 (-0.028 to -0.010)	< 0.001	< 0.001	-1.30 (-1.96 to -0.63)	
	Control	0.818 ± 0.025	0.817 ± 0.030	0.814 ± 0.028	-0.5					
Sum of skinfold thicknesses (mm)	1v1 SSG	96.90 ± 15.78	91.85 ± 14.90	86.65 ± 14.20	-10.6	-9.90 (-11.47 to -8.33)	< 0.001	< 0.001	-3.94 (-4.99 to -2.89)	< 0.001
	3v3 SSG	96.37 ± 15.82	90.45 ± 16.20	84.60 ± 15.70	-12.2	-11.42 (-13.21 to -6.63)	< 0.001	< 0.001	-3.99 (-5.05 to -2.93)	
	Control	97.15 ± 6.29	97.05 ± 6.08	96.80 ± 6.08	-0.4					

Values at each time point are mean ± standard deviation. Δ% was calculated from group means as [(week 8 − baseline) / baseline] × 100. Model estimates are week 8 difference-in-differences versus control from linear mixed-effects models including group, time, and group × time, with participant as a random intercept. Negative model estimates indicate a greater reduction than control. Holm p values were adjusted across the intervention-versus-control contrasts in the anthropometry/body-composition family. Hedges' g is the standardized between-group difference in baseline-to-week 8 change versus control; CI = confidence interval.

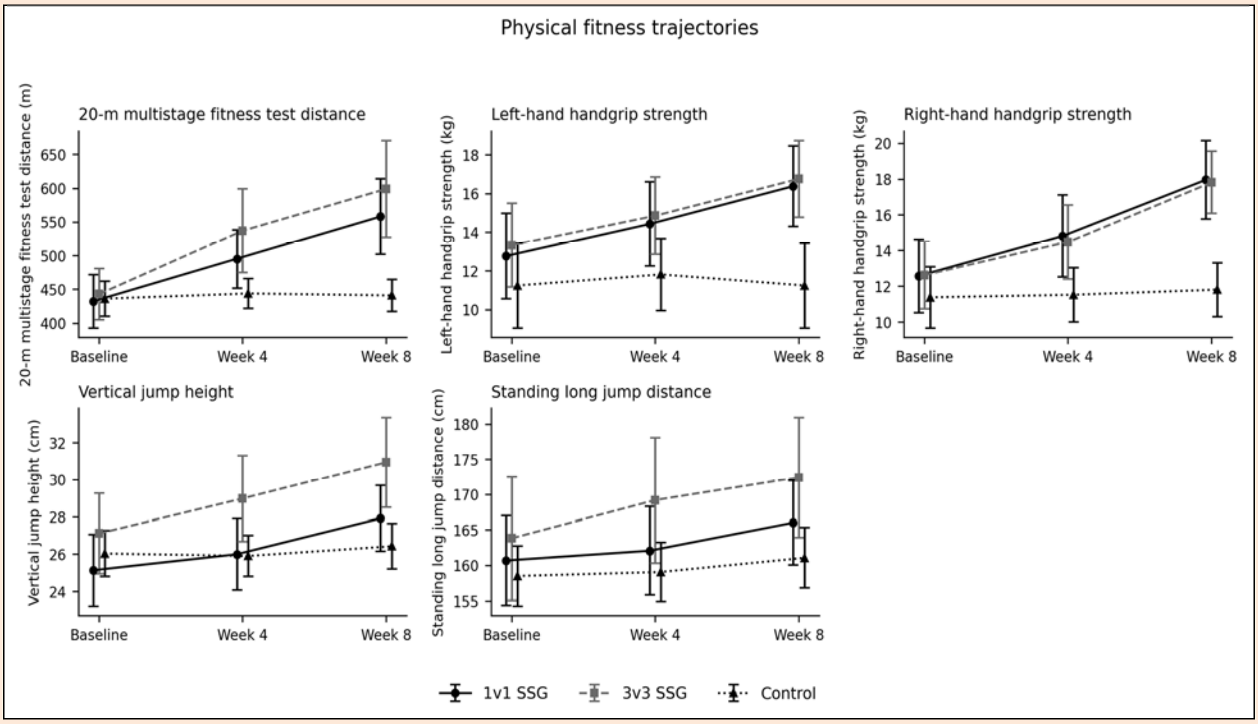

Figure 4. Physical fitness trajectories from baseline to week 8. Values are group means with 95% confidence intervals. SSG = small-sided games.

Discussion

In this 8-week randomized controlled trial in sedentary female college students, both 1v1 and 3v3 basketball SSGs produced greater improvements than the control condition in the primary outcome, 20-m multistage fitness test distance. Secondary analyses also supported favorable intervention-related changes in body mass, body mass index, waist circumference, waist-to-hip ratio, the sum of skinfold thicknesses, handgrip strength, vertical jump height, and standing long jump distance. The corrected analysis showed that not all anthropometric contrasts were statistically significant, because the 3v3-versus-control comparison for hip circumference was not significant. Exploratory direct comparisons between the two active formats suggested larger gains after 3v3 for vertical jump height and standing long jump distance, whereas differences between 1v1 and 3v3 were not statistically significant for multistage fitness test distance or handgrip strength. Therefore, format-specific findings should be interpreted as selected secondary-outcome signals rather than confirmatory evidence that one SSG format is globally superior to the other.

Aerobic performance improved substantially in both SSG formats compared with the control condition, with numerically larger improvement in the 3v3 group; however, the direct 3v3-versus-1v1 contrast for multistage fitness test distance was not statistically significant and should therefore be interpreted cautiously. This aligns with evidence that SSG-based training can elicit sustained cardiovascular loading (often 80 - 85% HRmax on average, with frequent time spent at high-intensity zones) and drive meaningful aerobic adaptations in previously untrained individuals (Stojanoví et al., 2021). A more continuous locomotor rhythm during 3v3 could be one plausible explanation for the pattern. However, the present study did not directly measure external locomotor load, time-motion characteristics, or physiological mechanisms. Accordingly, the aerobic findings support the efficacy of both basketball SSG formats versus control, but they do not establish a definitive format-specific aerobic mechanism.

Lower-limb vertical power improved more in both intervention groups than in the control group, and the exploratory direct comparison indicated a larger increase after 3v3 than after 1v1. Because this was a secondary outcome and the active-format comparison was exploratory, this result should be interpreted as hypothesis-generating rather than as definitive evidence of 3v3 superiority. The observed pattern is compatible with the repeated jumping, landing, acceleration, deceleration, and transitional actions expected during basketball SSG play, and with the broader literature describing stretch-shortening cycle adaptations after repeated high-force lower-limb activity (Markovic and Mikulic, 2010). However, the present study did not quantify jump counts, braking forces, acceleration load, or muscle-tendon adaptations, thus these mechanisms remain plausible explanations rather than directly observed mediators.

Horizontal power (standing long jump) improved in both interventions, with a larger gain in 3v3 than 1v1. This outcome suggests a possible format-related difference in horizontal power adaptation, but it should not be generalized to overall neuromuscular superiority because handgrip strength did not differ between active formats and other mechanical-load variables were not measured. Evidence from basketball SSG monitoring indicates that format changes alter movement profiles (including acceleration/deceleration counts and intensity distribution), supporting the idea that task constraints can preferentially bias neuromuscular outputs (Stojanoví et al., 2021). While task constraints can alter movement profiles in SSGs, the present data cannot determine whether the larger standing-long-jump gain was caused by greater horizontal propulsion demands, more frequent transitions, or other unmeasured training-load characteristics. Future studies should combine field fitness outcomes with external-load monitoring, such as inertial sensors, local positioning systems, accelerometry, or video-coded technical actions, to test these proposed mechanisms directly.

Handgrip strength increased markedly in both SSG formats compared with the control condition, with no statistically significant difference between 1v1 and 3v3. Although handgrip is not a basketball-specific performance endpoint, SSGs play involves repeated ball control, gripping, upper-body stabilization, and contact-related bracing actions. These repeated sport-specific exposures may partly explain the observed intervention-versus-control improvements in previously results, but this interpretation remains tentative because upper-limb loading, contact frequency, and technical-action counts were not directly measured (Stojanoví et al., 2021). Repeated high-intensity, multi-directional sport play

Table 4. Physical fitness outcomes from baseline to week 8.

Outcome	Group	Baseline	Week 4	Week 8	Δ%	Difference in change vs control (95% CI)	p	Holm p	Hedges g (95% CI)	Group × time p
20-m multistage fitness test distance (m)	1v1 SSG	432.38 ± 92.41	495.24 ± 101.37	558.10 ± 131.13	+29.1	120.95 (81.38 to 160.52)	< 0.001	< 0.001	2.01 (1.26 to 2.76)	< 0.001
	3v3 SSG	442.86 ± 88.61	537.14 ± 145.37	599.05 ± 167.15	+35.3	151.43 (111.86 to 191.00)	< 0.001	< 0.001	1.72 (1.01 to 2.43)	
	Control	436.19 ± 60.21	443.81 ± 50.84	440.95 ± 55.67	+1.1	Reference				
Left-hand handgrip strength (kg)	1v1 SSG	12.76 ± 5.17	14.43 ± 5.10	16.38 ± 4.84	+28.4	3.62 (2.79 to 4.45)	< 0.001	< 0.001	3.09 (2.18 to 3.99)	< 0.001
	3v3 SSG	13.33 ± 5.08	14.86 ± 4.69	16.76 ± 4.61	+25.7	3.43 (2.60 to 4.26)	< 0.001	< 0.001	1.90 (1.17 to 2.64)	
	Control	11.24 ± 5.12	11.81 ± 4.33	11.24 ± 5.12	+0.0	Reference				
Right-hand handgrip strength (kg)	1v1 SSG	12.57 ± 4.80	14.81 ± 5.35	17.95 ± 5.12	+42.8	4.95 (3.78 to 6.12)	< 0.001	< 0.001	2.60 (1.77 to 3.43)	< 0.001
	3v3 SSG	12.62 ± 4.38	14.48 ± 4.84	17.81 ± 4.04	+41.1	4.76 (3.59 to 5.93)	< 0.001	< 0.001	1.90 (1.16 to 2.63)	
	Control	11.38 ± 3.99	11.52 ± 3.54	11.81 ± 3.50	+3.8	Reference				
Vertical jump height (cm)	1v1 SSG	25.14 ± 4.46	26.00 ± 4.47	27.91 ± 4.14	+11.0	2.39 (1.39 to 3.39)	< 0.001	< 0.001	1.11 (0.46 to 1.77)	< 0.001
	3v3 SSG	27.11 ± 5.04	28.98 ± 5.41	30.94 ± 5.65	+14.1	3.44 (2.44 to 4.44)	< 0.001	< 0.001	1.43 (0.75 to 2.11)	
	Control	26.03 ± 2.85	25.90 ± 2.58	26.42 ± 2.83	+1.5	Reference				
Standing long jump distance (cm)	1v1 SSG	160.67 ± 14.78	162.05 ± 14.61	166.00 ± 13.99	+3.3	2.76 (0.97 to 4.56)	0.003	0.003	0.97 (0.33 to 1.62)	< 0.001
	3v3 SSG	163.81 ± 20.40	169.19 ± 20.77	172.43 ± 19.91	+5.3	6.05 (4.25 to 7.84)	< 0.001	< 0.001	1.39 (0.72 to 2.07)	
	Control	158.48 ± 9.85	159.05 ± 9.66	161.05 ± 9.97	+1.6	Reference				

Values at each time point are mean ± standard deviation. Δ% was calculated from raw group means as [(week 8 − baseline) / baseline] × 100. Model estimates are week 8 difference-in-differences versus control from linear mixed-effects models including group, time, and group × time, with participant as a random intercept. Positive model estimates indicate a greater increase than control. Holm p values were adjusted across the intervention-versus-control contrasts in the physical-fitness family. Hedges' g is the standardized between-group difference in baseline-to-week 8 change versus control. SSG = small-sided games; CI = confidence interval.

can improve general strength capacity through neuromuscular coordination and repeated high-tension exposures, even in the absence of formal resistance training, an effect that is also consistent with broader evidence that training modalities producing frequent high-force outputs can meaningfully increase strength outcomes in previously untrained participants (Wewege et al., 2022). The handgrip findings should be interpreted as evidence of general neuromuscular improvement after basketball SSG participation, not as evidence of format-specific upper-limb adaptation.

Body mass, BMI, and the sum of skinfolds decreased meaningfully in both SSG groups compared with control, with numerically larger reductions for body mass and skinfolds in 3v3. These changes are directionally consistent with randomized trials in sedentary young adults using recreational SSGs team-sport interventions (albeit often soccer-based), where structured SSG exposure improves body composition and fitness versus low-exercise controls (Xu et al., 2024). More broadly, meta-analytic evidence indicates that vigorous interval-type training reduces total and abdominal adiposity, and that intermittent high-intensity exercise can be a time-efficient strategy for improving fat mass indicators (Maillard et al., 2018). In the present trial, however, energy intake, non-intervention physical activity, substrate use, and total energy expenditure were not directly measured. Consequently, reductions in adiposity-related indicators should be attributed to the overall intervention context rather than to a confirmed metabolic pathway. Repeated high-intensity sessions may have contributed to negative energy balance over time, but this remains an inference rather than a directly tested mechanism (Børsheim and Bahr, 2003).

Waist circumference and WHR also improved in both SSG formats (with slightly larger waist reduction in 1v1), supporting a beneficial impact on central adiposity-related proxies. This aligns with controlled evidence that exercise training, particularly when it includes vigorous elements, can reduce waist measures and abdominal fat depots, even when body weight changes are modest (Wewege et al., 2017). The slightly larger waist response observed in 1v1 should be treated descriptively, because the study did not measure trunk-specific muscular work, local energy expenditure, or external-load characteristics that would allow a mechanistic explanation of format-specific waist changes.

Some limitations should prevent interpretation and guide future work. Diet and non-intervention physical activity were not controlled. More specifically, nutritional intake was not monitored using dietary records, recalls, or standardized feeding procedures, and free-living physical activity outside the intervention was not objectively quantified. Therefore, changes in body mass, BMI, waist-related measures, and the sum of skinfold thicknesses cannot be attributed solely to the exercise intervention, because spontaneous dietary changes or changes in non-intervention activity may have contributed to the observed adiposity-related outcomes. Given the magnitude of body-mass reduction over 8 weeks, future trials should quantify energy intake and free-living activity (e.g., dietary logs plus accelerometry) to better attribute body-composition changes. The primary confirmatory inference was based on baseline-to-week 8 intervention-versus-control contrasts for the 20-m multistage fitness test. Although outcomes were also measured at week 4, any mid-intervention patterns should be viewed as descriptive time-course information rather than independent confirmatory evidence, particularly for format-specific interpretation. The sample size was selected to support the primary intervention-versus-control comparison and was not designed to provide robust confirmatory power for 1v1-versus-3v3 format comparisons. Accordingly, direct comparisons between active formats should be interpreted as exploratory and hypothesis-generating.

The trial was single-site and limited to sedentary young women, which constrains generalizability. Findings may not generalize directly to sedentary young women from other universities, regions, cultural contexts, baseline fitness levels, BMI ranges, or prior sport-exposure backgrounds. Multicenter replication with broader participant characteristics is needed to strengthen external validity. Although all randomized participants completed the scheduled assessments and adherence during the 8-week intervention was high, the study did not include post-intervention follow-up. Therefore, the durability of the adaptations and the long-term sustainability of adherence to basketball SSGs remain unknown. In addition, the study did not include direct measures of external load, movement patterns, technical actions, energy intake, energy expenditure, or physiological mediators. Therefore, mechanistic explanations in the discussion should be interpreted as plausible hypotheses rather than demonstrated causal effects. Finally, psychological mediators (enjoyment, self-efficacy, social connectedness) were not measured, even though they may differ by format and influence adherence.

From a practical perspective, both 1v1 and 3v3 basketball SSGs appear to be feasible options for university-based exercise promotion among sedentary female students. The intervention required limited equipment, used a familiar sport context, and was implemented with high adherence during the 8-week period. For practitioners, physical-education staff, and university health-promotion programs, these results suggest that recreational basketball SSGs can be used as an efficient group exercise sessions when the goal is to improve health-related fitness. The 1v1 format may be useful when space or participant numbers are limited and when high individual involvement is desired, whereas 3v3 may be more appropriate when the aim is to preserve social interaction and team-based decision-making. Nevertheless, the current data do not justify prescribing one format as superior. Instead, format selection should consider participant preference, facility availability, supervision capacity, safety, and progression of training load.

Conclusion

In sedentary female college students, an 8-week program of recreational basketball SSGs performed three times per week was associated with favorable changes in aerobic performance, neuromuscular fitness, and anthropometric indicators compared with a non-training control condition. Both 1v1 and 3v3 formats were associated with reductions in body mass/BMI and waist-related measures, as well as improvements in strength and jump performance, relative to control. Exploratory direct comparisons suggested larger changes after 3v3 in lower-limb power outcomes, but direct between-format differences for multistage fitness test distance and handgrip strength were not statistically significant. Because the study was powered for intervention-versus-control inference on the primary cardiorespiratory outcome, and because direct format comparisons were exploratory, the present findings should not be interpreted as establishing superiority of either 1v1 or 3v3. Given the single-site sample, the absence of strict dietary/free-living activity control, the use of field-based body-composition methods, and the absence of direct external-load, the results support basketball SSGs as a feasible university-based exercise strategy, but warrant confirmation in larger multicenter trials with control of confounders, direct training-load monitoring, and longer-term follow-up to assess sustainability. Future research should confirm these findings in larger multicenter trials, include longer-term follow-up to evaluate sustainability and adherence, monitor diet and free physical activity, and use direct internal- and external-load measures to clarify whether 1v1 and 3v3 formats produce distinct adaptive profiles.

Acknowledgements

The datasets generated during the current study are not publicly available but are available from the corresponding author upon reasonable request. The authors declare that they have no conflict of interest. All experimental procedures were conducted in compliance with the relevant legal and ethical standards of the country where the study was carried out. The authors declare that no Generative AI or AI-assisted technologies were used in the writing of this manuscript.

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Key points

- Both 1v1 and 3v3 basketball small-sided games improved the primary outcome, 20-m multistage fitness test distance, compared with the non-training control condition after 8 weeks. The increase was 29.1% in the 1v1 group and 35.3% in the 3v3 group, compared with 1.1% in the control group.
- Both intervention formats produced favorable changes in several anthropometric and body-composition outcomes, including body mass, body mass index, waist circumference, waist-to-hip ratio, and the sum of skinfold thicknesses. The corrected analysis did not support the previous statement that all anthropometric intervention-versus-control comparisons were significant at $p < 0.001$, because the 3v3-versus-control contrast for hip circumference was not statistically significant.
- Both formats improved neuromuscular fitness outcomes compared with control, including handgrip strength, vertical jump height, and standing long jump distance. Exploratory direct comparisons suggested larger gains in vertical jump height and standing long jump distance after 3v3 than 1v1, whereas between-format differences for multistage fitness test distance and handgrip strength were not statistically significant.

AUTHOR BIOGRAPHY

Lu LI
Employment
Gdansk University of Physical Education and Sport, Gdańsk, Poland
Degree
Master
Research interests
Sports training, sport intervention, sports psychology
E-mail: lu. li@awf.gda.pl

Xiejie HAN
Employment
Gdansk University of Pysical Education and Sport, Gdańsk, Poland
Degree
Master
Research interests
Soccer training; Adolescent physical development
E-mail: xinjie.han@awf.gda.pl

Jiawei CHEN
Employment
Hunan Mechanical and Electrical Vocational Technical College.
Degree
Doctoral candidate
Research interests
Adolescent health behaviour.
E-mail: karlhun@163.com

Wenpan QING
Employment
Gdansk University of Physical Education and Sport, Gdańsk, Poland
Degree
Master
Research interests
Physical health; sports training
E-mail: qingpan.wen@awf.gda.pl

Gustavo De Conti Teixeira COSTA
Employment
Physical Education Department, Federal University of Goiás, Goiás, Goiânia, Brazil
Degree
Ph.D.
Research interests
Match analysis; performance analysis; physical exercise
E-mail: conti02@ufg.br

Robert TRYBULSKI
Employment
Provita Żory Medical Center, 44-240 Żory, Poland
Degree
Ph.D.
Research interests
Physiotherapy; sports medicine; muscle recovery
E-mail: roberttrybulski@proton.me

Filipe Manuel CLEMENTE
Employment
Applied Research Institute (i2A), Polytechnic University of Coimbra, 3045-601 Coimbra, Portugal
Degree
Ph.D.
Research interests
Athletic performance; sports training; performance analysis
E-mail: filipe.clemente5@gmail.com

✉ **Filipe Manuel Clemente**
Applied Research Institute (i2A), Polytechnic University of Coimbra, 3045-601 Coimbra, Portugal