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Research article

Small-Sided Soccer Games Promote Greater Adaptations on Vertical Jump and Change-of-Direction Deficit and Similar Adaptations in Aerobic Capacity than High-Intensity Interval Training in Females

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Abstract
The objective of this study was to compare the effectiveness of both small-sided games (SSG) and short interval running-based high-intensity interval training (HIIT) programs over an 8-week period in fostering adaptations in aerobic capacity, change-of-direction abilities, and jumping performances of youth female soccer players. The study involved 48 female youth participants under the age of 19, competing at the regional level, who took part in a randomized controlled trial. Participants were assigned to either the SSG group, the HIIT group, or a control group, which involved regular in-field sessions. Assessments were conducted at baseline and after the 8-week training intervention, measuring aerobic capacity using the 30 - 15 intermittent fitness test (VIFT), change of direction (COD) using the 5 - 0 - 5 test, and jumping performance using the countermovement jump test (CMJ). Time × group analysis revealed significant interactions in CMJ (p = 0.005; $\eta_p^2 = 0.213$) and VIFT ($p < 0.001$; $\eta_p^2 = 0.433$), although no significant interaction were found in COD deficit ($p = 0.246$; η_p^2 = 0.060). Within-group analysis revealed that SSG significantly improved CMJ ($p < 0.001$), COD deficit ($p < 0.001$), and VIFT ($p <$ 0.001). HIIT group also significantly improved CMJ ($p = 0.029$), COD deficit ($p = 0.001$), and VIFT ($p < 0.001$). As conclusion, the study revealed that SSG promoted significantly improvements in VIFT, CMJ and COD deficit, being significantly better than control group, while HIIT was only significantly better than control in VIFT. SSG revealed to be effective approach for favoring key physical attributes of female soccer players, being an interesting and recommended training approach to increase the ecology of the training practice, while favoring physical positive adaptations.

Key words: Football, high-intensity interval training, drill-based games, aerobic capacity, neuromuscular performance.

Introduction

Comparing various training approaches can be particularly pertinent in the context of soccer training, especially considering whether the training is more analytical (e.g., running-based) or ecological in nature (e.g., small-sided games, SSG) (Davids et al., 2013). Understanding the impact on critical physical fitness parameters is essential, particularly in facilitating the necessary adaptations to enhance player performance. Among others, aerobic capacity, change of direction (COD) ability, or jumping performance play important roles in enhancing athletic performance in female soccer players (Krustrup et al., 2005; Datson et al., 2014). Aerobic capacity is essential for sustaining high-intensity efforts throughout a match, allowing players to cover greater distances and recover faster between high-intensity locomotor demands (McCormack et al., 2014). Studies have shown that higher aerobic fitness levels are associated with improved performance in soccer, including better overall match running performance (McCormack et al., 2014; Gonçalves et al., 2021). Change of direction ability is critical for escaping opponents and quickly changing direction during attacking or defensive actions (Emmonds et al., 2019). Research indicates that superior change of direction skills correlates with enhanced agility, speed, and performance in soccer-specific tasks (Jones et al., 2015; Alanen et al., 2023). Additionally, jumping performance (Beato et al., 2023) is vital for winning aerial duels, executing headers, and performing explosive movements such as fast accelerations, or shots. Therefore, multidimensional training program targeting aerobic capacity, COD, and jumping performance is essential for maximizing athletic potential and success in female soccer (Wright and Laas, 2016).

High-intensity interval training (HIIT) has emerged as a highly effective method for enhancing various athletic performance variables such as aerobic capacity, COD, and jumping performance in athletes, including female soccer players (Clark, 2010; Dolci et al., 2021). HIIT induces significant adaptations in the cardiovascular system, leading to improved maximal oxygen uptake (Gibala and MacInnis, 2022). Studies have demonstrated that HIIT protocols elicit greater or similar improvements in maximal oxygen uptake compared to traditional continuous aerobic training methods (Rowan et al., 2012). Furthermore, HIIT engages fast-twitch muscle fibers during high-intensity intervals (Buchheit and Laursen, 2013a), particularly in short intervals due to the speed and mechanical strain, contributing to enhanced neuromuscular adaptations crucial for COD and jumping performance. This type of training also stimulates mitochondrial biogenesis and increases muscle oxidative capacity, facilitating better energy production and utilization during intense exercise bouts (Fransson et al., 2018). Neuromuscular adaptations induced by HIIT, particularly those involving turns, include enhanced motor unit recruitment, improved intermuscular coordination, and increased muscle activation, all of which are essential for executing rapid COD and explosive movements like jumping (Ferrete et al., 2014). Therefore, the physiological and neuromus-

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cular adaptations elicited by HIIT (Buchheit and Laursen, 2013a; 2013b) make it a compelling training method for simultaneously improving aerobic capacity, COD, and jumping performance in female soccer players.

SSGs have gathered attention as an alternative and game-based approach to achieving adaptations like HIIT (Clemente et al., 2024). Research indicates that SSGs effectively enhance aerobic capacity through repeated bursts of high-intensity efforts interspersed with brief recovery periods, mirroring the intermittent nature of soccer matches (Moran et al., 2019). Studies comparing SSGs with traditional aerobic training have shown comparable improvements in maximal oxygen uptake and other markers of aerobic fitness (Jastrzebski et al., 2014; Los Arcos et al., 2015). Moreover, SSGs offer unique advantages by simultaneously targeting multiple facets of tactical-technical performance (Ometto et al., 2018; Clemente and Sarmento, 2020). The dynamic and unpredictable nature of SSGs demands rapid changes in direction, acceleration, and deceleration, promoting neuromuscular adaptations crucial for agility and COD (Young et al., 2015). Furthermore, the frequent transitions between attacking and defensive actions in SSGs require players to execute explosive movements, possibly leading to improvements in lower limb power and reactive strength (Rebelo et al., 2016). Additionally, SSGs facilitate skill development, decision-making, and tactical awareness in a game-specific context, enhancing overall soccer performance (Correia da Silva et al., 2019; Ometto et al., 2021).

While research on the effects of SSG and HIIT is well-established among men soccer players, suggesting that both induce similar significant effects on aerobic performance (Clemente et al., 2024), exists an inconsistency in findings regarding their impacts on COD and jumping abilities (Faude et al., 2013; Arslan et al., 2020). Specifically, studies indicate contradictory outcomes, with those concerning COD favoring HIIT (Faude et al., 2013; Arslan et al., 2020). However, research in female soccer remains limited in this regard. One of the few studies comparing SSG and HIIT in female soccer players revealed that both were effective in improving performance in the 30-15 intermittent fitness test, countermovement jump (CMJ), and COD time (Nayıroğlu et al., 2022). However, a more recent study (He et al., 2024) comparing the effects of SSG and HIIT in both men and women suggested that in women, the heterogeneity of adaptations is greater, while HIIT appears to ensure a more uniform adaptation in jumping performance, acceleration, COD, and aerobic performance.

Given the substantial under-representation of research involving females (Cowley et al., 2021), and acknowledging the inconsistency in findings from the limited studies comparing SSG and HIIT (Nayıroğlu et al., 2022; He et al., 2024), further research is necessary to understand whether SSG is equally effective as HIIT in enhancing aerobic performance, COD, and jumping ability. Considering that SSGs offer opportunities to target both athletic fitness and tactical/technical aspects (Ometto et al., 2018), a thorough understanding of their impact on athletic performance could assist coaches in making informed decisions regarding their inclusion in training plans to optimize efficiency. By investigating the physical fitness adaptations resulting from SSG and HIIT in female players, we can contribute to understanding the impact of these training approaches in a population that is underrepresented in research. This provides insights into their applicability in personalized training processes, especially considering the growing trend towards enhancing the overall quality of training for female soccer player. Therefore, the objective of this study was to compare the effectiveness of both SSG and short interval HIIT programs over an 8-week period in fostering adaptations in aerobic capacity, change-of-direction abilities, and jumping performance among youth female soccer players. Based on prior research, significant positive adaptations in aerobic capacity are anticipated in both the SSG and HIIT groups (Nayıroğlu et al., 2022; He et al., 2024). Additionally, positive adaptations in change-of-direction and jumping performance are also expected (Nayıroğlu et al., 2022; He et al., 2024).

Methods

Study design and experimental approach

This research utilized a randomized controlled trial design, where two experimental intervention groups, namely SSG and HIIT, were incorporated alongside the regular training routine. A control group exclusively underwent standard soccer training sessions (Figure 1). Participants were conveniently recruited from three soccer teams. To ensure that the training approach of each team would not bias the adaptations, we balanced the players exposed to each of the groups (i.e., SSG, HIIT, and control) within each team. In team 1, each group consisted of 5 players. Meanwhile, in team 2, the SSG and control groups comprised 6 players each, while the HIIT group consisted of 5 players. In team 3, the HIIT group had 6 players, whereas the SSG and control groups each had 5 players. Allocation concealment was ensured through randomization before the initial assessment, employing opaque envelopes randomly assigned to soccer players. Evaluations were conducted by independent researchers, who remained unaware of group assignments, one week before the intervention beginning and immediately after the 8-week period. The study was conducted during the pre-season phase, starting in the second week of pre-season training. During the experimental period, the players engaged in regular training sessions and participated in non-official matches (n = 4). In the SSG group, the total duration of non-official match time was 2880 minutes, while in the HIIT group, it was 3072 minutes, and in the control group, it was 2752 minutes.

Evaluations were conducted on the same days of the week (Tuesdays) both before and after the intervention, ensuring consistency. The assessments for anthropometrics and vertical jump were conducted indoors, while those for the change-of-direction test and aerobic capacity took place outdoors in the afternoon on a synthetic field. Preceding the evaluations was a 48-hour rest period after the latest training session. The evaluation protocol consisted of the following sequential steps: (i) collection of demographic data, (ii) anthropometric assessments, (iii) warm-up comprising 5 minutes of running, 10 minutes of lower-limb dynamic stretching, and 5 minutes of acceleration actions, (iv) countermovement jump, (v) 5-0-5 COD test, and

(vi) 30-15 Intermittent Fitness Test. Each assessment was interspersed with a 5-minute rest interval. Standardization was maintained as all participants underwent the assessments in the same order and sequence during both evaluation periods.

The study protocol underwent thorough examination and received approval from the Ethics Committee of XX under code number 3/2024. Prior to initiation, participants and their legal guardians were briefed on the study's design, associated risks, and potential benefits. Furthermore, they were explicitly informed of their right to withdraw from the study at any point without incurring any penalties. Upon agreement from both participants and their legal guardians, the latter provided their signatures on a freely given informed consent document. The study adhered to the ethical guidelines outlined in the Declaration of Helsinki.

Participants

Prior to the study, the sample size was determined to an effect size of 0.25, considering three groups and two measurements. The aim was to achieve a statistical power of 0.85 while upholding a significance level of 0.05 for ANOVA repeated measures, within-between interaction. Analysis conducted using G*Power software (version 3.1.9., Universität Düsseldorf, Germany) indicated that the study should encompass 48 participants.

Upon recruiting into the soccer teams, an initial pool of 57 candidates was identified. However, subsequent screening based on the following eligibility criteria was conducted: (i) commitment to participate in both assessment phases, (ii) possession of a minimum of two years' experience in the sport, (iii) attendance at a minimum of 90% of regular training sessions, (iv) absence of injury or illness throughout the experiment or in the month prior to its start, (v) non-enrollment in supplementary training programs besides soccer training, and (vi) female gender. As a result, 48 participants met these criteria and were selected for inclusion in the study. These individuals were then evenly and randomly distributed across the three designated groups.

Among the 48 female participants, the average age was 17.1 ± 1.0 years, with a height of 1.62 ± 0.05 m, body mass of 55.3 ± 6.4 kg, and body mass index of 20.9 ± 1.9 kg/m^2. The SSG group (n = 16) had an average age of 17.2 ± 1.2 years, a body mass of 54.4 ± 6.5 kg, a height of 1.63 ± 0.06 m, and a body mass index of 20.5 kg/m^2. Meanwhile, the HIIT group (n=16) had an average age of 17.1 ± 0.8 years, a body mass of 55.5 ± 6.9 kg, a height of 1.63 ± 0.04 m, and a body mass index of 20.9 kg/m^2. Lastly, the control group (n = 16) exhibited an average age of 17.0 ± 1.1 years, a body mass of 56.0 ± 6.0 kg, a height of 1.62 ± 0.04 m, and a body mass index of 21.3 kg/m^2. All teams competed at the regional level, having 3 to 4 training sessions weekly, each lasting 80 to 90 minutes on the field.

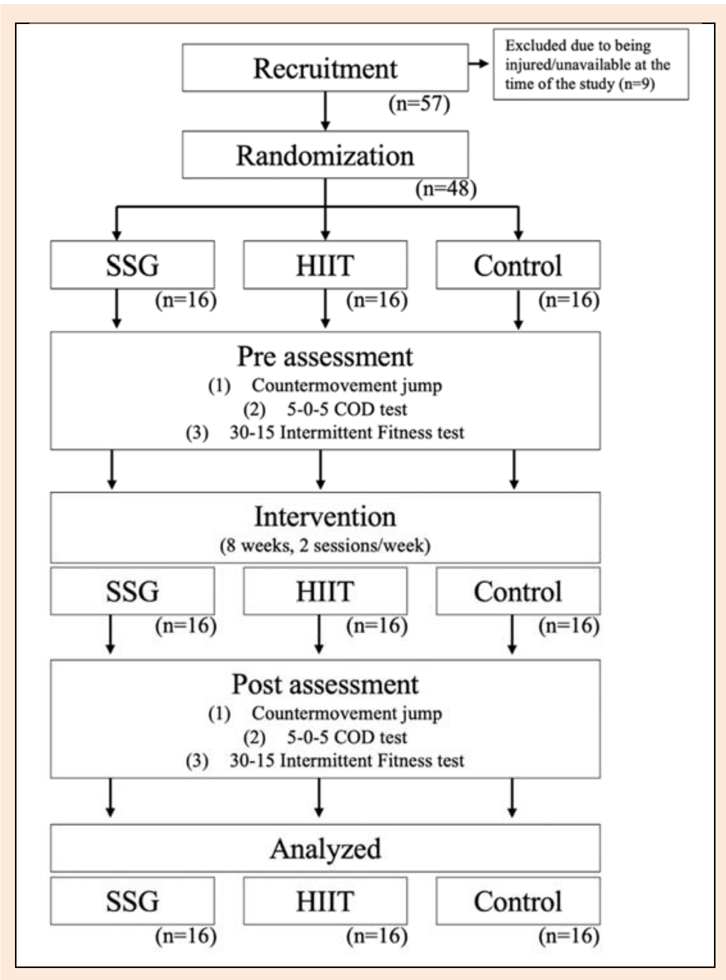

Figure 1. Participants flowchart.

Table 1. Description of the training regimens employed over the intervention period.

	SSG Session 1	SSG Session 2	HIIT Session 1	HIIT Session 2
Week 1	4×2'/3' rest Format of play: 2v2	4×2'/3' rest Format of play: 2v2	4×2'×15'':15'' @ 90%VIFT/3' rest	4×2'×15'':15'' @ 90%VIFT/3' rest
Week 2	4×2'/3' rest Format of play: 2v2	4×2'/3' rest Format of play: 2v2	4×2'×15'':15'' @ 90%VIFT/3' rest	4×2'×15'':15'' @ 90%VIFT/3' rest
Week 3	4×2'/3' rest Format of play: 2v2	4×2'/3' rest Format of play: 2v2	4×2'×15'':15'' @ 90%VIFT/3' rest	4×2'×15'':15'' @ 90%VIFT/3' rest
Week 4	4×2'/3' rest Format of play: 2v2	4×2'/3' rest Format of play: 2v2	4×2'×15'':15'' @ 90%VIFT/3' rest	4×2'×15'':15'' @ 90%VIFT/3' rest
Week 5	4×4'/3' rest Format of play: 4v4	4×4'/3' rest Format of play: 4v4	4×4'@ 85%VIFT/3' rest	4×4'@ 85%VIFT/3' rest
Week 6	4×4'/3' rest Format of play: 4v4	4×4'/3' rest Format of play: 4v4	4×4'@ 85%VIFT/3' rest	4×4'@ 85%VIFT/3' rest
Week 7	4×4'/3' rest Format of play: 4v4	4×4'/3' rest Format of play: 4v4	4×4'@ 85%VIFT/3' rest	4×4'@ 85%VIFT/3' rest
Week 8	4×4'/3' rest Format of play: 4v4	4×4'/3' rest Format of play: 4v4	4×4'@ 85%VIFT/3' rest	4×4'@ 85%VIFT/3' rest

SSG: small-sided games; HIIT: high-intensity interval training; VIFT: final velocity at 30-15 Intermittent Fitness Test; @: at; ': minutes; '': seconds.

Training intervention

The players assigned to the experimental groups (SSG and HIIT) underwent an additional 16 sessions over 8 weeks, with two sessions per week. These interventions were incorporated into the coach's regular training regimen, while the control groups continued solely with their standard training sessions. The specifics of the training interventions are outlined in Table 1. Participants in the HIIT group underwent a phased approach to their intervention. Initially, for four weeks, they engaged in short intervals, adjusting running intensity based on their individualized final velocity attained during the 30-15 Intermittent Fitness Test (30-15IFT). In the subsequent four weeks, they transitioned to long intervals, accompanied by an increase in overall training volume. Similarly, players in the SSG group began with smaller play formats (e.g., 2v2), typically associated with achieving a maximal heart rate percentage of about 90%. After four weeks, the format shifted to a longer duration of play, with the format expanding to 4v4, typically resulting in a heart rate intensity ranging from 85% to 90% of maximal heart rate. The duration of each session and the overall training load were consistent between SSG and HIIT groups (SSG: average 8.3 ± 1.2 A.U.; HIIT: average 8.5 ± 0.9 A.U.), with only the modality varying.

The intervention sessions preceded the regular team training sessions and were conducted and supervised by members of the research team. Players commenced each session with a standardized warm-up protocol consisting of 5 minutes of running, followed by 10 minutes of dynamic stretching for the lower limbs, and concluding with 5 minutes of acceleration exercises. Subsequently, on the synthetic turf, they engaged in the intervention activities.

For the SSG sessions, the 2v2 format was utilized on a pitch measuring 25x16 meters (100 m^2/player), with small goals positioned at each team's endline, measuring 2x1 meters. Similarly, the 4v4 format was implemented on a pitch measuring 35x23 meters (101 m^2/player), with identical small goals. In both formats, the offside rule was not implemented, and ball repositioning was conducted manually. Various balls (n > 4) were strategically placed around the pitch of each game to facilitate quick ball retrieval whenever it went out of bounds. No verbal encouragement was provided during gameplay. The teams were composed by the coach with the goal of balancing technical/tactical proficiency and playing positions. For 2v2 matches, one player more associated towards defensive roles and one towards attacking roles were required. In 4v4 matches, each team had to include at least one defender, one midfielder, and one attacker. These team compositions were predetermined and remained consistent across all sessions to optimize team dynamics. Only the opposing teams changed between sessions.

Similarly, during HIIT sessions, no verbal instructions were given. The HIIT protocol incorporated change-of-direction maneuvers at each stage, with running trajectories spanning 40 meters or adjusted based on individualized velocity.

To measure the intensity experienced by players during the intervention, they were prompted to report their perceived exertion at the conclusion of each intervention session. This involved scoring their response to the question, "How intense was the session?" on the CR-10 Borg scale (Borg, 1998), which was administered individually to each player. The reported scores were recorded and subsequently utilized for additional descriptive analysis.

Physical assessments

Soccer players underwent assessment twice, both before and after the intervention, under consistent conditions to ensure replicability. These assessments were conducted with a 48-hour rest period, on the same day of the week, and during the afternoon. Temperature conditions averaged 20.1 ± 2.1ºC, with a relative humidity of 58.2 ± 1.4%. The sequence of test procedures remained consistent, as did the order of player evaluations. A 5-minute rest interval was provided between tests.

Countermovement jump test

The countermovement jump (CMJ) with hands on hips was implemented. The soccer player started from a standing position, proceeded to swiftly lower their body by flexing the hips, knees, and ankles in a rapid downward motion. Following this phase, they immediately transitioned into a vertical leap, maintaining extended knees and hands on their hips throughout the movement, before returning to the ground. Each participant was given one familiarization attempt, followed by two recorded trials, with a 3-minute break between each trial. Jump height (in centimeters) was measured utilizing the MyJump 2 mobile application (version 1.0.8, Xiaomi 11i, China). The mobile phone and the examiner were positioned 3 meters from the player, with the camera's height set at 0.90 m using a tripod. Prior studies have reported the reliability and validity of this mobile application when compared to force plates (Haynes et al., 2019). The highest recorded jump height was selected for data analysis. The within-player variability was 2.2%.

5-0-5 COD test

The original version of the 5-0-5 test was employed in this study. This test entails accelerating at maximum intensity over a distance of ten meters, followed by a 5-meter sprint performed at maximal intensity. Subsequently, a 180° change-of-direction (COD) maneuver is executed, followed by another 5-meter maximal intensity sprint back to the starting point.

All players initiated their attempts with their preferred leg, and the braking phase at the COD line was also executed using the preferred leg. To maintain consistency, the same preferred leg was used for all attempts by each player. Each player completed two attempts, with a three-minute rest period provided between each attempt to facilitate adequate recovery.

For the starting position, players began 0.3 meters away from the first pair of photocells (Fusion Sport, Coopers Plains, Australia), positioned 60 centimeters above the ground and located at the starting line. Participants adopted a staggered stance, placing the same foot in front. The best time achieved from the two trials for each foot was used as the reference measurement, expressed in seconds. From these measurements, the COD deficit was assessed (Nimphius et al., 2016), quantifying the difference between the 10-meter COD time and the 10-meter linear sprint time measured during the initial acceleration phase of the test.

30-15 Intermittent Fitness Test

The 30-15 Intermittent Fitness Test (Buchheit, 2008) was applied to assess the aerobic fitness levels of the participants. This test involved alternating 30-second bursts of intense running with 15 seconds of active recovery. The intensity increased gradually as the test progressed, with the initial running speed set at 8 km/h. At each stage, the running speed rose by 0.5 km/h until the participant reached their maximum capacity, signaled by an audio prompt. The final velocity (stage) achieved by the player (VIFT) was recorded as the main measure of aerobic performance for subsequent data analysis.

Statistical procedures

Following the identification and resolution of potential outliers, descriptive statistics were compiled, presenting means and standard deviations. Prior to proceeding with inferential analyses, the normal distribution of the sample was evaluated and confirmed through the Kolmogorov-Smirnov test (p > 0.05). Furthermore, verification of homogeneity assumption was conducted using Levene's test (p > 0.05). Considering the study's design, which encompassed two assessments across three groups, a mixed ANOVA was deployed to scrutinize interactions between time and groups. This analytical approach also entailed the calculation of partial eta squared (η_p^2). The magnitude of effect sizes was interpreted according to predefined thresholds (Richardson, 2011): values above 0.01 were classified as small, those exceeding 0.06 were considered moderate, and values surpassing 0.14 were categorized as large. Additionally, post-hoc comparisons were undertaken via the Bonferroni test. Statistical computations were executed employing JASP software (version 0.18.3, University of Amsterdam, The Netherlands), with a predetermined significance level of p < 0.05.

Results

Table 2 presents the descriptive statistics obtained for the three groups in both moments of assessment (i.e., pre and post-intervention. No significant differences were found between groups on the pre-intervention assessments (p > 0.05).

Time × group analysis revealed significant interactions in CMJ ($F_{2,45}$ = 6.094; p = 0.005; η_p^2 = 0.213, large effect size) and VIFT ($F_{2,45}$ = 17.215; p < 0.001; η_p^2 = 0.433, large effect size), although no significant interaction were found in COD deficit ($F_{2,45}$ = 1.446; p = 0.246; η_p^2 = 0.060, moderate effect size).

Within-group analysis revealed that SSG significantly improved CMJ (2.19 cm; p < 0.001), COD deficit (0.180 s; p < 0.001), and VIFT (1.56 km/h; p < 0.001). HIIT group also significantly improved CMJ (0.98 cm; p = 0.029), COD deficit (0.092 s; p = 0.001), and VIFT (1.59 km/h; p < 0.001). No significant differences were found on control group regarding CMJ (0.05 cm; p = 0.903) and COD deficit (0.049 s; p = 0.062), although significant improvements were observed in VIFT (0.41 km/h; p = 0.017). Figure 2 illustrates the within-player variations in the three groups. Between-group analysis in post-intervention

Table 2. Descriptive statistics (mean ± standard deviation) of the physical outcomes between groups in both moments of assessment.

		SSG (n = 16)	HIIT (n = 16)	Control (n = 16)	Between-group analysis
CMJ (cm)	Pre	24.1 ± 2.4	23.9 ± 2.0	23.2 ± 2.0	$F_{2,45}$ = 0.723; p = 0.491; η_p^2 = 0.031
	Post	26.3 ± 1.8	24.8 ± 2.8	23.3 ± 2.1	$F_{2,45}$ = 7.059; p = 0.002; η_p^2 = 0.239
COD deficit (s)	Pre	0.67 ± 0.14	0.68 ± 0.14	0.74 ± 0.19	$F_{2,45}$ = 0.704; p = 0.500; η_p^2 = 0.030
	Post	0.56 ± 0.11	0.59 ± 0.13	0.69 ± 0.12	$F_{2,45}$ = 4.692; p = 0.014; η_p^2 = 0.173
VIFT (km/h)	Pre	14.9 ± 1.5	15.1 ± 1.4	15.0 ± 1.3	$F_{2,45}$ = 0.031; p = 0.970; η_p^2 = 0.001
	Post	16.5 ± 1.2	16.7 ± 1.1	15.4 ± 1.2	$F_{2,45}$ = 5.433; p = 0.008; η_p^2 = 0.195

SSG: small-sided games; HIIT: high-intensity interval training; CMJ: countermovement jump; COD: change-of-direction; VIFT: final velocity at 30-15 Intermittent Fitness Test.

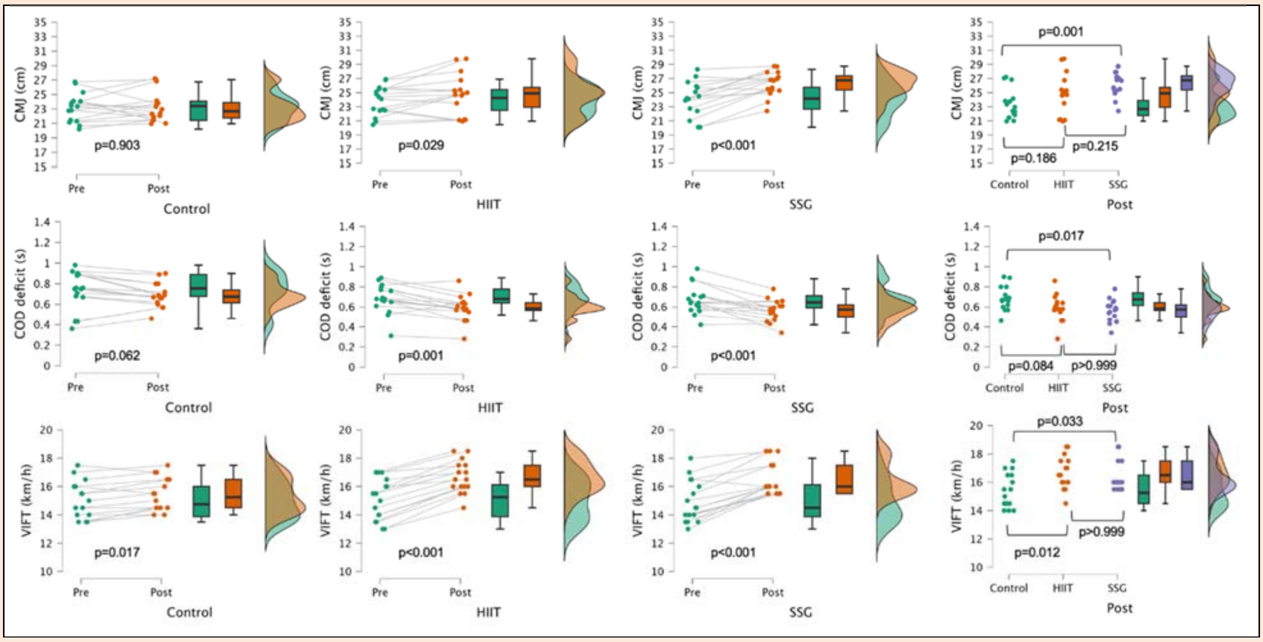

Figure 2. Graphical representation of the within and between-group differences. SSG: small-sided games; HIIT: high-intensity interval training; CMJ: countermovement jump; COD: change-of-direction; VIFT: final velocity at 30-15 Intermittent Fitness Test.

assessment (Figure 2) revealed that SSG had significantly greater CMJ than control (3.03 cm; $p = 0.001$), although no significant differences were found with HIIT (1.48 cm; $p = 0.215$). No significant differences were found between HIIT and control in CMJ (1.54 cm; $p = 0.186$). Considering the COD deficit, it was observed that SSG had significant smaller deficit than control group (0.122 s; $p = 0.017$), although no being significantly different from HIIT (0.027 s; $p > 0.999$). No significant differences were observed between HIIT and control (0.095 s; $p = 0.084$). Finally, control group presented significantly smaller VIFT in post-intervention assessment than SSG (1.09 km/h; $p = 0.033$) and HIIT (1.25 km/h; $p = 0.012$). No significant differences were found between SSG and HIIT (0.16 km/h; $p > 0.999$).

Discussion

The current research findings indicate that SSG led to significant improvements in vertical jump, change of direction performance, and aerobic capacity compared to the control group. Additionally, SSG demonstrated significantly superior outcomes compared to the control group in enhancing vertical jump and COD deficit. Conversely, HIIT showed significant improvements only in aerobic capacity compared to the control group. Thus, while both SSG and HIIT showed significant improvements within their respective groups, only SSG exhibited significant superiority over the control group across all analyzed outcomes. These results suggest that SSG is a highly effective training method for enhancing the performance of female players.

The experimental study showed that both SSG and HIIT significantly enhanced aerobic performance in the 30-15IFT by approximately 1.5 km/h, with both methods being significantly more effective than the control group, which shown an improvement of 0.4 km/h. These results are consistent with previous research indicating that both SSG and HIIT are equally effective in enhancing aerobic performance in male and female soccer players alike (Arslan et al., 2020; Nayıroğlu et al., 2022; He et al., 2024). SSGs are characterized by intense and repeated actions interspersed with brief periods of rest (Hill-Haas et al., 2011; Dellal et al., 2012), mimicking the intermittent nature of the 30-15IFT. These formats of play induce physiological adaptations such as increased aerobic capacity (Moran et al., 2019), anaerobic power (Eniseler et al., 2017), and muscular endurance (Querido and Clemente, 2020), all of which are crucial for improving performance on the 30-15IFT. Similarly, HIIT induces various physiological adaptations, including enhanced aerobic and anaerobic energy systems (Sporis et al., 2008), improved mitochondrial density (Michailidis et al., 2023), and increased lactate threshold (Jastrzebski et al., 2014). These adaptations may lead to improved cardiovascular function (Bonato et al., 2017), greater tolerance to high-intensity exercise, and enhanced recovery between intense efforts, all of which are directly relevant to performance on the 30-15IFT.

In our study, we observed significant improvements in CMJ following interventions with both SSG and HIIT. However, only SSG showed a significant difference compared to the control group. These findings appear somewhat contradictory to previous studies (Clemente et al., 2021), which have indicated that neither method is consistently effective in promoting improvements in this outcome. Nevertheless, certain individual studies have shown that both SSG and HIIT can indeed have a positive impact on CMJ (Arslan et al., 2020; Nayıroğlu et al., 2022; He et al., 2024). One possible factor contributing to this improvement is the neuromuscular adaptation induced by SSGs. Studies have shown that participation in SSGs can lead to increased neural drive and motor unit recruitment (Rebelo et al., 2016), resulting in enhanced muscle activation during explosive movements such as the CMJ. Furthermore, the dynamic and unpredictable nature of SSGs necessitates athletes to execute rapid changes in direction, accelerations, and decelerations (Chaouachi et al., 2014). These actions can enhance neuromuscular coordination and eccentric muscular engagement (Madison et al., 2019). Such adaptations are pivotal for maximizing CMJ performance, as they facilitate more efficient force production and transfer throughout the jump (Harper et al., 2020).

CMJ greatly relies on eccentric and concentric muscle actions, in the lower limbs SSGs, with their emphasis on rapid changes in direction, accelerations, and decelerations, likely provide more specific mechanical loading patterns that closely mimic the demands of jumping (Duggan et al., 2023). On the other hand, HIIT may not offered the same level of eccentric loading and explosive force development required for optimal CMJ performance in our study. Possibly the fewer decelerations and accelerations in SSGs may have contributed to a lesser accumulation of muscular strain, potentially explaining why, despite both the HIIT and SSG groups showing significant improvements in CMJ, the difference between the HIIT group and the control was not as pronounced as that between the SSG group and the control.

In our study, it was observed that both SSG and HIIT significantly enhanced COD deficit in female soccer players, although only SSG showed significant differences from the control group after the intervention. Similarly, this trend was observed in the case of CMJ. The literature reveals contradictory findings in this regard; while some studies suggest that SSG alone is insufficient to improve COD performance (Faude et al., 2014), in certain cases, HIIT also demonstrates superior benefits compared to SSG (Stojiljković, Gušić and Molnar, 2019). However, our study yielded somewhat different results. One possible factor contributing to the improved COD among players could be attributed to the use of very small formats played on small pitches, which increases exposure to multivariate directions involving changes in direction, acceleration, and deceleration (Krosta et al., 2020). Although the enhancement in ability from these games could be linked to anticipatory skills for changing direction (Young and Rogers, 2014), the physical manifestation measured by COD deficit also showed improvement.

From a technical standpoint, SSGs inherently involve frequent and rapid changes in direction, demanding players to execute footwork, proper body positioning, and effective anticipation of opponents' movements (Young et al., 2022). Through repetitive exposure to these dynamic situations, players enhance their neuromuscular coordination, and spatial awareness, thereby possibly improving their ability to execute efficient COD movements (Mota et al., 2022). Moreover, the tactical nature of SSGs encourages players to make quicker decisions and execute faster movements, further honing their COD skills (Davids et al., 2013).

Despite the valuable insights gained from this study, it is important to acknowledge certain limitations. Firstly, the intervention period lasted only 8 weeks, and there was no follow-up assessment over a longer term. Conducting such follow-ups could offer a more comprehensive understanding of the sustainability of the observed improvements and the potential impact of trainability in later stages, particularly regarding adaptations to SSG. Additionally, although efforts were made to standardize the training protocols for both SSG and HIIT groups, variations in individual efforts may have influenced the results. This is particularly pertinent in the case of SSG, where heterogeneity is inherent due to the dynamic nature of the games. Furthermore, the fact that some players acted as starters while others did not may play a particular role in the adaptations (Silva et al., 2022; Janusiak et al., 2024), although the average time played in non-official matches was similar across the groups. Furthermore, while the study primarily focused on physical performance outcomes, it did not assess other relevant factors such as tactical, technical, or psychological variables. Including these variables could provide a more holistic understanding of the effects of SSG and HIIT interventions. Future research endeavors should aim to address these limitations by conducting longer-term studies and identifying trainability as a potential moderator or mediator of adaptations. Moreover, monitoring impacts on tactical and technical levels would contribute to a more comprehensive evaluation of the interventions' effects. Lastly, it is crucial to consider the potential influence of trainability on the extent of adaptations, particularly since our study was conducted during the pre-season with regional-level athletes. It remains uncertain whether the observed results are replicable in higher competitive tiers, especially during the in-season period when trainability and potential for adaptations are reduced. Therefore, future research should aim to include high-competitive level athletes and compare the extent of adaptations across various stages of the season.

Despite its limitations, the research findings presented highlight practical implications for training processes in female soccer players. SSG emerge as a highly effective training method, demonstrating significant improvements in vertical jump, COD performance, and aerobic capacity compared to control groups. The dynamic and unpredictable nature of SSGs fosters neuromuscular performance and rapid decision-making, crucial for enhancing COD movements. Moreover, SSGs may offer specific mechanical loading patterns aimed at benefiting jumping demands, potentially leading to superior improvements in CMJ performance compared to HIIT. Despite both SSG and HIIT significantly enhancing aerobic performance, SSGs simulate the intermittent nature of the 30-15 Intermittent Fitness Test more effectively. Although both methods show improvements in CMJ and COD, SSGs exhibit more pronounced benefits compared to HIIT, likely due to the emphasis on rapid changes in direction inherent in SSG formats. These findings highlight the importance of integrating SSGs into training regimes to enhance physical performance, emphasizing the need to incorporate diverse training methodologies personalized to specific athletic demands.

Conclusion

In conclusion, the findings of the current research emphasize the efficacy of SSG as a highly effective training method for improving the performance of female soccer players across various parameters. Compared to HIIT and the control group, SSG yielded significant enhancements in vertical jump, COD performance, and aerobic capacity. Particularly important was SSG's superiority in improving vertical jump and COD deficit compared to the control group, suggesting its efficacy in addressing specific athletic demands. The observed improvements in COD and vertical jump following SSG interventions can be attributed to the game's inherent emphasis on rapid changes in direction, and explosive actions. Moreover, SSGs appear to provide more specific mechanical loading patterns conducive to optimizing jumping performance. On the other hand, both SSG and HIIT demonstrated significant and similar improvements in aerobic capacity. Despite improvements observed with both methods in vertical jump and COD, SSGs exhibited more pronounced benefits, likely due to their dynamic and unpredictable nature. These findings emphasize the importance of integrating SSGs into training programs for female soccer players. However, it is essential to acknowledge the study's limitations, such as the relatively short intervention period and the need for further exploration of tactical, technical, and psychological variables.

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The authors declare that there are no conflicts of interest. The experiments comply with the current laws of the country where they were performed. The data that support the findings of this study are available on request from the corresponding author.

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Key points

- SSGs lead to greater improvements in vertical jump and change-of-direction abilities compared to HIIT among female soccer players.
- Both SSG and HIIT groups demonstrated significant improvements in aerobic capacity, suggesting comparable effectiveness in this aspect of fitness training.
- SSGs offer superior benefits in addressing specific athletic demands like vertical jump and change-of-direction deficit, attributed to their dynamic and unpredictable nature, emphasizing the importance of integrating them into training programs for female soccer players.

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