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Effects of small-sided games combined with high-intensity interval training versus high-intensity interval training alone on physical fitness of youth soccer players

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Abstract

Introduction. **Small-sided games (SSGs) and running-based high-intensity interval training (HIIT) are training methods that has been used in combination or isolation to improve performance of soccer players.** Aim of Study. **This study aimed to compare the effects of an eight-week training intervention using SSGs combined with running-based HIIT versus running-based HIIT alone on the physical fitness of young male soccer players.** Material and Methods. **Thirty-six young male soccer players (aged 14.0 ± 1.1 years) participated in the study. Both intervention groups completed an eight-week training protocol with two sessions per week. The SSGs + HIIT group used different SSGs formats (e.g., 5 vs 5) in combination with running-based HIIT. In contrast, the HIIT group performed running-based HIIT alone. Pre- and post-intervention 10 m and 30 m linear sprint (i.e., acceleration and maximal speed), aerobic capacity, body fat percentage (%BF), and change of direction (COD) were measured, using validated tests.** Results. **The HIIT and SSGs + HIIT interventions showed no significant differences in improving 10 m linear sprint (HIIT: 6.3% vs SSGs + HIIT: 7.4%), 30 m linear sprint (HIIT: 3.4% vs SSGs + HIIT: 4.2%), and %BF (HIIT: 11.6% vs SSGs + HIIT: 7.3%; $p > 0.05$). However, SSGs + HIIT induced significantly greater improvements in maximal oxygen consumption (HIIT: 6.7% vs SSGs + HIIT: 9.1%; $p = 0.003$) and COD (HIIT: 4% vs SSGs + HIIT: 1.9%; $p = 0.002$) compared to the HIIT group.** Conclusions. **The findings suggest that the SSGs + HIIT intervention was more effective in improving aerobic performance and COD among young soccer players. However, both training interventions were similarly effective in improving the 10 m and 30 m linear sprint times.**

KEYWORDS: cardiorespiratory fitness, athletic performance, soccer, game-based training, body composition.

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Introduction

Small-sided games (SSGs) are conditioned and adjusted forms of a soccer game (e.g., pitch dimensions, number of players) that are used by soccer coaches to achieve some specific technical-tactical goals while changing physiological, physical, and psychological demands [4]. These game-based drills are often used during training sessions where coaches adjust drills and rules (e.g., setting conditions) based on achieving a specific stimulus on players [4]. However, although a large body of knowledge regarding the effects of SSGs on physiological, locomotor, technical, and tactical demands of soccer players is available,

there is still scarce information about physiological and physical adaptations promoted by the consistent use of SSGs in youth soccer players [4].
Since SSGs use the game's dynamics while promoting a high-intensity physiological stimulus, some studies have tried to compare the use of SSGs against the high-intensity interval training (HIIT) methods [20]. Briefly, the evidence is solid regarding the similar benefits of SSGs and HIIT on the development of aerobic fitness of soccer players [24]. However, in other physical fitness outcomes, such as linear sprinting or change of direction speed, HIIT training adds some advantages SSGs cannot offer so effectively [28]. This difference may be due to small pitch sizes used in SSGs, which do not offer enough space for players to achieve higher speed intensities, thus limiting high-intensity locomotor demands in players [6].
Linear sprinting in short distances of 10 to 30 meters is among soccer's most important activities as it plays a decisive role in situations immediately preceding a goal [27]. In previous studies, the importance of linear sprints and their role in the performance of soccer players have been mentioned. Therefore, this issue should be considered in conditioning programs of soccer players in addition to SSGs. When planning HIIT or SSGs training programs, there can be a great deal of variation in activity time, recovery intervals, number of repetitions per training session, number of players, and size of pitch [22]. The HIIT protocols improve aerobic as well as anaerobic parameters of soccer players [19], while SSGs improves both fitness (i.e., aerobic and anaerobic) and tactical-technical aspects of performance [10]. Hence, the comparison of HIIT and SSG trainings' effects on performance (e.g., physical, physiological) has always interested researchers and practitioners.
The most apparent discrepancy between SSGs and running-based HIIT is the execution of drills with a ball during SSGs, which imposes a soccer-specific demand for improved technical-tactical skills [18]. Additionally, a previous study suggested that SSGs may be used to develop motivation (i.e., increased participation of players) in addition to physical fitness improvements, compared to intermittent exercises in professional soccer players [17], as well as overweight young soccer players [19].
Previous studies compared the combination of HIIT and SSGs in soccer players [26], which shows improved aerobic fitness and body composition. At the same time, some studies also reported improved sprinting performance [8, 28]. However, the evidence is limited, and comparisons between SSGs + HIIT vs HIIT alone have not been conducted. This comparison may allow practitioners to decide if combining SSGs with HIIT would yield better physical fitness adaptations compared to HIIT alone.

Aim of Study

Therefore, this study aimed to compare the effects of eight-week SSGs + HIIT versus HIIT intervention on the physical performance of young soccer players. Based on the previous evidence, the authors hypothesized that there would be a significant difference in improvement between both training methods, with SSGs + HIIT yielding better results.

Material and Methods

Participants

The required sample size was calculated using an A priori sample size calculation using the G-Power software (version 3.1). The alpha level, power, and effect size were set as 0.05, 0.8, and 0.6, respectively, which indicated that a minimum sample size of 35 participants was required to achieve statistical significance. Thirty-six young male soccer players (age: 14.0 ± 1.1 years, height: 161.6 ± 9.6 cm, body mass: 48.3 ± 6.8 kg, body fat percentage [%BF]: 23.2 ± 4.3%) were recruited as participants in this study (Table 1). This study was

Table 1. Anthropometric and demographic information of the participants

Characteristics	SSGs + HIIT group	HIIT group	Overall
Participants (n)	20	16	36
Participants excluded* (n)	1	3	4
Age (years)	14.0 ± 0.1	14.0 ± 0.2	14.0 ± 0.1
Training experience (years)	4 ± 1.0	4 ± 1.0	4 ± 1.0
Height (cm)	165.5 ± 11.1	157.8 ± 8.2	161.7 ± 9.6
Body mass (kg)	51.2 ± 7.9	45.5 ± 5.8	48.3 ± 6.9
Body mass index (kg/m^2)	18.8 ± 1.5	18.5 ± 1.4	18.6 ± 1.5
Defenders (n)	7	6	13
Midfielders (n)	8	6	15
Attackers (n)	5	4	9
Adherence (%)	100	100	100

Note: HIIT – high-intensity interval training, SSGs – small-sided games
* due to injuries, sickness, or drop-out

approved by the Ethics Committee of the University of Isfahan (Approval No.: IR.UI.REC.1400.016) and conducted in accordance with the Declaration of Helsinki. Informed written consent forms were signed by the participant's parents or legal guardians, and assent forms were signed by the participants.

Experimental design

A quasi-experimental pre-post-study design was used to conduct this study. The study was conducted between July 5, 2020 and September 5, 2020, with the collaboration of two teams participating in the under-14 national soccer league (i.e., the top competition in the country). The study began five weeks after the start of the preseason training sessions. A total of 15 training sessions were conducted before initiating the study, and five matches were already played during this period. After that, the training intervention was implemented over eight weeks. The inclusion criteria for participants to be included in the study were as follows: (I) soccer training experience of more than two years; (II) age between 13 and 14 years; (III) no history of cardiovascular and other chronic diseases in the last six months; and (IV) not taking any medicine, as evaluated by a medical health questionnaire. The exclusion criteria were getting injured during training sessions and not participating in at least 85% of training sessions. However, all participants included in the final analysis attended all the training sessions (i.e., 100% attendance).

Goalkeepers were excluded from the study since they did not participate in the same training program as all other soccer players. The players were familiar with all protocols as a part of their regular implementation assessment program. All participants were members of the two youth soccer teams that participated in the official matches of the national U-14 league competitions every weekend. The players were divided into two groups: the SSGs + HIIT group (n = 20, maximal oxygen consumption [$\dot{V}O_2$ max]: 44.56 ± 2.8 ml·kg^{-1}·min^{-1}) and the HIIT group (n = 16, $\dot{V}O_2$ max: 43.54 ± 1.1 ml·kg^{-1}·min^{-1}).

Testing procedures

All pre- and post-test assessments were conducted from Saturday to Thursday (three days were allocated for each team as per convenience). On the first day, anthropometric and body composition evaluations, including height, body mass, and %BF, were conducted in the afternoon. Subcutaneous fat fold was measured at three sites using a skinfold caliper (Harpenden, Bedfordshire, UK), following the standard protocols, including calves, subscapular area, and triceps. %BF was estimated with the Slaughter's skinfold equation [29]. On day two, at 4–5 p.m., 10 m (for acceleration) and 30 m (for maximal speed) linear sprints and a 5-0-5 change of direction (COD) speed test were conducted, respectively. On the third day, a 30-15 Intermittent Fitness Test (30-15 IFT) [1] was performed to assess $\dot{V}O_2$ max of the players. During 30-15 IFT, the players wore a chest strap of a heart rate monitor (Polar team, Polar H10).

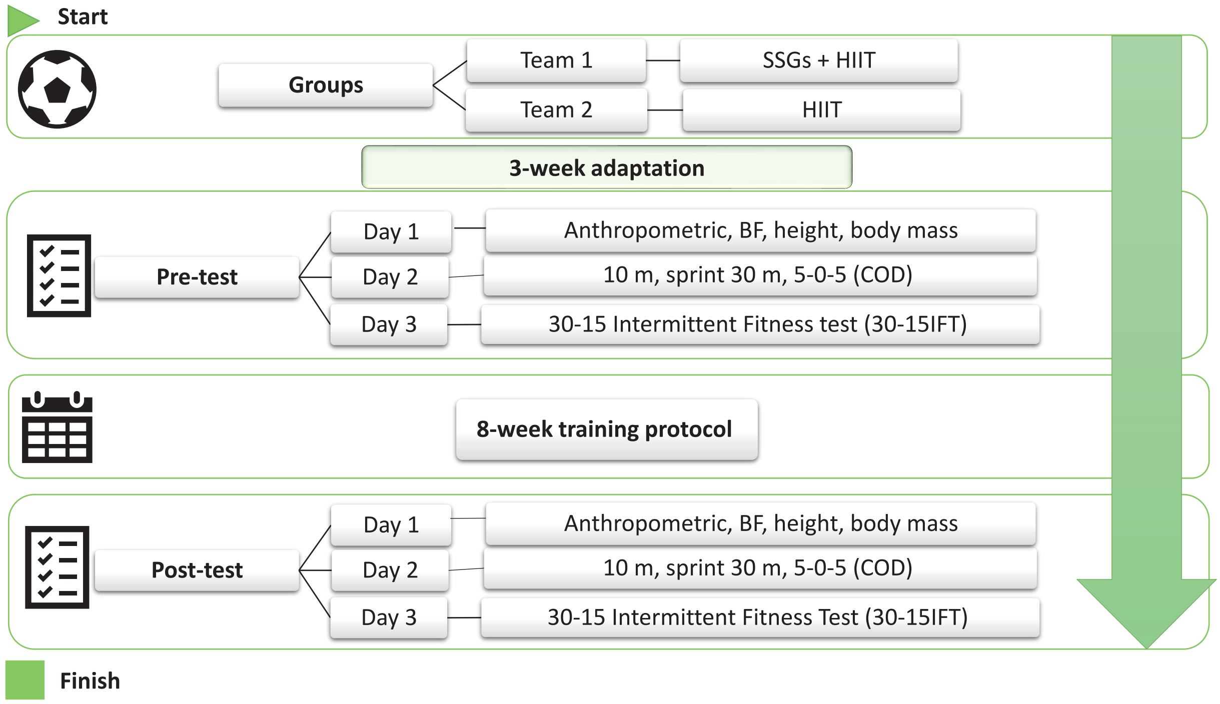
Familiarization sessions for the testing protocols were conducted for the players of each team on separate days. Furthermore, each team started all performance assessments following a standardized warm-up protocol containing the FIFA 11+ warm-up program for beginners level. This warm-up program was conducted in three parts, with a total duration of 15 minutes, with a precisely programmed exercise load and precisely scheduled rests between sets. The first section included warming up through running while performing tasks; the second section contained various strength training exercises, plyometrics, stabilization, and balance exercises, and the third section also covered running, including specific tasks (Figure 1).

Linear sprinting test

Electronic timing gates (Newtest Power Timer Finland 2002) were positioned at 0 m, 10 m, and 30 m. The players started 0.3 m behind the first photocell. The timing gates were adjusted to appropriate hip height per the sample group's mean stature. The players were allowed to start the sprint on their own. The assessors instructed the players to run at their maximum speed during the test. The interclass correlation coefficient (ICC) with 95% confidence interval (CI) for the 10 m linear sprint test was 0.93 (0.87 to 0.96), and for the 30 m linear sprint was 0.97 (0.94 to 0.98).

COD test

The 5-0-5 COD test is a valid and reliable test and was conducted following the established protocols. The procedure involved a 15-meter linear sprint from a static start, followed by a 180° turn on a predetermined turn leg (right or left), ensuring contact with a designated line. After the turn, the participants completed a five-meter return sprint through an identified finish line. The time was recorded to complete the final five meters of the 15-meter linear sprint, the turn, and the five-meter return sprint. A pair of timing gates was positioned at the starting and finishing lines of the test (i.e., at 10 m



BF – body fat, COD – change of direction, SSGs – small-sided games, HIIT – high-intensity interval training

Figure 1. Schematic representation of the study

from the start). The players were instructed to complete the test as quickly as possible. Trials were discarded if the participants cut over the top of a cone, and a trial was re-attempted after a three-minute rest period. Three successful trials were recorded for analysis. The ICC with 95% CI was 0.86 (0.72 to 0.93).

30-15 IFT

The test consists of 30-second shuttle runs alternated with 15-second inactive recovery periods. The participants performed the shuttles between two lines (40 m apart) at a given pace of pre-recorded audio beeps. The test began at the velocity of 8 km/h that was increasing by 0.5 km/h for each successive 30-second stage. The assessors verbally encouraged the participants to complete as many stages as possible. The test ended when the players were completely exhausted and discontinued of their own volition or if they were unable to reach the next three-meter zone at the beep three times in succession. The running speed during the last stage was recorded as the maximum running speed (VIFT). The reliability of 30-15 IFT is high (ICC = 0.90–0.96) across a range of sports [1]. $\dot{V}O_2\,max_{IFT}$ was estimated from VIFT measured with the following equation: $\dot{V}O_2\,maxIFT\,(ml \cdot min \cdot kg) = 28.3 - (2.15 \times G) - (0.741 \times A) - (0.0357 \times BM) + (0.0586 \times A \times VIFT) + (1.03 \times VIFT)$, where G represents gender (male = 1, female = 2), A is age (in years), BM is body mass (in kg), and VIFT is the final velocity (in km/h) reached in the 30-15 IFT

Hooper Index

The players assessed their personal well-being in the morning of each training day, using the Hooper Index. The Hooper Index is a composite measure derived from subjective ratings across four domains: sleep quality (regarding a night preceding the assessment), fatigue levels, stress, and delayed onset muscle soreness (DOMS) [14]. Each of these parameters was evaluated on a 1 to 7 Likert scale, where 1 signifies minimal impact and 7 indicates severe impact. This index provides a holistic view of an individual's well-being and recovery status.

Training protocols

The eight-week training intervention commenced four weeks before the start of the competitive season. During this period, the players participated in two specific sessions per week, comprising SSGs + HIIT and HIIT exercises, which were conducted before each regular soccer-specific training session. In addition to these specific training sessions, a coach primarily focused on developing aerobic fitness and technical

Table 2. Summary of the eight-week training protocol

Week	Session	Game format	Dimension (meters)	SSGs + HIIT	HIIT
1	1	5 × 5	35 × 30	2 × (3 min.), 3 min. rest + 2 × (3 min. at 65% of VIFT), 3 min. rest	4 × (3 min. at 65% of VIFT), 3 min. rest
	2	5 × 5	35 × 30	2 × (3 min.), 3 min. rest + 2 × (3 min. at 65% of VIFT), 3 min. rest	4 × (3 min. at 65% of VIFT), 3 min. rest
2	3	5 × 5	35 × 30	2 × (3 min.), 3 min. rest + 4 × (3 min. at 75% of VIFT), 3 min. rest	4 × (3 min. at 75% of VIFT), 3 min. rest
	4	5 × 5	35 × 30	2 × (3 min.), 3 min. rest + 2 × (3 min. at 75% of VIFT), 3 min. rest	4 × (3 min. at 75% of VIFT), 3 min. rest
3	5	4 × 4	35 × 25	2 × (3 min.), 3 min. rest + 2 × (3 min. at 80% VIFT), 3 min. rest	4 × (3 min. at 80% of VIFT), 3 min. rest
	6	4 × 4	35 × 25	2 × (3 min.), 3 min. rest + 2 × (3 min. at 80% of VIFT), 3 min. rest	4 × (3 min. at 80% of VIFT), 3 min. rest
4	7	4 × 4	35 × 25	2 × (3 min.), 3 min. rest + 2 × (3 min. at 75% of VIFT), 3 min. rest	4 × (3 min. at 75% of VIFT), 3 min. rest
	8	5 × 5	35 × 30	2 × (3 min.), 3 min. rest + 2 × (3 min. at 75% of VIFT), 3 min. rest	4 × (3 min. at 75% of VIFT), 3 min. rest
5	9	3 × 3	30 × 20	2 × (3 min.), 3 min. active rest + 2 × (3 min. at 80% of VIFT), 3 min. active rest	4 × (3 min. at 80% of VIFT), 3 min. active rest
	10	3 × 3	30 × 20	2 × (3 min.), 3 min. active rest + 2 × (3 min. at 83% of VIFT), 3 min. active rest	4 × (3 min. at 83% of VIFT), 3 min. active rest
6	11	3 × 3	33 × 23	2 × (3 min.), 3 min. active rest + 2 × (3 min. at 85% of VIFT), 3 min. active rest	4 × (3 min. at 85% of VIFT), 3 min. active rest
	12	3 × 3	33 × 23	2 × (3 min.) 2:30 min. active rest + 2 × (3 min. at 85% of VIFT), 2:30 active rest	4 × (3 min. at 85% of VIFT), 2:30 min. active rest
7	13	4 × 4	35 ×25	2 × (3 min.), 2:30 min. active rest + 2 × (3 min. at 87% of VIFT), 2:30 active rest	4 × (3 min. at 87% of VIFT), 2:30 min. active rest
	14	5 × 5	35 × 30	2 × (3 min.), 2 min. active rest + 2 × (3 min. at 87% of VIFT), 2 min. active rest	4 × (3 min. at 87% of VIFT), 2 min. active rest
8	15	3 × 3	33 × 23	2 × (3 min.), 2 min. active rest + 2 × (3 min. at 85% of VIFT), 2 min. active rest	4 × (3 min. at 85% of VIFT), 2 min. active rest
	16	3 × 3	33 × 23	2 × (3 min.), 2 min. active rest + 2 × (3 min. at 80% of VIFT), 2 min. active rest	4 × (3 min. at 80% of VIFT), 2 min. active rest

Note: HIIT – high-intensity interval training, SSGs – small-sided games, VIFT – maximum speed reached in the last stage of the 30-15 Intermittent Fitness Test skills throughout the intervention. Each training session began with a 15-minute general warm-up, which included low-intensity running, flexibility exercises, and soccer-specific drills. Following the warm-up, the players engaged in either SSGs + HIIT or HIIT exercises. The total training time for both groups was evenly distributed by their in-season periodization. The SSG + HIIT group performed various types of SSGs, including 3 × 3, 4 × 4, and 5 × 5 formats, in two sets of three minutes each. These possession-based SSGs were played on pitch sizes of 25 × 35 m and 20 × 30 m, respectively. Afterward, this group conducted HIIT exercises consisting of two three-minute sets of running at an intensity of 65–87% VIFT, with 2–3 minutes of active recovery between the sets. Meanwhile, the HIIT group performed four three-minute sets of running at the same intensity, interspersed with 2–3 minutes of active recovery between the repetitions, with each session lasting 18–24 minutes. Table 2 provides a summary of the eight-week training protocol.

Statistical analyses

Means and standard deviations were calculated as descriptive statistics for all the variables. The normality of data was checked by the Shapiro–Wilk statistical test, whereas the homogeneity of variance was assessed using the Levene's test. The analysis of covariance (ANCOVA) with the baseline measures as a covariate was used to assess the effects of training intervention on physical fitness outcomes. Furthermore, post hoc tests with Bonferroni adjustments were used to determine between-group differences and analyze the research hypotheses. Percentage change scores were also calculated for each variable in each group using the equation in a Microsoft Excel sheet: $[(mean_{post} – mean_{pre})/mean_{pre}] \times 100$. The magnitude of effects for η_p^2 was interpreted as small (< 0.06), moderate (≥ 0.06–0.13), and large (≥ 0.14) [9], while Hedge's g was interpreted as trivial (< 0.2), small (0.2–0.6), moderate (> 0.6–1.2), or large (> 1.2–2.0) [15]. The level of significance was set at $p \leq 0.05$, and the data was analyzed using the SPSS software for Windows (Version 24, Chicago, IL, USA).

Results

Table 3 present the participant's characteristics at pre- and post-test. Table 4 presents the data of dependent variables at pre- and post-test, effect sizes, and percentage change. Significant changes were observed in all dependent variables (except HR max and average HR) from pre- to post-test ($p \leq 0.05$) (Table 4). The results of ANCOVA statistics with adjustments for the pre-test measurements as the covariate variables showed a significant difference in improvement between both training interventions for $\dot{V}O_2$ max (HIIT: 6.7% vs SSG + HIIT: 9.1%, p = 0.003) and COD (HIIT: 4% vs SSGs + HIIT: 1.9%, p = 0.002), favoring the SSGs + HIIT group. However, there were no significant differences between the intervention groups for the %BF (HIIT: 11.6% vs SSG + HIIT: 7.3%, p = 0.443), Hooper Index (HIIT: 10.0% vs SSGs + HIIT: 9.0%, p = 0.904), 10 m acceleration sprint (HIIT: 6.3% vs SSGs + HIIT: 7.4%, p = 0.432), and 30 m maximal speed sprint (HIIT: 4.2% vs SSGs + HIIT: 3.4%, p = 0.423).

Table 3. Participants' characteristics in the pre- and post-test measurements

Measured variables	Groups	Pre-test	Post-test	Percentage of changes (%)
Age (years)	HIIT	14.0 ± 0.1	–	–
	SSGs + HIIT	14.0 ± 0.2		
Body mass (kg)	HIIT	45.5 ± 5.8	45.6 ± 5.9	0.28
	SSGs + HIIT	51.2 ± 7.9	52.1 ± 7.9	1.77
Height (cm)	HIIT	157.8 ± 8.2	158.2 ± 8.1	0.27
	SSGs + HIIT	165.5 ± 11.1	166.0 ± 10.9	0.34
Body mass index (kg/m^2)	HIIT	18.5 ± 1.4	18.3 ± 1.5	0.81
	SSGs + HIIT	18.8 ± 1.0	18.1 ± 1.0	3.72

Note: HIIT – high-intensity interval training, SSGs – small-sided games

Data presented as mean ± SD.

Discussion

This study aimed to compare the effects of eight weeks of performing either the HIIT or SSGs + HIIT training protocols in addition to the regular soccer training on 10 m acceleration and 30 m maximal speed sprinting, aerobic capacity, %BF, and COD speed of youth male soccer players. The significant main effect of time was observed in all variables except maximum heart rate. Furthermore, significant differences in improvements were observed in $\dot{V}O_2$ max and COD speed between both interventions, favoring the SSG + HIIT group. Similar improvements were observed in 10 m and 30 m linear sprints, %BF, rate of perceived exertion, Hooper Index, and heart rate measures (i.e., average and maximal heart rate [HR max]).

The eight weeks of SSGs and HIIT protocols improved $\dot{V}O_2$ max of both groups by 9.1% vs 6.7%, respectively. The findings indicate that the SSGs + HIIT protocols

Table 4. Results for physiological and performance variables measured pre- and post-test

Variables	SSGs + HIIT (20)				HIIT (16)				Main effect time (p-value)	Between-group (p-value)
	Pre	Post	%Δ	ES (g)	Pre	Post	%Δ	ES (g)		
	Mean ± SD				Mean ± SD					
$\dot{V}O_2$ max (ml·kg^{-1}·min^{-1})	44.56 ± 2.8	48.62 ± 2.5†	9.1	1.50	43.54 ± 1.1	46.47 ± 1.2†	6.7	2.48	<0.001	0.003‡
Change of direction (sec)	2.54 ± 0.2	2.49 ± 0.2†	1.9	0.25	2.47 ± 0.1	2.37 ± 0.2†	4	0.07	<0.001	0.002‡
10 m linear sprint (sec)	1.08 ± 0.1	1 ± 0.1†	7.4	0.78	1.11 ± 0.9	1.04 ± 0.1†	6.3	0.11	<0.001	0.432
30 m linear sprint (sec)	3.49 ± 0.2	3.37 ± 0.2†	3.4	0.59	3.52 ± 0.3	3.37 ± 0.3†	4.2	0.49	<0.001	0.423
Body fat (%)	21.78 ± 4.1	20.17 ± 3.8†	7.4	0.40	24.70 ± 4.5	21.83 ± 4.6†	11.6	0.61	<0.001	0.443
RPE (1–10)	5.47 ± 0.67	6.30 ± 1.03†	15.1	0.94	5.52 ± 0.71	6.61 ± 0.65†	19.7	1.56	<0.001	0.189
Hooper Index (%)	2.01 ± 0.55	1.84 ± 0.43†	9.1	0.34	2.00 ± 0.33	1.81 ± 0.23†	9.2	0.65	<0.001	0.701
Heart rate max (bpm)	204.1 ± 8.3	207.0 ± 5.8	1.4	0.40	202.6 ± 4.7	199.8 ± 4.5	1.4	0.61	0.098	0.006‡
Average heart rate (bpm)	165.2 ± 16.0	172.1 ± 7.3	4.1	0.54	161.9 ± 12.7	167.0 ± 6.14	3.1	0.50	<0.001	0.189

Note: BMI – body mass index, HIIT – high-intensity interval training, RPE – rating of perceived exertion; SD – standard deviation, SSGs – small-sided games, $\dot{V}O_2$ max – maximum oxygen consumption
† – significantly different between pre- and post-tests; ‡ – significantly different between experimental groups

induced more improvement in $\dot{V}O_2$ max compared to the HIIT group, which is consistent with previous studies [7, 16]. The cardiorespiratory demands of soccer players reveal that various exercise methods could lead to advancements in the aerobic fitness of soccer players. In addition, the current study's result has been reported by previous studies, which indicated that SSGs + HIIT protocols produced better cardiorespiratory responses than SSGs [3, 23].

Aerobic capacity is an important prerequisite for success in soccer, and traditionally, continuous low-intensity training has been used to improve certain aspects of endurance capacities [13], such as maximum oxygen consumption. The HIIT method, distinguished by periods of intense exercise at > 85% of HR max alternating with periods of low-intensity recovery, shows great potential to enhance certain aspects of the endurance of youth soccer players. However, adding SSGs to HIIT shows positive results in improving youth soccer players' aerobic capacity. One of the plausible reasons may be the nature of SSGs, which use the games-based training approach. SSGs have been shown to ensure motivation as well as enthusiasm of players [4]. Indeed, adding verbal encouragement during SSGs has improved physiological responses, rate of perceived exertion, enjoyment, and mood [25]. Moreover, with a previous meta-analysis showing similar improvements in aerobic performance after SSGs and HIIT [5], the current finding that SSGs + HIIT yields superior improvements compared to HIIT alone is novel.

In addition, the study's findings also revealed a significant difference between the two training modalities to improve COD of young soccer players, with a greater improvement achieved with SSGs + HIIT. Previous studies suggested that both reducing a number of players and playing pitch sizes resulted in greater improvements in COD of adolescent soccer players [2]. In contrast, another study compared 4 vs 4 SSGs with 15s-15s HIIT at 110% of maximum speed among elite soccer players and reported no significant difference in COD from a baseline as well as between-group [12]. However, the current study's results suggest that young soccer players can improve the COD performance by following the SSGs + HIIT protocol, compared to HIIT alone. A greater improvement in the COD performance may be possible due to the nature of both training interventions. For example, SSGs includes playing soccer-specific games in a restricted area, which allows players to move freely and, therefore, get involved in COD activity, thus providing a specific stimulus. In contrast, HIIT majorly involves linear movements with a lesser COD stimulus. Indeed, a study that compared SSGs and regular linear-based soccer warm-up protocols reported a significant COD improvement after SSGs compared to a linear-based warm-up protocol [30].

Furthermore, the present study's findings revealed that eight weeks of soccer training, including HIIT and SSGs + HIIT, similarly improved (i.e., significant main effect of time [$p < 0.001$]) the body composition in the youth soccer players with no significant difference between the groups. This result is supported by previous studies that suggest both HIIT and SSGs can improve the body composition of athletes [21]. Acceptable %BF is not only one of the main factors related to health and sports performance but also, together with other factors, determines the quality of soccer players' motion and the final level of performance [11]. Therefore, both training protocols can be used to improve the body composition of young soccer players.

The current study also reported no significant differences in an improvement between HIIT and SSGs + HIIT in the post-training 10 m acceleration and 30 m maximal sprint performances. However, compared to the baseline, there were significant improvements in both groups. This shows that the energetic contribution by anaerobic metabolism was equal for both training modalities. Although no previous studies compared HIIT with SSGs + HIIT, previous studies that used the SSGs + HIIT approach found improvement in linear sprint time [21]. These results align with recommendations from a previous meta-analysis that compared HIIT and SSGs [6]. The meta-analysis reported a significant difference in an improvement of linear sprint time, favoring HIIT over a SSGs protocol, suggesting that SSGs should be accompanied by some form of sprinting activity to induce linear sprint improvements [6].

Lastly, the principal differences between HIIT and combined SSGs + HIIT that could have affected the performance and skill-based abilities are the ball and the opponent's presence, which imitates the competitive environment of soccer matches. These differences may be associated with the high levels of enjoyment and play level increase observed with SSGs. The lack of control over diet and activity may be considered a limitation of this study.

Limitations and future directions for research

During the intervention, it was observed that training between 80% and 87% of VIFT was too intense for the 14-year-old players, causing excessive fatigue and difficulty in maintaining intensity. This suggests that training intensity should be gradually increased over a longer period for proper adaptation. Therefore, future research should extend the duration of interventions and vary training frequency to determine the optimal duration and frequency for significant fitness improvements. Incorporating GPS tracking alongside heart rate monitors, rating of perceived exertion, and the Hooper Index would allow for precise monitoring of both external and internal load parameters and provide deeper insights into training responses. Additionally, assessing motivation and engagement during training, especially in SSGs, could reveal important psychological factors affecting training effectiveness. Lastly, although the current study focused on comparing the effects of SSGs + HIIT and HIIT alone, an additional control group could further help to distinguish the real effects produced by the training intervention, and not only by maturation itself. By addressing these specific limitations, future research can provide deeper insights into the comparative SSGs + HIIT vs HIIT alone on the physical fitness of youth soccer players.

Conclusions

The current study demonstrated that the SSG + HIIT and HIIT protocols are both effective in improving aerobic endurance, COD speed, linear sprints, Hooper Index, and rate of perceived exertion. However, greater improvements in aerobic endurance and COD speed were achieved with SSG + HIIT compared to HIIT alone. Based on the present study's findings, practitioners may combine SSG and HIIT to attain maximum benefits during preseason training. However, more research with better design (controlled and randomized) is required to confirm these findings across various age groups.

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Conflict of Interest

The authors declare no conflict of interest.

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