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Original Article

Comparative impact of small-sided games and high-intensity interval training on physical performance in youth soccer players

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Abstract:
Small-sided games (SSGs) serve as a valuable tool for aerobic training for both professional and amateur teams. Nevertheless, some studies suggest that, under specific conditions, small SSGs may not replicate the high-intensity efforts (20–25 km/h) and repeat sprints (>25 km/h) demanded by full games when compared with larger small-side game formats or match play. Conversely, high-intensity interval training (HIIT) has been shown to enhance maximal oxygen uptake, the lactic threshold, intermittent high-intensity effort capabilities, and rapid recovery between intense efforts. This study aimed to evaluate the effects of SSGs in comparison to HIIT on maximal oxygen uptake (VO_{2MAX}), repeat sprint ability (RSA), and agility in youth soccer players. A randomized parallel-group study involving 12 players per group was conducted. The experimental group underwent a nine-week SSGs-based intervention, ranging from two vs. two to six vs. six formats, with a training duration between 20 and 40 min, while the control group engaged in HIIT for the same duration and frequency. The testing battery (baseline and postintervention) occurred over three different days with assessments at 8:00 a.m., both at the club's training ground (Course Navette, Sprint Repeated Test, and Illinois Test) and in the laboratory (ergospirometry) with an environmental temperature of 24°C and relative humidity of 60%. The study commenced in the middle of the competitive season. Statistical analyses revealed no significant differences in maximal oxygen uptake between the SSGs-based training group and the control group (p = 0.44). However, the experimental group exhibited a 6% improvement in performance, while the control group showed a 12% improvement, with a moderate effect size (ES = 0.4). Additionally, the experimental group demonstrated statistically significant improvements in all RSA variables: best time (p = 0.02; 95% confidence interval (CI95%): −0.18; −0.01; ES = 1.1), average time in all sprints (p = 0.005; CI95%: −0.33; −0.06; ES = 1.4), total time in all sprints (p = 0.003; CI95%: −2.17; −0.52; ES = 1.4), and the percentage of decrease tended towards significance (p = 0.07; CI95%: −3.07; 0.15; ES = 0.8) compared with the control group. Agility showed no significant differences between the two groups (p = 0.45). Overall, no statistically significant differences were found in maximal oxygen uptake and agility between youth soccer players practicing SSGs and those engaged in HIIT after nine weeks. Notably, a significant enhancement in repeat sprint ability was observed in the SSGs group compared to the HIIT group. Consequently, during the in-season, amateur team coaches should favor SSGs training instead of interval exercises to optimize training.
Keywords: **aerobic capacity, football, athletic performance, repeated sprint ability, agility, training program**

Introduction

Traditional methodologies of aerobic resistance training, such as continuous and interval running, focus on the general development of athletes' maximal oxygen uptake (VO_{2MAX}). In other words, the nature of the load does not mimic that experienced in competitions. The introduction of contemporary methodologies emphasizing specific training has led to the application of loads that closely resemble the demands of competition. On the basis of this, the terms "general physical preparation" and "specific physical preparation" emerged (Siff & Verkhoshansky, 2004).

Consequently, in general physical preparation, the non-specific resistance training method is based on the continuous method. This method has been employed in preparing athletes, particularly in sports like athletics and soccer, given their intermittent nature. In these sports, periods alternate between high-intensity work [>85% maximum heart rate (HRmax)] and moderate or low-intensity work (30–50% HRmax). This type of training necessitates resistance training stimulation similar to that experienced during competitions (Mohr et al., 2003), leading to the development of the high-intensity interval training (HIIT) method (Laursen & Buchheit, 2019). The documented effects of the continuous method include improvements in capacity and aerobic power (Bravo et al., 2008), running economy (Chamari et al., 2005), and blood lactate profile (Iaia et al., 2009).

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HIIT is a training method that involves performing repeated periods of high-intensity work (>85% HRmax) above the lactate threshold (4 mmol/l), interspersed with periods of low-intensity intervals (30–50% HRmax) or full recoveries (>3 min) (Laursen & Buchheit, 2019). Running-based HIIT can be performed using various approaches, such as submaximal short or long intervals, repeated sprint training (maximal effort), sprint interval training (maximal effort), or game-based drills, as seen in small-sided games (SSGs) (Laursen & Buchheit, 2019).

In recent years, the primary goal of training has shifted towards simulating real game situations that occur in competitions, aiming to train players under specific conditions. This involves modifying certain characteristics of the game, including the size of the field and the number of players (Morgans et al., 2014). In the context of soccer, coaches prioritize specificity when designing training tasks to foster the development of all athletes' structures—coordinative, cognitive, conditional, creative–expressive, emotional–volitional, and socio–affective (Alcalá et al., 2020; Espar, 2017; Sánchez, 2021). This approach aims to optimize performance and achieve the objectives set in the training process. The evolution of sports training has been underpinned by physical effects, with training specificity and responses to these stimuli becoming a specialized topic and a prominent area of research in recent years (Gurrutxaga, 2021; Halouani et al., 2014; Sarmento et al., 2018).

SSGs stand out as one of the most common methods employed by soccer coaches worldwide (Clemente & Sarmento, 2021; Halouani et al., 2014). While historically used primarily for enhancing player interaction and developing technical and tactical skills (Aguiar et al., 2012; García-Gómez et al., 2019; Kunz et al., 2019; McLean et al., 2016), SSGs are now widely adopted by both professional and amateur teams as an optimal tool for aerobic training (Moran et al., 2019; Sgrò et al., 2018). This training approach allows for more time spent under conditions resembling actual competitions compared to non-specific training methods, which lack the characteristics aligned with the internal logic of the sport (e.g., continuous HIIT runs without a ball). Consequently, the majority of exercises in team sports training sessions, including soccer, basketball, and rugby, incorporate SSGs with reduced numbers of players in smaller areas than those used in official matches (Rampinini et al., 2007).

However, some results suggest that when compared with large SSGs formats or match play, small SSGs (under certain conditions) do not simulate the high-intensity efforts (20–25 km/h) and repeat sprints (>25 km/h) that the full game demands (Halouani et al., 2014).

Previous studies have reported that professional soccer players cover distances in the range of 10–12 km, including 3–7% of high-intensity actions during a competitive match (Beenham et al., 2017; Bradley et al., 2009; Dellal et al., 2011; Di Salvo et al., 2007, 2009; Sangnier et al., 2019). This corresponds to an average of 80–90% of HRmax and 75–80% of VO_{2MAX} (Stølen et al., 2005). Physical abilities with the potential to impact running performance throughout the game include speed, explosive strength, and maximum incremental running speed (Buchheit et al., 2010).

The ability to perform high-intensity intermittent exercises with changes of direction and the ability to execute repeated sprints (Girard et al., 2011) are the most determining physical requirements in a soccer game owing to the frequency with which these actions are requested (typically, 3–5 s) (Brughelli et al., 2008; Stølen et al., 2005). Therefore, the specific development of these capacities is of great interest to coaches (Dellal et al., 2012).

The effects produced by the HIIT method result from improvements in maximal oxygen uptake, the lactic threshold, the ability to perform intermittent high-intensity efforts, and rapid recovery between intense efforts (Laursen & Buchheit, 2019). Some studies indicate that SSGs are equally effective in enhancing aerobic power, similar to HIIT, with an intensity of 90–95% HRmax. Additionally, certain SSG formats (one vs. one, two vs. two, and three vs. three) have been shown to elicit heart rate (HR) responses, lactate concentrations, and ratings of perceived exertion (RPE) comparable to those achieved by short intermittent runs (intervals of 10 s of work for 10 s of passive rest, 15 s of work for 15 s of passive rest) (Clemente et al., 2021; Dellal et al., 2012; Laursen & Buchheit, 2019; Moran et al., 2019).

More pronounced effects have been observed in physiological responses such as maximum heart rate (>90%) and rating of perceived exertion in favor of the HIIT method compared to SSGs (Massamba et al., 2020). Conversely, SSGs have demonstrated greater effects on these physiological responses compared to HIIT (Bujalance-Moreno et al., 2019). Furthermore, previous studies indicated no significant differences between SSGs and HIIT methods in HRmax responses, lactate levels, and rating of perceived exertion (Arslan et al., 2020; Kunz et al., 2019; Moran et al., 2019). Continuous efforts are needed to provide ongoing empirical evidence and studies that establish cause-and-effect relationships between SSGs and HIIT. Maximal oxygen uptake, defined as the maximum amount of oxygen (O_2) that an organism can absorb, transport, and consume per unit of time (Chicharro & Vaquero, 2010), serves as a crucial parameter for quantifying energy metabolism. The direct measurement or indirect estimation of this parameter enables the quantification of energy metabolism because O_2 serves as a precursor for all cellular combustion processes. This transformation of chemical energy, found in the chemical bonds of immediate nutritional components (carbohydrates, lipids, and proteins), into mechanical energy (muscular contraction) and cellular work is fundamental to understanding physiological processes (Chicharro & Vaquero, 2010).

Sprinting, a brief-duration exercise, involves covering a short distance (<20 m) and is deemed an acceleration action requiring maximum (or near-maximum) effort. Typically, it lasts for 10 s or less (Girard et al., 2011). The ability to consistently achieve the best mean sprint time over a series of sprints, interspersed with recovery periods of 60 s or less, is referred to as repeat sprint ability (RSA) (Bishop et al., 2011). This parameter is important for athletes in team sports, particularly soccer players, who frequently perform this action during a match (Clemente et al., 2021).

Agility, traditionally defined as the ability to change direction quickly (Sheppard & Young, 2006), involves a swift preprogrammed movement of the entire body accompanied by a change in speed or direction (Pérez et al., 2017).

Young et al. (2002) proposed two main components of agility. The first encompasses the speed of direction change, influenced by technical, anthropometric, linear speed, and strength stimuli. The second emphasizes perceptual and decision-making factors, including visual stimuli, situational awareness, anticipation, and pattern recognition. This study aimed to contribute to the understanding of the training process in the physical aspects of soccer, particularly in comparing specificity to optimize different stimuli for VO_{2MAX}, RSA, and agility.

Consequently, this study aimed to assess the effects of SSGs in comparison to HIIT on VO_{2MAX}, RSA, and agility in youth soccer players after 18 sessions in the middle of the competitive season.

Materials and methods

Study design

This study adopted a parallel randomized experimental design (Ato et al., 2013; Friedman et al., 2015; Lazcano-Ponce et al., 2004). This work has an explanatory scope because it establishes cause-and-effect relationship (Hernández-Sampieri et al., 2018). The cause is the independent variable (SSGs and HIIT), and the effect is the dependent variable (maximal oxygen uptake, repeat sprint ability, and agility). The athletes were randomly assigned to two groups—experimental (SSGs) and control (HIIT)—in the week before the pretest. The post-test was conducted two weeks after the intervention ended.

The study spanned nine weeks, with both interventions conducted twice a week, resulting in a total of 18 training sessions with the same volume (in minutes) for both groups. Commencing 13 weeks into the season, the study corresponded with the midpoint of the competitive season.

Participants

Twenty-four male youth soccer players (median age: 19 years; interquartile range: 2 years; height: 1.73 ± 0.07 m; body mass median: 68 kg; interquartile range: 7 kg; federated experience: 11.26 ± 2.22 years) took part in this study. All athletes belonged to the same team, competing in the First A category of the Antioquia Soccer League (Colombia), corresponding to tier 3, Highly Trained/National Level, as per the Participant classification framework (McKay et al., 2022). The sample was intentionally non-probabilistic. In other words, the choice of elements did not depend on probability but on the characteristics of the investigation (Hernández-Sampieri et al., 2018). The participants adhered to a training regimen of five sessions per week, each lasting 80 min, in addition to participating in a competitive match. All subjects were thoroughly briefed on the research procedures, requirements, potential benefits, and associated risks. Written informed consent was obtained from each athlete.

Sample size

The sample size was calculated following a previous study (Dellal et al., 2012) with a difference of 1.2 ml/kg/min in VO_{2MAX} between the experimental and control groups. This difference is significant from a practical point of view because an increase in VO_{2MAX} improves soccer performance, specifically increasing the distance covered, the number of sprints, and the number of actions with the ball (Helgerud et al., 2001). There were 12 players per group.

Selection criteria

Inclusion criteria

The inclusion criteria were outfield players without injury or illness during the training intervention period, those present at both assessment moments, and those with an adherence to the training intervention of at least 70%. These criteria were applied to all soccer players.

Exclusion criteria

Athletes who experienced ligamentous ruptures in the last six months, acute bone injuries, acute muscle injuries, acute tendon injuries, asthma, inhaler usage, ongoing hormonal treatment, heart disease, failure to pass the pre-medical evaluation conducted by the medical department of Indeportes Antioquia, and those not registered in the health system were excluded. Additionally, athletes with less than 70% adherence to training sessions or those who missed one of the assessments (baseline or postintervention) were not included.

Randomization

The participants were randomly assigned, employing a stratified approach based on the level of play. This classification involved considering the number of minutes played in official matches to distinguish starting players from substitutes for subsequent random assignment, utilizing the opaque envelope technique. A software program (Programa para Análisis Epidemiológico de Datos, Epidat Versión 3.1, Consellería de Sanidade, Xunta de Galicia, España; Organización Panamericana de la Salud; Universidad CES, Colombia) facilitated the random number generation. In the stratification process based on participants' level of play during competition, the initial assignment to the experimental or control group involved 11 starters, followed by the substitutes. Subsequently, each participant was designated with the letter X (experimental) or Y (control) using the ballot technique.

Masking

The principal investigator processed the collected data. Subsequently, the coded data were handed over to the co-investigator, who conducted the statistical analysis without knowledge of the identity associated with the data. Consequently, this was a single-blind study.

Procedure

The testing battery (baseline and postintervention) was performed over three different days, interspaced. The first assessment day was preceded by 48 h of rest following the last match or session, and the second and third assessment days also had a 48-h rest period before them. The assessments took place at 8:00 a.m. at the club's training ground (Course Navette, RSA, and Illinois) and in the laboratory of Indeportes (ergospirometry), with an environmental temperature of 24°C and relative humidity of 60%. The assessment days were scheduled for Monday, Wednesday, and Friday.

Pretest and post-test

Day 1. Anthropometric tests and sociodemographic survey

All tests and training commenced and concluded at similar times of the day (Drust et al., 2005). The participants were instructed to wear a training uniform (shorts, T-shirt, socks, and athletic shoes) to ensure comfort during the pretest and post-test.

For anthropometric assessments, including height and mass, athletes did not wear shoes. The following instruments were previously calibrated: stadiometer (Seca 222, Hamburg, Germany; precision: 1 mm) and scale (Seca 634, Hamburg, Germany). These measurements were conducted in the laboratory (Indeportes Antioquia) following the recommendations of a nutritionist with 10 years of experience: abstain from eating or drinking any liquids in the 3 h before the measurements, refrain from exercising for 24 h before the measurements, avoid alcohol consumption for 48 h before the measurements, abstain from diuretics for seven days before the measurements, and ensure the absence of any metallic elements in the body. Additionally, the body mass index (BMI) was calculated using the weight and height data.

Sociodemographic variables, encompassing age, socioeconomic status, sports experience, and academic training, were examined using a predesigned ad hoc survey.

Day 1. Assessment of maximal oxygen consumption

The VO_{2MAX} test during the pretest was conducted with the direct measurement using ergospirometry, applying the protocol proposed by Kindermann et al. (1980). The evaluations took place in the laboratory at Indeportes Antioquia. The evaluation day began with an 8-min activation session involving walking on a treadmill at a speed of 6 km/h. Ergospirometry was chosen for its accurate and validated estimation of maximal oxygen uptake (VO_{2MAX}) (de Groot & Nieuwenhuizen, 2013).

Four individuals (two coaches and two sports retrainers), each with three years of experience in this type of evaluation, were responsible for the test. The electrocardiogram was performed by the medical committee before starting the tests. The sample analysis was carried out with an automatic dry-chemistry analyzer system (Spotchem EZ SP-4430; Arkray, Inc., Kyoto, Japan). Calibration was performed daily, following the manufacturer's recommendation, using indicated reagent cards with an intraclass correlation coefficient of 0.95 and a coefficient of variation of 0.5. The activation phase included activation, stability, and mobility exercises at different intensity levels for 10 min; this was performed in all evaluations.

In the post-test, the evaluation of maximal oxygen uptake was conducted with indirect measurement through the Course Navette test. This test was chosen because, according to García and Secchi (2014), in team sports such as soccer, rugby, and basketball (also considered acyclic or intermittent sports), actions involve changes of direction, accelerations, and decelerations, making this test relevant. Additionally, Aziz et al. (2005) evaluated the VO_{2MAX} of long-distance athletes and team sports athletes with both ergospirometry and the Course Navette test, showing no statistically significant differences in group athletes between the VO_{2MAX} obtained in the field and the laboratory. This is the primary reason that the Course Navette is directly associated with team sports (Arcuri, 2009; Búa et al., 2013).

The evaluations were conducted at 8:00 a.m. at the club's training ground after dividing the athletes into groups of eight players. Following the standardized warm-up, the main coach provided feedback, explaining the nature of the test (the athletes had prior experience). Afterward, he carried out the evaluation.

Four individuals were involved in these measurements: the main trainer (seven years of experience), the physical trainer (15 years of experience), an invited coach (eight years of experience), and a professional sports practitioner. These individuals had assigned tasks: one managed the sound related to the test protocol, another provided verbal motivation to the athletes to encourage their best effort, and the other two kept records for four athletes each. The recorded data included the last stage reached in the test, the participant's age, and the duration in minutes of each test. A formula was applied to calculate the VO_{2MAX} using these data.

The test proposed by Leger et al. (1988), which involved running a total of 20 m (Figure 1), was employed. The test commenced at a speed of 8.5 km/h and increased by 0.5 km/h every minute, controlled by an audible signal. The test concluded when the athletes voluntarily chose to finish or were unable to maintain the running speed with the rhythm of the auditory signal, allowing for two consecutive failures. In other words, the test ended if, on two consecutive occasions, the athlete did not pass the 20 m line with the whole body at the time the auditory signal sounded or did not step on the 20-m marking line. This test had an intraclass correlation coefficient of 0.95 and a variation coefficient of 5.7% (García & Secchi, 2014).

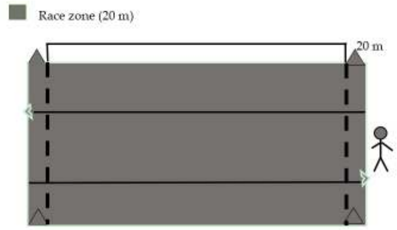

Fig. 1. Course Navette test. Source: own elaboration

Day 2. Repeated sprint test

The group test lasted 30 min and was performed immediately after the warm-up. The test comprised eight 30-m maximal sprints with 25 s of active recovery (Rodriguez-Fernandez et al., 2017). After passing through the photocells located at the end of the course, the subjects jogged back to the starting line to continue with the sprints (Figure 2). At the initiation of the test, the athletes had to position themselves 0.5 m behind the starting line where the first photocell was located (DSDLaser System®, DSD, Inc., León, Spain) to prevent activating it prematurely (Chaouachi et al., 2010). The photocells had an intraclass correlation coefficient of 0.96 and a coefficient of variation of 4.47 s (Villa et al., 2012).

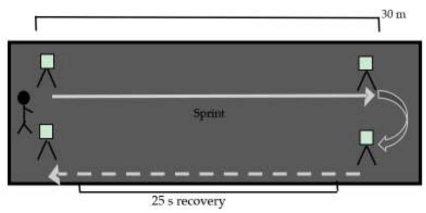

Fig. 2. Repeated sprint ability test. Source: own elaboration

Day 3. Change of direction

The test involved running a circuit made up of cones (Figure 3) in the shortest time possible, incorporating linear sprints and turns to the right and left. Each athlete needed to pass behind each cone. Every athlete completed the test twice, and the best time of the two attempts was recorded. The test was previously validated and tested for reliability (Hachana et al., 2013).

Time was measured using photocells. Thus, the athletes were required to start the test 0.5 m behind the first photocell to prevent activating it prematurely. No start signal was given; the athlete initiated the test when considered ready. This approach ensured that reaction time did not influence the results. The test demonstrated an intraclass correlation coefficient of 0.96 and a coefficient of variation of 0.1 (Hachana et al., 2013). The photocells (DSDLaser System®, DSD, Inc., León, Spain) had an intraclass correlation coefficient of 0.96 and a coefficient of variation of 4.47 s (Villa et al., 2012).

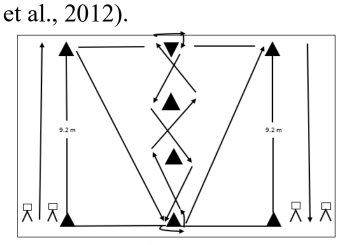

Fig. 3. Illinois test. Source: adapted from Vescovi and Mcguigan, (2008, p.99)

Training interventions

Intervention protocol for SSGs

This study was conducted during the competitive period, featuring a progression in the formats of SSGs from two vs. two to six vs. six, some of which included inside floaters (IF). Additionally, the game spaces per player were adjusted based on the number of participants (Table 1).

Table 1. Intervention protocol for SSGs

Session	Game format	Intervention prescription	Dimension of the playing area (m)	Playing area per player (m^2)	Density work: recovery	Total game volume (min)	Total stimulus volume (min)	Tactical principles
1	2 *vs*. 2	4 × 3 min/3 min rest	25 × 16	100	1:1	12	24	Pressure after losing the ball
2	5 *vs*. 5+2IF	3 × 8 min/2 min rest	64 × 46	245	2:1	21	30	Ball possession and position
3	3 *vs*. 3	4 × 4 min/3 min rest	30 × 25	125	2:1	16	28	Defensive sector start of play
4	5 *vs*. 5+2IF	3 × 8 min/2 min rest	64 × 46	245	2:1	21	30	Pressure after losing the ball
5	3 *vs*. 3	4 × 4 min/3 min rest	30 × 25	125	2:1	16	28	Connect with the third man
6	6 *vs*. 6	3 × 8 min/2 min rest	64 × 46	245	2:1	21	30	Possession of the ball
7	2 *vs*. 2	4 × 3 min/3 min rest	25 × 16	100	1:1	12	24	Pressure after losing the ball
8	5 *vs*. 5+2IF	3 × 8 min/2 min rest	64 × 46	245	2:1	21	30	Ball possession and position
9	3 *vs*. 3	4 × 4 min/3 min rest	30 × 25	125	2:1	16	28	Defensive sector start of play
10	6 *vs*. 6	3 × 8 min /2min rest	64 × 46	245	2:1	21	30	Possession of the ball
11	2 *vs*. 2	4 × 3 min/3 min rest	25 × 16	100	1:1	12	24	Pressure after losing the ball
12	5 *vs*. 5+2IF	3 × 8 min/2 min rest	64 × 46	245	2:1	21	30	Pressure after losing the ball
13	3 *vs*. 3	4 × 4 min/3 min rest	30 × 25	125	2:1	16	28	Defensive sector start of play
14	6 *vs*. 6	3 × 8 min/2 min rest	64 × 46	245	4:2	24	30	Possession of the ball
15	2 *vs*. 2	4 × 3 min/3 min rest	25 × 16	100	1:1	12	24	Pressure after losing the ball
16	5 *vs*. 5+2IF	3 × 8 min/2 min rest	64 × 46	245	2:1	21	30	Ball possession and position
17	3 *vs*. 3	4 × 4 min/3 min rest	30 × 25	125	2:1	16	28	Defensive sector start of play
18	5 *vs*. 5+2IF	3 × 8 min/2 min rest	64 × 46	245	2:1	21	30	Pressure after losing the ball

Source = own elaboration; min = minutes; m = meters; IF = internal floater

All games incorporated scoring mechanisms, including small goals, consecutive passes per team, crossing goal lines, or placing the ball in designated end zones.

The SSGs were meticulously designed, taking into account the individual space of interaction or relative space per player in square meters. This relative field area per player was determined by dividing the total playing area by the total number of players (Castellano et al., 2013; Clemente, 2016; Hill-Haas et al., 2011). The two vs. two format involved the addition of four players, the three vs. three format included six additional players, and the five vs. five plus two internal floaters format incorporated twelve more players. Similarly, the six vs. six format involved the inclusion of an additional twelve players.

The game formats implemented a 25% progression in playing area per player. Specifically, the small two vs. two format was characterized by 100 m² per player, the medium three vs. three format ranged between 100 and 200 m² per player, and the large five vs. five plus two internal floaters and six vs. six formats exceeded 200 m² per player (Castellano et al., 2013; Sarmento et al., 2018). Consistent findings across studies investigating various game area dimensions (three vs. three, four vs. four, five vs. five, six vs. six, and seven vs. seven formats) indicated that areas larger than 100 m² per player lead to increased heart rate responses, increased lactate concentrations, and elevated ratings of perceived exertion in both youth and older soccer players. These responses are closely associated with aerobic power (Alben et al., 2022; Castellano et al., 2013; Clemente, 2016; Hodgson et al., 2014; Sarmento et al., 2018).

Intervention protocol for HIIT

In line with recommendations by Laursen and Buchheit (2019), the load parameters for HIIT training interventions were adjusted, as outlined in Table 2. The intensity of the intervals was specifically configured to reach 85% of the maximal aerobic speed.

Table 2. Intervention protocol for HIIT

Session	Work interval duration (s)	Recovery interval duration (s)	Duration time of the series (min)	Number of series	Recovery time between sets/type of recovery between sets	Total stimulus volume (min)
1	10	20	3	4	3 min/passive	24
2	15	15	6	3	4 min/ passive	30
3	10	10	4	4	3 min/ passive	28
4	30	30	6	3	4 min/ passive	30
5	10	20	4	4	3 min/ passive	28
6	15	15	6	3	4 min/ passive	30
7	10	10	3	4	3 min/ passive	24
8	30	30	6	3	4 min/ passive	30
9	10	20	4	4	3 min/ passive	28
10	15	15	6	3	4 min/ passive	30
11	10	10	3	4	3 min/ passive	24
12	30	30	6	3	4 min/ passive	30
13	10	20	4	4	3 min/ passive	28
14	15	15	6	3	4 min/ passive	30
15	10	10	3	4	3 min/ passive	24
16	20	20	6	3	4 min/ passive	30
17	15	15	4	4	3 min/ passive	28
18	15	15	6	3	4 min/ passive	30

Source = own elaboration; s = seconds; min = minutes

HIIT interventions comprised brief intervals, alternating between 10 s of work and 10 s of recovery, with variations such as 15 s/15 s, 20 s/20 s, 10 s/20 s, and 30 s/30 s, as specified by Laursen and Buchheit (2019). The study encompassed two types of HIIT: Type 1, designed to stimulate the aerobic system, and Type 2, aiming to activate both the aerobic and neuromuscular systems, following the classification by Buchheit and Laursen (2013).

Training control

To control stimuli in the interventions, loads were matched with an equal volume (in minutes) for both the experimental and control groups. Both groups underwent heart rate monitoring, albeit with different devices. The experimental group utilized a global positioning system device (BioHarness 3.0, Zephyr, USA), while the control group employed pulse meters (RS800, Polar Electro, Kempele, Finland). The disparity in heart rate measurement instruments was due to their insufficient availability for all participants. Table 3 lists the heart rate dynamics during each of the 18 training sessions conducted throughout the intervention period. It is noteworthy that the average heart rate in each group exceeded 180 beats per minute, placing it in heart rate zone five (>90% HRmax) according to Sperlich et al. (2011). Specifically, the experimental group maintained an average heart rate of 184 beats per minute, while the control group registered an average heart rate of 188 beats per minute.

Table 3. *Training control*

Heart rate		
Sessions	**Mean beats per minute experimental group**	**Mean beats per minute control group**
1	185	189
2	184	193
3	184	192
4	187	189
5	180	189
6	182	188
7	190	188
8	184	188
9	184	187
10	187	187
11	185	188
12	186	190
13	183	188
14	184	189
15	184	189
16	185	188
17	184	189
18	184	188

Source = own elaboration

For the rating of perceived exertion (RPE), the questionnaire developed by Foster et al. (2001) was utilized. This scale ranges from 0 to 10. Following the conclusion of each training session, each athlete was asked to answer a series of questions related to his perception of the training intensity. However, Weston et al. (2015) demonstrated that there are no significant differences in RPE scores when collected 10 and 30 min after the end of the training. Therefore, 10 min after the training session, each athlete was asked to provide their RPE. Before the interventions commenced, athletes underwent training in the use of the RPE scale during 35 training sessions over eight weeks. The meaning associated with each number on the scale was thoroughly explained to them (Table 4).

Table 4. Rating of perceived exertion

NUMBERS	PERCEPTION
0	Rest
1	Very easy
2	Easy
3	Moderate
4	Somewhat hard
5	Hard
6	
7	
8	Very hard
9	
10	Maximal

Source = own elaboration

Statistical analysis

The distribution test was conducted using the Shapiro–Wilk test to assess the data distribution. Means and standard deviations were reported for normally distributed data. In contrast, medians and interquartile ranges were reported for non-normally distributed data. In the inferential analysis, the Levene test assessed the homogeneity of variances ($p > 0.05$). Independent mean differences were analyzed with Student's *t*-test for data with a normal distribution, and the Mann–Whitney U (M_{WU}) test was employed for data with a non-normal distribution. Effect size (ES) was calculated using the formula (d = (Meangroup1 − Meangroup2 / SD grouped), where the standard deviation (SD) grouped is = $\sqrt{([SD^2}$group1 + SD^2group2] / 2) (Cohen, 1988). Effect sizes less than 0.4 indicated a small magnitude of change: between 0.4 and 0.7 a moderate magnitude, between 0.7 and 1.0 a large magnitude, and those greater than 1.2 a very large magnitude of change (Cohen, 1988). The percentage of change was calculated intragroup (post-test – pretest / pretest × 100). All analyses were performed with a significance level of $p < 0.05$ and a confidence level of 95%, using the statistical software SPSS version 24 for Windows (SPSS Inc., Chicago, IL, USA).

Ethical aspects

The research adhered to the principles outlined in the Declaration of Helsinki concerning studies involving human subjects, and compliance with the guidelines set forth by the Ministry of Health in Resolution N°. 008430 from 1993 was ensured. According to this resolution, the study posed a risk level higher than the minimum because it involved a cardiorespiratory test, a sprint test, and an agility test. However, these tests did not threaten the participants' health, and they were conducted with the utmost care to minimize any potential risks. None of the participants experienced psychological stress, and they were treated cordially throughout the study. Approval for this study was obtained from the Ethics Committee of the University Institute of Physical Education and Sports at the University of Antioquia during its ordinary session on March 23, 2021 (act # 074).

Results

Figure 4 shows the flow chart detailing the entire process throughout the phases of the randomized parallel trial. This includes recruitment, assignment, follow-up, and subsequent pretest and post-test analyses.

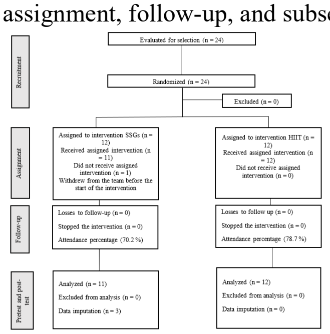

Fig. 4. Flowchart depicting the phases of the randomized parallel trial. Source: own elaboration

In the baseline characteristics discriminated by group (Table 5), no discrepancies were observed at the study's commencement in variables such as height, age, weight, and BMI. Nevertheless, despite employing stratified random assignment, the HIIT group exhibited more federated experience than the SSGs group (p = 0.001).

Variables	SSGs group MEAN ± SD	HIIT group MEAN ± SD
Height (m)	1.71 ± 0.06	1.75 ± 0.07
Federated experience (years)*	9.82 ± 1.54	12.58 ± 1.93
	MEDIAN ; IQR	**MEDIAN ; IQR**
Age (years)	19 ; 2	19.5 ; 4.25
Weight (kg)	66 ; 8	70 ; 6.5
BMI (kg/m^2)	23.3 ; 1.47	23.44 ; 1.86
Attendance percentage (%)	83.33 ; 55.5	77.77 ; 33.33

Table 5. Baseline characteristics discriminated by group
Source = own elaboration; SSGs = small-sided games; HIIT = high-intensity interval training; SD = standard deviation; IQR = interquartile range; BMI = body mass index; * = significant difference $p < 0.05$

Analysis inferential

The primary outcomes of the study during the pretest, encompassing variables such as maximal oxygen uptake, repeat sprint ability, and agility for both the experimental group and the control group, are detailed in Table 6. The results show homogeneity between the groups in the primary study outcomes (p > 0.05) at the inception of the study. Noteworthy are the experimental group's slightly elevated values in maximal oxygen uptake ($\bar{X}$ = 49.20 ml/kg/min; SD = 3.68 vs. 47.25 ml/kg/min; SD = 4.88), best sprint RSA ($\bar{X}$ = 4.19 s; SD = 0.10 vs. 4.25 s; SD = 0.11), mean RSA ($\bar{X}$ = 4.43 s; SD = 0.07 vs. 4.48 s; SD = 0.21), and total time RSA ($\bar{X}$ = 35.44 s; SD = 0.62 vs. 35.91 s; SD = 1.68).

Table 6. Variables with normal distribution in the pretest: VO_{2MAX}, $RSA_{best\ sprint}$, and agility

Variables	Group	Pretest $\bar{X}$ (SD)	t	p	CI95%
VO_{2max} (ml/kg/min)	Experimental	49.20 ± 3.68	0.80	0.43	−2.32 ; 5.23
	Control	47.75 ± 4.88			
$RSA_{best\ sprint}$ (s)	Experimental	4.19 ± 0.10	−1.31	0.20	−0.14 ; 0.03
	Control	4.25 ± 0.11			
Agility (s)	Experimental	14.66 ± 0.34	0.73	0.46	−0.24 ; 0.52
	Control	14.52 ± 0.51			

Source = own elaboration; SD = standard deviation; VO_{2max} = maximal oxygen uptake; CI95% = 95% confidence interval; RSA = repeat sprint ability; ml/kg/min = milliliter/kilogram/minute

The variables exhibiting non-normal distribution in the pretest included RSA_{mean}, percentage of decrease (evaluated through the median performance decrease over the eight sprints), and total time (Table 7). Statistical analysis revealed no significant differences between the experimental and control groups in RSA_{mean} (M_{WU} = 43.5; Z = −1.65; p = 0.09; M_{WU} = 60; Z = −0.69; p = 0.48; M_{WU} = 60; Z = −0.69; p = 0.48) during the pretest, as determined by the Mann–Whitney U test.

Table 7. Variables with non-normal distribution in the pretest: RSA (mean, percentage of decrease, and total time)

Variables	Group	Median; IQR	M_{WU}	z	p
RSA_{mean} (s)	Experimental	4.44; 0.30	60	−0.69	0.48
	Control	4.45; 0.87			
$RSA_{\%\ decrease}$ (s)	Experimental	4.50; 0.58	43.5	−1.65	0.09
	Control	2.40; 5.67			
$RSA_{total\ time}$ (s)	Experimental	35.53; 2.43	60	−0.69	0.48
	Control	35.60; 6.94			

Source = own elaboration; IQR = interquartile range; M_{WU} = Mann–Whitney U

Table 8 displays postintervention data for each group in the post-test concerning repeat sprint ability and agility variables. Levene's test was employed to assess homogeneity of variances for $RSA_{best\ sprint}$, RSA_{mean}, and $RSA_{total\ time}$ (p > 0.05). However, for the variable of the percentage decrease of RSA, the assumption of equality in variances was not met (p < 0.05). Consequently, non-parametric statistics were applied to this variable. Upon conducting Student's t-test, statistically significant differences were identified in all variables of repeat sprint ability in the experimental group: best sprint ($\bar{X}$ = 4.09 s; SD = 0.09; p = 0.02; CI95% = −0.18: −0.01; ES = 1.1), mean time of the eight sprints ($\bar{X}$ = 4.24 s; SD = 0.09; p = 0.005; CI95% = −0.33: −0.06; ES =

1.4), total time of the eight sprints (X̅ = 33.99 s; SD = 0.74; $p = 0.003$; CI95% = −2.17: −0.52; ES = 1.4). In the percentage of decrease, there was a tendency to statistical significance (median = 3.80; IQR = 0.70; $p = 0.07$; CI95% = −3.07: 0.15; ES = 0.8) compared to the control group: best sprint (X̅ = 4.20 s; SD = 0.11; $p = 0.02$; CI95% = −0.18: −0.01; ES = 1.1), mean time of the eight sprints (X̅ = 4.45 s; SD = 0.20; $p = 0.005$; CI95% = −0.33: −0.06; ES = 1.4), total time of the eight sprints (X̅ = 35.34 s; SD = 1.15; $p = 0.003$; CI95% = −2.17: −0.52; ES = 1.4). In the percentage of decrease, there was a tendency to statistical significance (median = 5.35; IQR = 3.28; $p = 0.07$; CI95% = −3.07: 0.15; ES = 0.8). In qualitative terms, the variable $RSA_{best\ sprint}$ had a large effect size, while the variables RSA_{mean} and $RSA_{total\ time}$ had a very large effect size.

Table 8. Inferential analysis of repeat sprint ability and agility in the post-test with normal distribution

Variables	Group	X̅ (SD)	% of change	*t*	*P*	CI95% LL;UL	Effect Size *d*	*size*
$RSA_{best\ sprint}$ (s)	Experimental	4.09 ± 0.09	−2.38	−2.45	0.02*	−0.18	1.1	large
	Control	4.20 ± 0.11	−1.41			−0.01		
RSA_{mean} (s)	Experimental	4.24 ± 0.09	−4.28	−3.12	0.005*	−0.33	1.4	very large
	Control	4.45 ± 0.20	−0.66			−0.06		
$RSA_{total\ time}$ (s)	Experimental	33.99 ± 0.74	−4.09	−3.38	0.003*	−2.17	1.4	very large
	Control	35.34 ± 1.15	−1.58			−0.52		
Agility (s)	Experimental	14.20 ± 0.53	−3.13	0.76	0.45	−0.28	0.3	small
	Control	14.04 ± 0.49	−3.30			−0.61		

Source = own elaboration; SD = standard deviation; RSA = repeat sprint ability; CI95% = 95% confidence interval; ES = effect size; % of change = percentage of change that occurs within the group, with the values of the pretest compared to the post-test (post-test – pretest / pretest × 100); LL = low limit; UL = upper limit; * = significant difference $p < 0.05$

Table 9 presents an analysis of data with non-normal distribution (maximal oxygen uptake and $RSA_{\%\ decrease}$). When applying the Mann–Whitney U test, it becomes evident that there are no statistically significant differences in VO_{2MAX} ($p > 0.05$; −0.76) between the experimental group ($M_{WU} = 54$; median = 52.1; IQR = 6; ES = 0.4) and the control group ($M_{WU} = 54$; median = 53.6; IQR = 3; ES = 0.4). However, the subjects in the experimental group increased their performance by 6% (3 ml/kg/min), and the participants in the control group increased their performance by 12% (5.8 ml/kg/min) compared with that in the pretest. Similarly, there was no statistically significant difference in the median performance decrease across the eight sprints ($RSA_{\%\ decrease}$) ($p > 0.05$; −1.53) between the experimental group ($M_{WU} = 45.5$; median = 3.80; IQR = 0.70; ES = 0.8) and the control group ($M_{WU} = 45.5$; median = 5.35; IQR = 3.28; ES = 0.8).

According to the post-test results, the differences in the magnitude of the effect for the variables of total time and mean time in the repeat sprint ability of the experimental group compared to the control group had a very large effect size (ES = 1.4).

Similarly, a large effect size (ES = 0.8) was observed in the variable percentage of decrease in RSA (Cohen, 1988). A small effect size (ES = 0.3) was observed in the agility variable. For maximal oxygen uptake, a moderate effect size (ES = 0.4) was observed.

Table 9. Post-test results with non-normal distribution

Variables	Group	Median; IQR	% of change	M_{WU}	z	p	Effect Size ***d***	***Size***
$VO_{2máx}$ (ml/kg/min)	Experimental	52.1; 6	6	54	−0.76	0.44	0.4	Moderate
	Control	53.6; 3	12.2					
$RSA_{\%\ decrease}$ (s)	Experimental	3.80; 0.70	−27.4	45.5	−1.53	0.07	0.8	Large
	Control	5.35; 3.28	−1.12					

Source = own elaboration; IQR = interquartile range; % of change = percentage of change; MWU = Mann–Whitney U; VO_{2max} = maximal oxygen uptake; ml/kg/min = milliliter/kilogram/minute.

Discussion

This study aimed to evaluate the impact of SSGs in comparison to HIIT on variables such as VO_{2MAX}, RSA, and agility after 18 sessions among youth soccer players in the midst of the competitive season.

The experimental group demonstrated a performance increase of 6% (3 ml/kg/min), while the control group exhibited a 12% improvement (5.8 ml/kg/min) compared to the pretest. Furthermore, a moderate ES of 0.4 was observed, indicating a significant magnitude of change. According to Helgerud et al. (2001), enhancing VO_{2MAX} by 6–12% contributes to improved soccer performance, encompassing increased distance coverage, more sprints, and increased engagement with the ball. This improved aerobic capacity enables soccer players to effectively withstand the demands of competition (Alben et al., 2022; Clemente, 2016; Rabbani et al., 2019; Salazar-Martínez & Jiménez-Trujillo, 2018) and facilitates rapid recovery between high-intensity actions such as sprints, accelerations, decelerations, and changes of direction. Consequently, these percentage changes hold practical significance and importance (Bujalance-Moreno et al., 2019; González et al., 2020; Sgrò et al., 2018).

Utilizing Hill's (1965) criteria, including the biological gradient, temporality, and biological plausibility, this study aimed to establish causal relationships for the observed effects. The biological gradient, reflecting the dose–response relationship, was considered in the development of the SSGs intervention, with space per player in square meters as a crucial parameter. The relative field area per player was defined as the total playing area divided by the total number of players (Álvarez & Sánchez, 2021; Castellano et al., 2013; Clemente, 2016; Hill-Haas et al., 2011; Valencia-Sánchez & Otálvaro-Vergara, 2021). The game formats in this intervention demonstrated a 25% progression in playing area per player. Starting from two vs. two (with HRmax values of 190 beats per minute and an RPE of nine), the game format transitioned to three vs. three (with HRmax values of 184 beats per minute and an RPE of seven), five vs. five plus two internal floaters (with HRmax values of 187 beats per minute and an RPE of eight), and six vs. six (with HRmax values of 184 beats per minute and an RPE of seven).

The HIIT interventions comprised various formats, evolving from 10 s of work for 10 s of recovery (with HRmax values of 192 beats per minute and an RPE of nine) to 10 s of work for 20 s of recovery (with HRmax values of 189 beats per minute and an RPE of eight), 15 s of work for 15 s of recovery (with HRmax values of 189 beats per minute and an RPE of eight), and 30 s of work for 30 s of recovery (with heart rate values of 190 beats per minute and an RPE of nine). The establishment of a dose–response relationship was evident because the values of the rating of perceived exertion and heart rate fell within the zones associated with the development of maximal oxygen uptake (RPE of seven to 10 and zone five of the HRmax). Despite the different interventions, both groups exhibited enhanced VO_{2MAX} performance, achieving and sustaining HRmax and RPE values necessary for improvements in this capacity (>90% HRmax and RPE values of 7–10).

The temporality criterion, asserting that the cause precedes the effect in time (Hill, 1965), was upheld through a nine-week intervention period involving both SSGs and HIIT, followed by the assessment of potential adaptations. Volumes of 24, 28, and 30 min were allocated for interventions in the two groups. Previous studies support the notion that VO_{2MAX} increases after four weeks (Amani-Shalamzari et al., 2019; Bahtra et al., 2020; Kunz et al., 2019). Furthermore, the criterion of biological plausibility, which establishes the etiology of the cause (i.e., the cardiovascular system's response to interventions) for improvements in athletes' maximal oxygen uptake, was examined. According to Kenney et al. (2021), cardiovascular adaptations to resistance training aimed at enhancing VO_{2MAX} initially involve an increase in heart size in response to heightened exertional demand, along with augmented heart weight, volume, left ventricular wall thickness, and chamber size.

The cardiac muscle, similar to skeletal muscles, experiences hypertrophy owing to resistance training, a phenomenon referred to as cardiac hypertrophy (Kenney et al., 2021). Initially viewed with concern, exercise-induced hypertrophy of the heart was often associated with a pathological condition. However, current understanding recognizes cardiac hypertrophy as a normal and adaptive response to training aimed at improving maximal oxygen uptake (Kenney et al., 2021).

Owen et al. (2012) observed that a four-week SSG-based intervention enhanced running economy, leading to reduced peak oxygen consumption and heart rate at running speeds of 9, 11, and 14 km/h. Conversely, Faude et al. (2014) noted that both interval running and SSGs marginally increased anaerobic threshold velocity (1.3%). Despite a decrease in peak heart rate (−1.8%), there was an increase in urea concentration (9.2%) during the training period. These findings align with the results of this study, wherein both the SSGs and HIIT groups demonstrated improvements in maximal oxygen uptake. These parallels can be attributed to the duration of interventions (>4 weeks), the frequency of stimulus application per week (twice), and the attainment of HRmax values exceeding 90% during the intervention period.

Moran et al. (2019) discovered that SSGs are equally effective as HIIT in enhancing aerobic endurance performance in youth soccer players. They emphasized that both groups experienced improvements with a frequency of stimuli twice a week, involving series of four or more, each lasting four minutes, with three-minute recovery periods. These findings align with the results of this study because similar loading parameters were established for youth soccer players. Additionally, Clemente and Sarmento (2021) reported that SSGs and HIIT training demonstrated comparable effects in improving maximal oxygen uptake. These results agree with those in studies by Köklü et al. (2020) and Harrison et al. (2015), where SSGs and HIIT-based training increased maximal oxygen uptake in soccer players, consistent with the results of this study.

According to the findings of this study, the SSG program did not yield statistically significant differences in maximal oxygen uptake in youth soccer players after 18 intervention sessions compared to the control group performing HIIT ($p = 0.44$).

Regarding repeat sprint ability, Rodriguez-Fernandez et al. (2017) reported increases after using SSGs in 18 training sessions. Changes in RSA parameters, including the percentage decrease in performance following SSGs in a six-week intervention period with a stimulus frequency of twice per week for a total of 12 training sessions, have been documented (Eniseler et al., 2017). These results differ from those in this study, which observed changes in the parameters of $RSA_{best\ sprint}$, RSA_{mean}, and $RSA_{total\ time}$ ($p < 0.05$). When comparing the SSGs and HIIT methods, Clemente et al. (2021) found that neither of these methods was effective in improving repeat sprint ability in soccer players. These results contrast with the data of this study, where the group that performed SSGs showed statistically significant differences in RSA compared to the HIIT group. On the other hand, when comparing SSGs and HIIT training, Arslan et al. (2020) found that the group that underwent HIIT increased its RSA performance compared to the SSG group.

The results of this study contrast with the findings of Buchheit et al. (2008) and Mohr et al. (2007), who observed significant improvements in repeat sprint ability with the HIIT method compared to SSGs. However, in this study, the group that underwent SSG-based training demonstrated significantly greater changes in this variable compared to the HIIT group.

The results of this study revealed statistically significant differences in various parameters for the group participating in the SSGs program compared to the HIIT group. Specifically, the SSGs group demonstrated significant improvements in the best sprint time ($\bar{X}$ = 4.09 s; SD = 0.09; p = 0.02; CI95% = −0.18: −0.01; ES = 1.1), mean time of the eight sprints ($\bar{X}$ = 4.24 s; SD = 0.09; p = 0.005; CI95% = −0.33: −0.06; ES = 1.4), total time of the eight sprints ($\bar{X}$ = 33.99 s; SD = 0.74; p = 0.003; CI95% = −2.17: −0.52; ES = 1.4), and there was a tendency towards statistical significance in the percentage decrease (median = 3.80; IQR = 0.70; p = 0.07; CI95% = −3.07: 0.15; ES = 0.8). In contrast, the HIIT group exhibited less pronounced improvements in these parameters: best sprint time ($\bar{X}$ = 4.20 s; SD = 0.11; p = 0.02; CI95% = −0.18: −0.01; ES = 1.1), mean time of the eight sprints ($\bar{X}$ = 4.45 s; SD = 0.20; p = 0.005; CI95% = −0.33: −0.06; ES = 1.4), total time of the eight sprints ($\bar{X}$ = 35.34 s; SD = 1.15; p = 0.003; CI95% = −2.17: −0.52; ES = 1.4), and a tendency towards statistical significance in the percentage decrease (median = 5.35; IQR = 3.28; p = 0.07; CI95% = −3.07: 0.15; ES = 0.8).
On the contrary, the experimental (SSG) group did not exhibit statistically significant differences in agility compared to the HIIT group in youth soccer players (p = .45). Nevertheless, both the experimental and control groups demonstrated improved performance, with increases of 3.13% and 3.30%, respectively, when comparing the pretest to the post-test. Additionally, an ES of 0.3 was calculated, indicating a small magnitude of change. The practical significance of a 3% improvement in this capacity is underscored by the frequent need for players to make rapid changes of direction during matches to gain advantageous positions based on game tactics (Stølen et al., 2005). Consequently, this minimum percentage of change is significant in soccer performance statistics. The ability to execute sudden and unpredictable changes of direction is commonly referred to as agility (Reilly, Bangsbo, et al., 2000; Reilly, Williams, et al., 2000; Stølen et al., 2005).

Chaouachi et al. (2014) employed game formats ranging from one vs. one to three vs. three (small formats). Their findings revealed that these formats elicit effective and sudden motor responses to external stimuli, concurrently enhancing various short-term anaerobic performances relevant to soccer. Results from longitudinal studies suggested that physical performance and skill development are age-dependent, with anaerobic capacity being particularly responsive to training-induced changes between the ages of 8 and 11, representing a sensitive phase in the development of soccer players (Reilly, 2005; Reilly, Williams, et al., 2000).
According to Chaouachi et al. (2014) and Rampinini et al. (2007), achieving significant improvements in agility through SSGs-based training necessitates small game dimensions (<100 m^2 per player). This allows for frequent high-intensity accelerations and decelerations, particularly effective when players are within an age range conducive to maximizing these effects. In this study, the game formats exhibited a 25% progression in playing area per player. Consequently, small formats (two vs. two) featured an area of 100 m^2 per player, medium formats (three vs. three) had 100–200 m^2 per player, and large formats (five vs. five plus two internal floaters and six vs. six) had >200 m^2 per player. Additionally, the soccer players' age may have contributed to the relatively small magnitude of change in the effectiveness of this capacity because they were not in their sensitive developmental phase (median age: 19 years; interquartile range: 2 years).

The nature of the stimulus applied to the control group, involving 180° direction changes, demanded additional muscular engagement owing to frequent accelerations and decelerations. This induced a higher glycolytic contribution, increased blood lactate concentration, and elevated ratings of perceived exertion compared to linear interval training (Dellal et al., 2010). HIIT incorporating changes of direction requires players to be in optimal condition in terms of VO_{2MAX}, as well as neural and muscular factors (Dellal et al., 2012). These authors suggested that initiating specific training for improving the ability to change direction should begin at an early age.

Limitations

The experimental and control groups did not achieve an 85% attendance rate, specified by the training plan. The experimental group had a slightly higher attendance, by approximately 5%, but this difference was not statistically significant (p > 0.05). Despite employing stratified random assignment and finding no baseline differences in the main variables, this approach did not work effectively owing to the limited number of players. Significant differences were found in federated experience, favoring the control group. For SSGs, parameters such as distance traveled, accelerations, decelerations, body orientation, and speed at different km/h values were not monitored. The primary limitation of this study was that the pretest for VO_{2MAX} used a direct test with a band ergospirometer. At the same time, the post-test employed an indirect test, i.e., the Course Navette test. However, the Course Navette test has been applied for over 30 years in various sports and population groups, showing an intraclass correlation coefficient of 0.95 and a coefficient of variation of 5.7% (García & Secchi, 2014). The change in the testing instrument was necessitated by a software failure in the pretest instrument in the days leading up to the post-test. Indicators of heart rate and rating of perceived exertion were not monitored in official matches, presenting another limitation. Additionally, the study had a limitation in terms of the sample size, suggesting that future research with larger sample sizes is recommended.

Practical applications

This study demonstrated that a 9-week period of training sessions, including SSGs, can increase aerobic capacity, repeat sprint ability, and agility in youth soccer players to a similar extent as HIIT sessions. Notably, SSGs had better effects on RSA compared to HIIT. Furthermore, both methods of training, when applied for 9 weeks, induced a similar effect on VO_{2MAX}, as evidenced by the increase in performance from the pretest to the post-test. Consequently, during the in-season, coaches of amateur teams should favor the use of SSGs training over interval exercises to optimize training.

Conclusions

Statistical analyses did not reveal significant differences in maximal oxygen uptake between the SSGs-based training group and the control group. However, when employing SSGs-based training, statistically significant differences were found in repeat sprint ability within this group compared with the HIIT group. Agility exhibited no significant differences between the two groups. Overall, no statistically significant disparities were found in maximal oxygen uptake and agility between youth soccer players practicing SSGs and those engaged in HIIT after nine weeks. However, a noteworthy improvement in repeat sprint ability was observed in the SSGs group compared to the HIIT group. This study demonstrated that a nine-week period of training sessions, including SSGs, can enhance aerobic capacity, repeat sprint ability, and agility in youth soccer players to a comparable extent as high-intensity interval training sessions. Importantly, SSGs demonstrated superior effects on RSA. Both training methods, when applied over nine weeks, induced a similar effect on VO_{2MAX}, as evidenced by the increased performance from pretest to post-test. Consequently, during the in-season, coaches of amateur teams should consider favoring the use of SSGs training over interval exercises to optimize training.

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