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Research article

Sex Influences the Extent of Physical Performance Adaptations in Response to Small-Sided Games and Running-Based High-Intensity Interval Training: A Parallel Study Design Involving Men and Women Soccer Players

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Abstract

The aim of this study was two-fold: (i) to compare physical fitness adaptations following small-sided games (SSG) and running-based high-intensity interval training (HIIT), considering sex interactions; and (ii) to describe intra-individual variations of adaptations in both men and women developmental/trained soccer players over an 8-week randomized parallel study design involving 25 women and 27 men. Pre and post-intervention assessments included countermovement jump (CMJ), 10-meter linear sprint test, change-of-direction (COD) deficit, and final velocity at 30-15 Intermittent Fitness Test (VIFT). Significant interactions between time, groups and sex were found in 10-m sprint ($F_{1,48}$ = 6.042; p = 0.018; η_p^2 = 0.112). No significant interactions between time, groups and sex were found in CMJ (F $F_{1,48}$ = 0.609; p = 0.439; η_p^2 = 0.013), COD deficit (F $F_{1,48}$ = 2.718; p = 0.106; η_p^2 = 0.054) and VIFT (F $F_{1,48}$ = 1.141; p = 0.291; η_p^2 = 0.023). Significant interactions were found between time and sex in CMJ (F $F_{1,48}$ = 29.342; p < 0.001; η_p^2= 0.379), 10-m sprint (F $F_{1,48}$ = 4.359; p = 0.042; η_p^2 = 0.083), COD deficit (F $F_{1,48}$ = 5.066; p = 0.029; η_p^2= 0.095) and VIFT (F $F_{1,48}$ = 11.248; p = 0.002; η_p^2 = 0.190). In conclusion, this study suggests similar effects of HIIT in both sexes. However, for women, SSG may entail less efficacy and more inter-individual variability compared to men. Therefore, HIIT could potentially be a better solution for women, whereas both training approaches were equally effective in men.

Key words: Football, physical fitness, aerobic, drill-based games.

Introduction

Soccer performance necessitates a well-conditioned physical fitness status, allowing players to effectively demonstrate their skills during a match (Stolen et al., 2005; Aquino et al., 2020). Essential physical attributes encompass the capability to sustain repeated physical efforts, requiring solid aerobic performance (Hoff, 2005; Manzi et al., 2022), in conjunction with the ability to execute powerful muscular actions like accelerations, changes of direction (COD), or jumps. Maintaining an optimal physical fitness status ensures the capacity to cover extended distances (11-14 kilometers), alternating between low-to-moderate activities and maximal efforts (Dolci et al., 2020). Furthermore, sustaining a high level of ability to perform powerful muscular actions can be particularly crucial during duels and pivotal moments in the match, such as counter-attacks (Otero-Esquina et al., 2017; Asian-Clemente et al., 2022b).

One effective method to enhance aerobic performance while inducing neuromuscular strain is through the implementation of high-intensity interval training (HIIT) (Buchheit and Laursen, 2013a; c). This approach involves repeated intense efforts typically performed at sub-maximal levels (e.g., short and long intervals) (Buchheit and Laursen, 2013a). HIIT seems to be effective in taxing aerobic metabolism, particularly under more intense running demands, while stimulating the neuromuscular system (Fransson et al., 2018).

HIIT is recognized for its effectiveness in improving aerobic performance, as well as jump performance and acceleration in soccer players (Clemente et al., 2021c). However, traditional running-based HIIT may be less enjoyable for soccer players compared to utilizing ecological-based drills (Selmi et al., 2020). Consequently, the incorporation of small-sided games (SSGs), which involve game-based scenarios (Clemente and Sarmento, 2020) with simplified and adjusted versions of the formal game (e.g., reducing the format of play and pitch sizes), becomes an interesting alternative (Clemente et al., 2021a). This ensures proximity to the context of practice while providing a comparable physiological and locomotor stimulus to traditional running-based HIIT (Moran et al., 2019).

Research has been conducted to compare the effects of SSG and running-based HIIT interventions on aerobic (Massamba et al., 2021; Boraczyński et al., 2023), jumping, acceleration, and COD (Kunz et al., 2019) performance in soccer players. For instance, a recent meta-analysis observed that SSGs appear to contribute similarly on aerobic performance adaptation as short or long HIIT training formats in men soccer players (Clemente et al., 2024). Conversely, HIIT seems to offer more benefits than SSGs in improving acceleration running or COD compared to SSGs (Clemente et al., 2022). In the case of jumping performance, both interventions seem to provide similar effects, although not significant enough to induce positive adaptations in soccer players (Clemente et al., 2021b).

Despite the evidence found in men players, research on women is notably underrepresented. While the comparisons between SSG and HIIT are well-established in men's soccer, there is only one known article published (to our knowledge) that explores this in women (Nayıroğlu et al.,

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2022). This study revealed that both interventions were effective in improving vertical and horizontal jump performance, COD, and aerobic capacity in women (Nayıroğlu et al., 2022). Given the growing competitiveness of women in soccer, it is clear a research gap in this population. Understanding the magnitude of the impact of SSG and HIIT while considering sex differences can be highly valuable, as this aspect is not well-documented in the existing literature.

Previous studies comparing men and women have explored potential biological sex influences on exercise adaptation. However, such influences have not been consistently observed in healthy, non-sport-trained populations, as demonstrated in a recent meta-analysis incorporating 28 trials examining the effects on maximal oxygen uptake (Lock et al., 2024). Conversely, in trained populations, differences in the impact of interventions such as HIIT between men and women have been noted (Hoffmann et al., 2021). Additionally, sex-effect interactions on the magnitude of muscular adaptations after training have been observed (Martel et al., 2006). Despite these findings, limited information exists regarding the implications of biological sex interactions on the magnitude of adaptations within the context of soccer training.

Moreover, considering that the magnitude of differences can depend on the interaction of individuals with the training stimulus, as well as being influenced by concurrent factors such as trainability, genetic predisposition, and the timing of the season (Mann et al., 2014), among others, there is a lack of research that specifically addresses within-player variation and identifies the ability of training programs to elicit higher responders and identify possible programs that may have more non-responders. This variability must also be considered since, to the best of our knowledge, it has not been consistently addressed in SSG and HIIT interventions.

This study aims to address this gap by being the first to compare the effects of SSG and HIIT in both men and women populations, evaluating them in terms of the magnitude of physical fitness adaptations. The main objectives of this research are: (i) to compare physical fitness adaptations following SSG and HIIT, considering sex interactions; and (ii) to describe intra-individual variations in adaptations among men and women developmental/trained soccer players using a randomized parallel study design. We hypothesize that significant differences between genders may arise in both training groups, particularly in aerobic performance and muscular-related tests (Martel et al., 2006).

Methods

Study design

This study utilized a randomized parallel study design to compare SSG with HIIT. A convenience sampling strategy was employed to identify suitable teams and players. Within each selected team, half of the players participated in SSG, while the other half engaged in HIIT. Simple randomization of players into the groups was carried out using sealed letters. The selection of players was done randomly by an individual not connected with the study. Both the randomization and group allocation processes were completed prior to the initial assessment. While the participants and coaches were not blinded to the study, the evaluators were kept unaware of the study details. As a result, they were not informed about the group assignments of the players.

The research followed ethical standards for research involving human subjects, as stipulated in the Declaration of Helsinki. After presenting the study to the participants, they signed a freely given informed consent form that explicitly stated the possibility to withdraw voluntarily at any time without any penalty. In instances where individuals are not legally responsible due to their age (<18 years old), the informed consent was signed by their legal guardians. Approval for the study's ethical considerations was granted by the Institutional Ethical Review Board of Chengdu Institute of Physical Education, and the reference code for the approval is 2023#104.

Context

The intervention lasted 8 weeks, with physical fitness assessments taking place in the week preceding and the week following the intervention. The intervention duration aligns with typical training interventions in SSGs and HIIT, which commonly range between 6 and 8 weeks, as reported in a prior systematic review and meta-analysis on the subject (Clemente et al., 2024).

In the week before the intervention commencement, players underwent assessments for jumping performance, acceleration, COD, and aerobic performance, following this specific sequence. These tests were conducted 48 hours after the latest training, and players were required to rest during this period. A similar approach was employed for the post-intervention assessment. The intervention was implemented in the early phase of the season, specifically 3 weeks after the beginning of the pre-season.

Participants

The a priori sample size estimation was based on the mean values of the COD deficit from a previous study comparing SSG vs HIIT in women (Nayıroğlu et al., 2022). Using G*Power (version 3.1.9.6., Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) for repeated measures between factors, considering 4 groups and 2 measurements, with a significance level (alpha) of 0.05 and a power of 0.85, the calculated sample size required for the study was 44 individuals.

The eligibility criteria for this study were as follows: (i) being an outfield player; (ii) not sustaining an injury during the intervention period or within the two weeks preceding the intervention; (iii) attending no fewer than 90% of the training intervention sessions; and (iv) not missing the physical fitness assessments. The exclusion criteria considered were: (i) players who missed any of the testing sessions; (ii) players who did not meet the adherence requirement of 90%.

After identifying the teams (one in women and one in men), the players were invited to participate in the study. Out of the 27 players available for the women's soccer team, 25 were included, with the exclusion of two goalkeepers (GKs). Similarly, among the 30 players available for the men's soccer team, three were excluded due to their GK position.

The average age of the 25 women soccer players was 18.2±0.8 years, with an average body mass of 54.2±7.7 kilograms, an average height of 162.5±4.9 centimeters and a body mass index of 20.5±2.6 kg/m^2. For the 27 men, the average age was 18.7±0.9 years, with an average body mass of 66.4±9.1 kilograms, an average height of 178.0±6.2 centimeters and a body mass index of 20.9±2.1 kg/m^2. The players belonged to a regional-level under-19 women's soccer team and an under-19 men's soccer team, both engaging in regular training sessions consisting of four sessions per week along with an additional match. The women's players had an average playing experience of 4.1±0.8 years, while the men's players had an average playing experience of 5.2±0.7 years.

Training intervention

Within each team, all players underwent the same collective training. However, within each team, they also received an additional intervention, with half of the team participating in the SSG training intervention and the other half in the HIIT training group (Figure 1). These interventions took place twice a week, with a 48-hour gap between them. Prior to each intervention, a standardized warm-up protocol was implemented, comprising an 8-minute jog, dynamic stretching with 15 repetitions for each of the major muscle groups (hips, glutes, quadriceps, hamstrings, and gastrocnemius), and a series of jumps including 5 squat jumps, 5 unilateral vertical jumps, 5 horizontal jumps, and 5 horizontal unilateral jumps. The interventions were immediately conducted in the early phase of the session, and the activities took place on an artificial grass surface.

The SSG training group engaged in a weekly session that involved four sets of 3-minute repetitions, separated by 2 minutes of rest, utilizing 3v3 and/or 3v3+1 formats. The alteration in SSG format was intended to diversify the stimuli and enhance the training regimen. It has been observed that in the absence of a floater, the intensities are smaller (Asian-Clemente et al., 2022a). Therefore, these games were initially introduced. Subsequently, as weeks progressed, games without floaters were introduced to gradually intensify the training regimen. GKs were not included, and a small goal was positioned at the center of the endline. The pitch dimensions were set at 30 by 22 meters. In the second weekly session, the team executed two sets of 6-minute repetitions, interspaced by 2 minutes of rest, using 6v6 and/or 7v6 formats, again without a GK, and employing a small goal centered on the endline. The pitch size for this session was increased to 40 by 32 meters. Team assignments were determined by the coaches, who used subjective perception to ensure competitiveness against opponents while striving to balance teams based on playing positions.

In the context of the HIIT groups, during the initial training session of the week, participants executed four sets of short intervals lasting 3 minutes each, with a work-to-rest ratio of 15 seconds of exertion followed by 15 seconds of rest. The running intensity during the work phase was set at 95% of the final velocity achieved in the 30-15 Intermittent Fitness Test (VIFT), while the rest periods were passive. In the second weekly session, the HIIT regimen involved four sets of 3-minute intervals at 85% of VIFT, with 2 minutes of rest between each set. The running was performed in a straight line across the field.

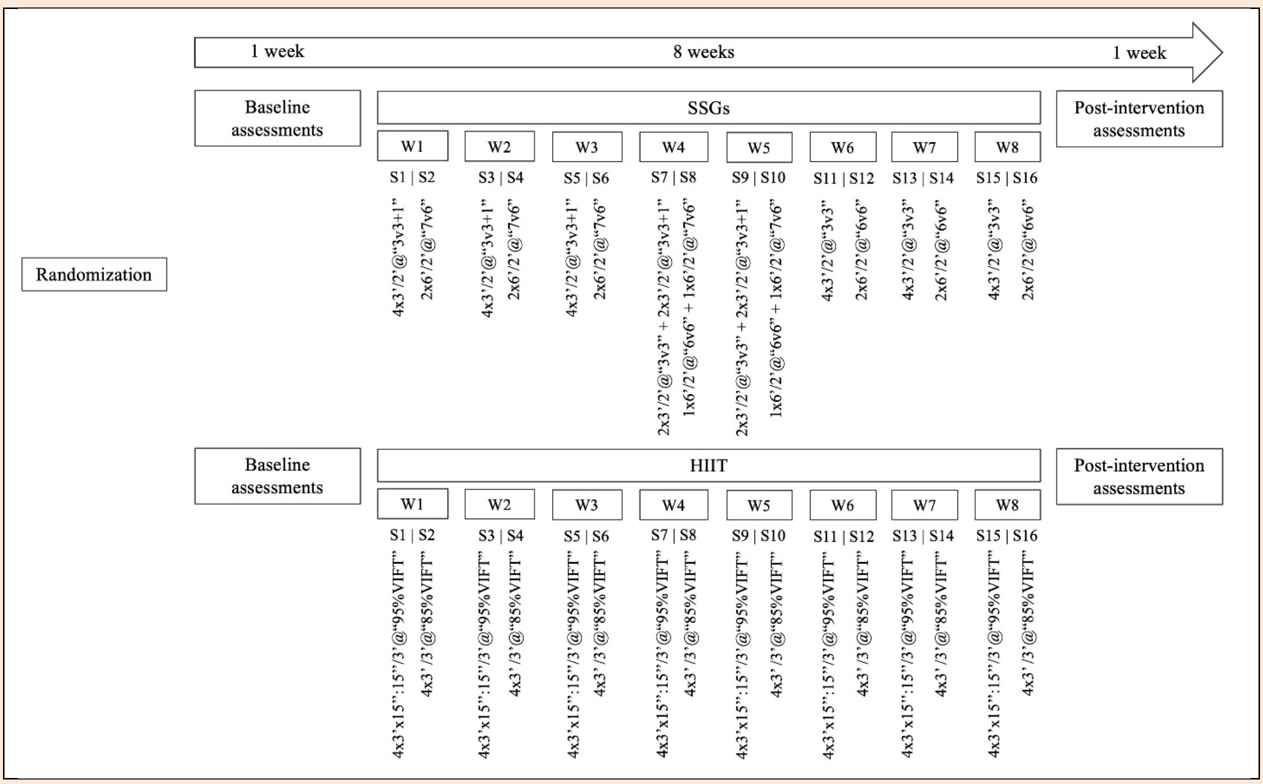

Figure 1. Illustration of the study design and training interventions. SSGs: small-sided games; HIIT: high-intensity interval training; W: week; S: session; VIFT: final velocity at 30-15 Intermittent Fitness test; : 'minutes; '': seconds; @: at.

Both groups received an additional 24-minute training supplement per week, either in SSG or HIIT, ensuring balanced exposure time. The regimen was diversified: in SSG, the first day was more intensive, employing a 3v3 format (4 sets of 3 minutes each), while the second session adopted a more extensive approach (2 sets of 6 minutes each). Similarly, participants in HIIT underwent a more intense first day (4 sets of 3 minutes with 15-second high-intensity and 15-second recovery intervals) and a more extensive second day (4 sets of 3 minutes each). These training interventions are in line with recommendations for the use of both SSG and HIIT, supported by previous studies (Little and Williams, 2006; Little, 2009; Buchheit and Laursen, 2013a; Buchheit and Laursen, 2013a). In the case of 6v6, it was used to moderate heart rate responses, allowing for longer practice sessions, while the decrease in intensity in HIIT on the second day followed the same rationale (Little and Williams, 2006; Little, 2009; Buchheit and Laursen, 2013a; Buchheit and Laursen, 2013b). In the case of SSGs, where adaptations to training are less individualized compared to HIIT, adjustments were made, including the incorporation of a floater, with the aim of beginning with a smaller physiological impact in line with existing literature (Asian-Clemente et al., 2022a), and then progressing to a more intense stimulus. The challenge of individualizing the stimulus in SSGs led us to employ this accommodation and adaptation strategy.

Physical assessments

Previous studies have suggested that both SSGs and HIIT are effective in enhancing aerobic capacity and the ability to perform repeated efforts, as evidenced by their alignment with intermittent tests such as the 30-15 Intermittent Fitness Test (Arslan et al., 2020; Nayıroğlu et al., 2022). Moreover, the 30-15 Intermittent Fitness Test is specifically designed to regulate HIIT, providing individual scores to control intensities (Buchheit, 2008). Additionally, due to the muscular tension and contractions involved in SSGs and HIIT, there may be potential impacts on muscular power (Rebelo et al., 2016). Therefore, the countermovement jump test was conducted to identify any possible consequences on this variable. Furthermore, both HIIT and SSGs often involve change-of-direction (COD) actions, which are complemented by acceleration profiles post-direction change (Young et al., 2015). In light of this, measurements were taken for acceleration at 10 meters and COD performance.

The assessments took place in the afternoon period, specifically at 4 pm, with players receiving their last meal two hours prior. Anthropometric measurements were taken using a stadiometer (213 SECA, Hamburg), while body mass was measured using a digital scale (Xiaomi Smart Scale, China). The evaluations were conducted on a synthetic turf, and the environmental conditions during the assessments were 20.1±1.7º Celsius with 60.1±2.3% relative humidity. The external evaluators, who were unaware of the players' allocation, held certifications in physical education and sports sciences, with over three years of experience in conducting sports assessments within the context of soccer. All players were familiar with the tests as they were routine components of their club activities.

Countermovement jump

The countermovement jump (CMJ) was employed to assess the vertical jump height of participants. Athletes began in a standing position with hands on their hips. They executed a swift downward movement by bending their knees and hips before promptly extending their lower body to achieve a vertical jump. The jump height was measured using the mobile application MyJump 2 (version 1.0.8, Xiaomi 11i, China), which has consistently demonstrated concurrent validity against gold-standard methods such as force plates and has also shown reliability (Haynes et al., 2019).

Participants underwent one familiarization attempt, followed by three trials interspaced by 30 seconds. The within-player variability between trials, expressed as a coefficient of variation, averaged 3.1%. The best height of the three jumps (expressed in centimeters) was used for further data analysis.

Acceleration performance at 10-meter linear sprint test

The acceleration performance during the 10-meter linear sprint test was conducted on a synthetic turf. Participants initiated the sprint from a split position, utilizing their preferred leg in the front. Starting 20 cm before the initial pair of photocells, they were instructed to maintain a consistent starting position and keep the same leg in front.

Upon the beginning signaled by a regression countdown in seconds, participants were instructed to initiate deceleration only after crossing the last pair of photocells. The height of the photocells was adjusted to match the hip height of the players. The sprint time was measured using two pairs of photocells (SmartSpeed, Fusion Sport, Queensland, Australia). The players performed two trials of 10-meter linear sprint, interspaced by 3 minutes of rest. The within-player variability between trials, expressed as a coefficient of variation, averaged 2.3%. The best time of the two sprints (expressed in seconds) was used for further data analysis.

Change-of-direction deficit

The original version of the 5-0-5 COD test was employed. Participants began in a split position, with their preferred leg in the front. After a 10-meter acceleration phase, they were monitored for the first 5 meters, a 180º COD, and then the return 5 meters (Ryan et al., 2022). The timings for the two 5-meter segments were recorded as the COD time and were subsequently subtracted from the 10-meter linear sprint time to calculate the COD deficit. This measure more accurately reflects COD ability (Nimphius et al., 2016), as COD time is significantly influenced by linear sprint performance (Sayers, 2014).

Players were instructed to consistently use the same preferred leg during the 180º COD. The COD time was measured using a pair of photocells (SmartSpeed, Fusion Sport, Queensland, Australia). The players performed two trials, interspaced by 3 minutes rest. The within-player variability between trials, expressed as a coefficient of variation, averaged 2.7%. The best COD deficit of the two trials (expressed in seconds) was used for further data analysis.

The 30-15 Intermittent Fitness Test

The original version of the 30-15 Intermittent Fitness Test was implemented to assess players' ability to perform progressive intermittent efforts until exhaustion (Buchheit, 2008). The test comprised a series of 30-second shuttle runs with 15 seconds of passive recovery, guided by audio beeps that dictated the pace (Buchheit, 2008). The initial running speed was set at 8 km/h and increased progressively by 0.5 km/h in each subsequent 30-second round. The test concluded when the participant could no longer maintain the required pace or chose to withdraw due to fatigue. The final outcome was determined by the latest running speed achieved in a completed 30-second round, representing the final velocity in the 30-15 Intermittent Fitness Test (VIFT) expressed as kilometer per hour.

Rate of perceived exertion

During the intervention sessions, players were instructed to rate their exertion using Borg's CR10 perceived exertion scale, a scale previously validated for its reliability in measuring effort intensity (Borg, 1982). This rating was requested 5 minutes after the intervention's conclusion and prior to any remaining in-field activities, ensuring focus solely on the implemented intervention (i.e., SSG and HIIT). Responding to the question "How intense were the exercises?" players individually provided a score between 0 and 10, supported by verbal anchors consistent with the original CR10 scale (Borg, 1982) and transcultural translation. These scores were then documented by individual researchers on a recording sheet. Given the players' prior familiarity and routine use of the scale, no additional familiarization was necessary. Scores were recorded for each session conducted.

Statistical analysis

In the results section, we presented descriptive statistics, including mean and standard deviation, along with the percentage of differences expressed as (post-pre/pre) * 100. Following confirmation of the normality and homogeneity of the data using the Kolmogorov-Smirnov test ($p > 0.05$) and Levene's test ($p > 0.05$), we proceeded with inferential statistical analysis. To compare both within and between groups while accounting for sex, we utilized a mixed repeated measures analysis of variance (ANOVA). Effect sizes for ANOVA were reported using partial eta squared. The interpretation of the effect size was conducted utilizing partial eta squared, with thresholds defined as follows: values greater than 0.01 were considered small, those exceeding 0.06 were deemed moderate, and those surpassing 0.14 were classified as large (Richardson, 2011). Post hoc analysis was conducted through Bonferroni tests. All statistical analyses (i.e., descriptive statistics, Kolmogorov-Smirnov test, Levene's test, mixed repeated measures ANOVA, partial eta squared and Bonferroni tests) were carried out using SPSS software (version 29.0.0., IBM SPSS Statistics, Armonk, NY: IBM Corp), with a significance level set at $p < 0.05$.

Results

Table 1 presents the descriptive statistics of physical performance variables of both sexes and groups pre and post-interventions. Baseline comparisons revealed no significant differences between groups (SSG vs. HIIT) in men considering the CMJ (p = 0.761; d = 0.119), 10-m sprint time ($p = 0.237$; d = 0.467), COD deficit ($p = 0.691$; d = 0.155) and VIFT (p = 0.786; d = 0.106). Baseline comparisons between the women's groups (SSG vs. HIIT) showed no significant differences in COD deficit ($p = 0.643$; d = 0.188) and VIFT ($p = 0.626$; d = 0.591). However, SSG exhibited significantly greater CMJ ($p = 0.004$; d = 1.267) and faster 10-meter sprint times ($p < 0.001$; d = 1.551).

There was a significant main effect of time on CMJ ($F_{1,48} = 99.612$; $p < 0.001$; $\eta_p^2 = 0.675$) excluding the interaction with groups and sex. No significant interactions between time, groups and sex were found in CMJ ($F_{1,48} = 0.609$; $p = 0.439$; $\eta_p^2 = 0.013$) and time and group ($F_{1,48} = 1.429$; $p = 0.238$; $\eta_p^2 = 0.029$), although significant interactions were found between time and sex ($F_{1,48} = 29.342$; $p < 0.001$; $\eta_p^2 = 0.379$). Group*sex interaction revealed that in SSG, women had significantly smaller CMJ than men (mean difference: −15.084cm; $p < 0.001$), as well as, in HIIT (mean difference: −17.808cm; $p < 0.001$). However, in women no significant differences were found between SSG and HIIT (mean difference: 2.987cm; $p = 0.151$) as well as in men (mean difference: 0.264cm; $p = 0.894$).

Table 1. Descriptive statistics (mean ± standard deviation) of physical fitness pre and post intervention.

		Women SSG (n=12)	Women HIIT (n=13)	Men SSG (n=14)	Men HIIT (n=13)	Mixed repeated measures ANOVA
CMJ (cm)	**Pre**	24.6±2.5	21.8±1.8	36.1±7.5	37.0±6.9	Time*sex*group (p=0.439;η_p^2=0.013)
	Post	27.4±3.1	24.2±3.2	46.0±8.4	44.6±5.3	Time*sex (p<0.001;η_p^2=0.379)
	Post-pre (%Δ)	+11.4%	+11.0%	+27.4%	+20.5%	Time*group (p=0.238;η_p^2=0.029)
10-m sprint (s)	**Pre**	2.00±0.09	2.13±0.08	1.78±0.14	1.85±0.15	Time*sex*group (p=0.018;η_p^2=0.112)
	Post	1.99±0.08	2.06±0.12	1.69±0.13	1.78±0.11	Time*sex (p=0.042;η_p^2=0.083)
	Post-pre (%Δ)	−0.5%	−3.3%	−5.1%	−3.8%	Time*group (p=0.344;η_p^2=0.019)
COD deficit (s)	**Pre**	0.68±0.16	0.71±0.15	0.22±0.3	0.22±0.01	Time*sex*group (p=0.106;η_p^2=0.054)
	Post	0.57±0.11	0.68±0.12	0.21±0.03	0.21±0.02	Time*sex (p=0.168;η_p^2=0.039)
	Post-pre (%Δ)	−16.2%	−4.2%	−4.5%	−4.5%	Time*group (p=0.029;η_p^2=0.095)
VIFT (km/h)	**Pre**	15.3±1.6	15.0±1.3	17.2±1.0	17.1±1.0	Time*sex*group (p=0.291;η_p^2=0.023)
	Post	16.5±1.5	16.5±1.3	19.3±1.1	19.1±1.1	Time*sex (p=0.002;η_p^2=0.190)
	Post-pre (%Δ)	+7.8%	+10.0%	+12.2%	+11.7%	Time*group (p=0.533;η_p^2=0.008)

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

There was a significant main effect of time on 10-m sprint ($F_{1,48}$ = 43.188; p < 0.001; η_p^2 = 0.474) excluding the interaction with groups and sex. Significant interactions between time, groups and sex were found in 10-m sprint ($F_{1,48}$ = 6.042; p = 0.018; η_p^2= 0.112) and time and sex ($F_{1,48}$ = 4.359; p = 0.042; η_p^2 = 0.083), although no significant interactions were found between time and group ($F_{1,48}$ = 0.915; p = 0.344; η_p^2 = 0.019). Group*sex interaction revealed that in SSG, women had significantly worse 10-m sprint than men (mean difference: –0.265s; p< 0.001), as well as, in HIIT (mean difference: –0.283s; p< 0.001). Significant differences were found between SSG and HIIT in women (mean difference: 0.100s; p = 0.031), although not in men (mean difference: 0.082s; p= 0.064).

There was a significant main effect of time on COD deficit ($F_{1,48}$ = 9.557; p = 0.003; η_p^2 = 0.166) excluding the interaction with groups and sex. No significant interactions between time, groups and sex were found in COD deficit ($F_{1,48}$ = 2.718; p = 0.106; η_p^2 = 0.054) and time and group ($F_{1,48}$ = 1.958; p = 0.168; η_p^2 = 0.039), although significant interactions were found between time and sex ($F_{1,48}$ = 5.066; p = 0.029; η_p^2 = 0.095). Group*sex interaction revealed that in SSG, women had significantly worse COD deficit than men (mean difference: 0.414s; p < 0.001), as well as, in HIIT (mean difference: 0.484s; p < 0.001). Significant differences were found between SSG and HIIT in women (mean difference: 0.070; p = 0.040), although not in men (p = 0.998).

There was a significant main effect of time on VIFT ($F_{1,48}$ = 416.232; p < 0.001; η_p^2 = 0.897) excluding the interaction with groups and sex. No significant interactions between time, groups and sex were found in VIFT ($F_{1,48}$ = 1.141; p = 0.291; η_p^2= 0.023) and time and group ($F_{1,48}$ = 0.393; p = 0.533; η_p^2 = 0.008), although significant interactions were found between time and sex ($F_{1,48}$ = 11.248; p = 0.002; η_p^2 = 0.190). Group*sex interaction revealed that in SSG, women had significantly smaller VIFT than men (mean difference: –2.336 km/h; p < 0.001), as well as, in HIIT (mean difference: –2.346 km/h; p < 0.001). No significant differences were found between SSG and HIIT in women (mean difference: 0.146 km/h; p = 0.762) as well as in men (mean difference: 0.136 km/h; p = 0.770). Figure 2 illustrates the interactions between sex and groups in relation to the post-pre variations observed in the analyzed outcomes.

Figure 3 exhibits individual variations among players in response to the interventions. Examining changes in CMJ, all men demonstrated improvements (100%), regardless of the training group. For women, 83.3% in SSG and 84.6% in HIIT improved their CMJ. Regarding 10-meter sprint time, 100% of men and 50% of women in SSG groups showed performance improvement, while in HIIT groups, 92.3% of men and 84.6% of women improved their times.

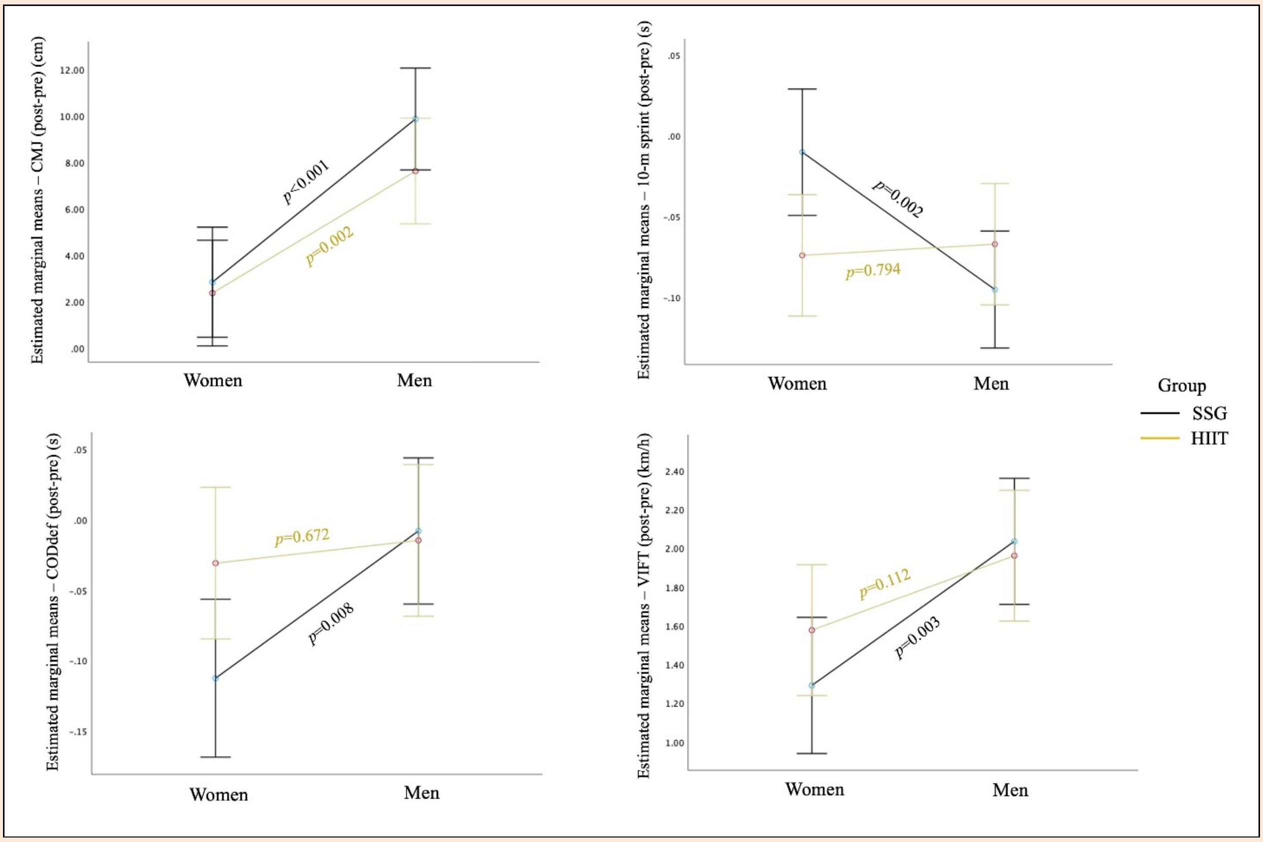

Figure 2. Estimated marginal means (95% confidence intervals) for the pro-pre contrasts considering the comparisons between men and women in both experimental groups. SSGs: small-sided games; HIIT: high-intensity interval training; CMJ: countermovement jump; COD: change-of-direction; VIFT: final velocity at 30-15 intermittent fitness test.

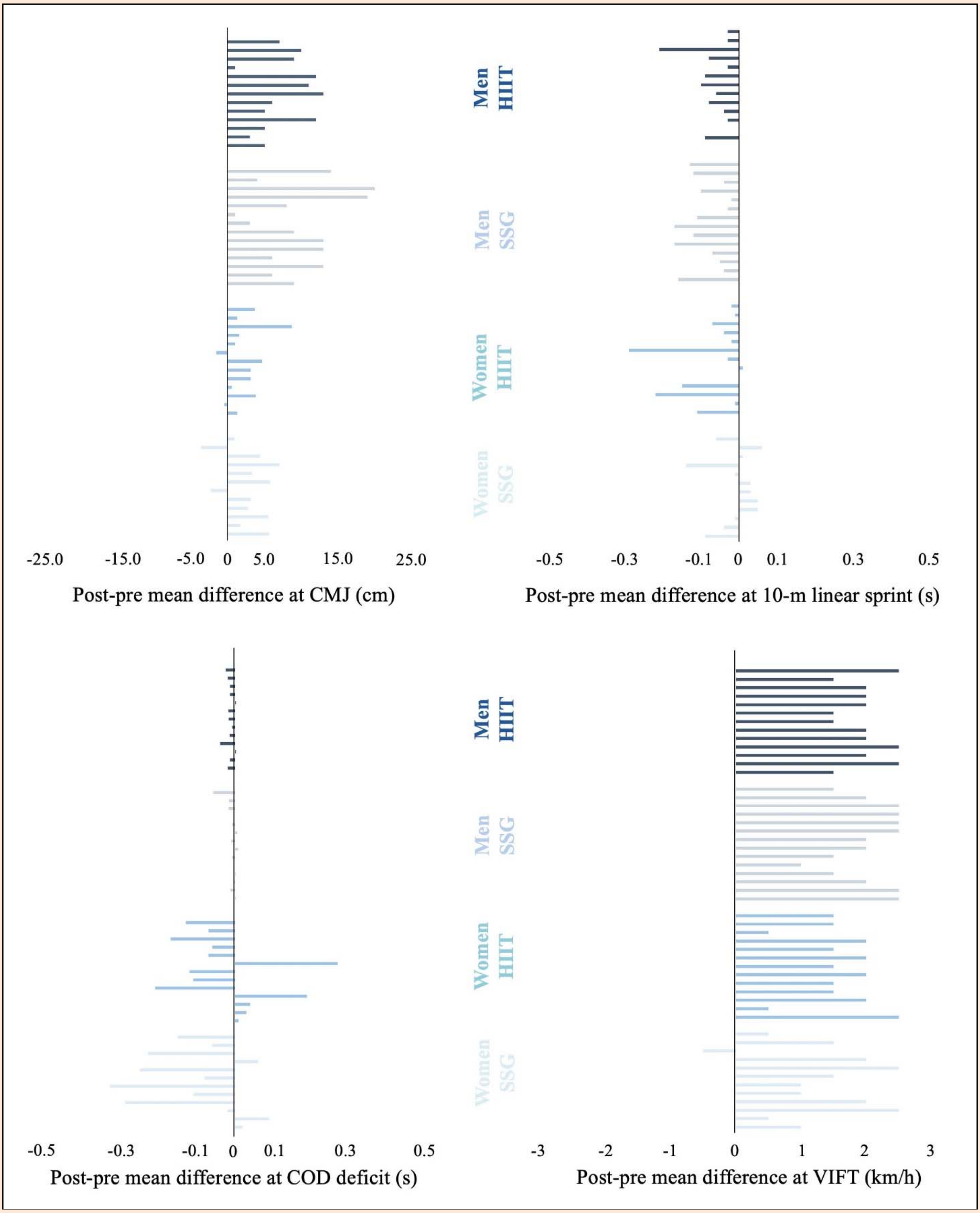

Figure 3. Individual mean differences (pro-pre) variations after interventions. SSG: small-sided games; HIIT: high-intensity interval training; CMJ: countermovement jump; COD: change-of-direction; VIFT: final velocity at 30-15 intermittent fitness test.

In terms of COD deficit, 50% of men and 75% of women in SSG groups improved their performance, while 92.3% of men and 61.5% of women in HIIT groups showed improvement. Lastly, concerning VIFT, all men exhibited improvements regardless of the training group, whereas 91.7% of women in the SSG group and 100% in the HIIT group improved their performance.

Figure 4 shows the average perceived exertion scores of the players during the training interventions. Among men participating in SSG, the average score was 8.2±0.5 A.U., while in HIIT, it was also 8.2±0.4 A.U. over the sixteen sessions. For women, those engaged in SSG had an average score of 8.1±0.5 A.U., whereas in HIIT, it was 8.3±0.4 A.U.

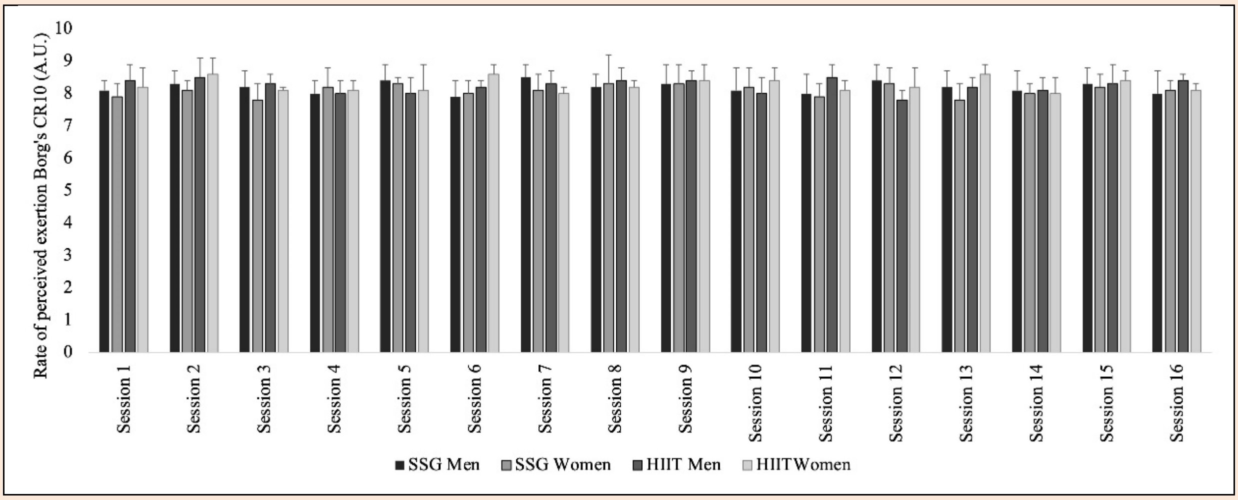

Figure 4. Mean and standard deviation of the players' perceived exertion rates during the training intervention sessions. SSG: small-sided games; HIIT: high-intensity interval training; A.U.: arbitrary units.

Discussion

As the first study dedicated to analyzing the effects of SSG and HIIT training in soccer players across sex, it reveals that while HIIT appears to allow similar adaptations in both men and women (with the exception of CMJ), SSGs lead to significantly greater improvements in men than in women, particularly in CMJ (+27.4% vs. +11.4%, respectively), COD deficit (−4.5% vs. −16.2%, respectively), 10-m sprint (−5.1% vs. −0.5%, respectively), and VIFT (+12.2% vs. +7.8%, respectively). Despite variations in the extent of adaptations, overall, both groups and sexes benefitted positively from the interventions.

Both SSG and HIIT interventions are frequently linked to the repetitive performance of high-intensity efforts, exerting an impact on both neuromuscular and cardiorespiratory systems and yielding positive consequences for aerobic performance (Dellal et al., 2012; Arcos et al., 2015; Özcan et al., 2018). Our study outcomes unveiled positive adaptations in VIFT within both groups, with no significant differences between the two training methods. These overall findings align with prior literature, which indicates similar positive adaptations following exposure to either SSG or short and long submaximal HIIT among players (Moran et al., 2019; Clemente et al., 2021c; 2024).

One contributing factor could be attributed to the capacity of both training modalities to enhance the blood's oxygen-carrying capability and concurrently improve cardiovascular system efficiency, facilitated by enhancements in mitochondrial function (Fransson et al., 2018). Notably, in our comparison across sexes, the extent of improvements showed that while HIIT produced similar enhancements for both sexes, SSG favored men significantly more than women in improving VIFT. Furthermore, all men exhibited improvements, whereas 91.7% of women in the SSG group experienced favorable adaptations. While it may not be possible to progress with a definitive understanding of the physiological mechanisms that could explain these results, it is conceivable that the locomotor and mechanical aspects, coupled with the physiological intensity during SSG and the between-players heterogeneity (Hill-Haas et al., 2008; Dello Iacono et al., 2023), may interact to provide a rationale for the observed findings.

Another results extracted from our study was that CMJ was significantly improved after both training interventions and in both sexes, although in SSG the extend of improvements had been higher in men than women. The current findings are aligned with some previous studies which found positive adaptations in CMJ after SSG and HIIT interventions in soccer players, both in men (Arslan et al., 2020) and women (Nayıroğlu et al., 2022), although contrasting with some others which reveals no positive effects of SSG or HIIT in CMJ improvements (Faude et al., 2014; Arcos et al., 2015). The CMJ is frequently linked to the capacity to utilize the stretch-shortening cycle (Bouguezzi et al., 2020). This ability could be particularly stimulated during the rapid acceleration, deceleration, and turns inherent in SSGs or HIIT, especially during turns (Makar et al., 2022). Consequently, these factors may provide a plausible explanation for the observed improvements in these players. However, the potentially greater high-intensity accelerations and decelerations encountered in men's SSGs (Dalen et al., 2021) may account for the more pronounced extent of improvements.

The outcomes for acceleration performance at 10 meters and COD deficit revealed disparate results within the groups. For instance, the COD deficit did not exhibit a significant improvement in women participating in SSG groups and in men engaged in HIIT groups. Additionally, the 10-meter acceleration performance showed no significant enhancement in men participating in SSG. Although both SSG and HIIT have the potential to enhance the repetition of accelerations, decelerations, and turns, a considerable portion of these activities occurs at submaximal intensities (Castagna et al., 2017). This is due to the limited size of the pitch in SSG, leading to fewer instances of high-speed running and sprints (Clemente, 2020). In our case, the implemented HIIT involved submaximal speed in a linear fashion, without incorporating turns. Our results align somewhat with previous findings that did not reveal significant differences between training methods concerning short sprints and COD performance, as well as improvements in both after interventions (Faude et al., 2014; Jastrzebski et al., 2014). Despite this, men demonstrated significantly greater improvements than women in SSG according to the contrast analysis. It was also observed that, while men were predominantly favored by the interventions in terms of acceleration, only 50% of the women in SSG experienced improvements.

Despite the innovative approach of our study, it is important to acknowledge certain limitations. One limitation is the absence of training load monitoring, preventing the integration of potential relationships between training load and individual variations following the intervention. Another limitation arises from the natural differences in training plans among the teams, despite similar training approaches, which may influence the effects of adaptations. A final limitation concerns the lack of a control group not subjected to a particular training intervention, which would enable the measurement of the potential magnitude of the effects of the interventions in comparison to a standard training approach. Therefore, future research should measure the training load at specific intervention points and consider other training procedures to determine the extent of the new intervention's impact on justifying the observed adaptations. Additionally, there is a need for fundamental research to understand the physiological and muscular mechanisms that can elucidate the evidence found in our study regarding the varying magnitude of improvements between sexes, particularly in SSG. Finally, future research should incorporate a control group that is not subjected to a specific training intervention, as opposed to the standard field-based training.

In terms of practical applications, this study represents, to the best of our knowledge, the first attempt to shed light on the effects of SSG and HIIT on both men and women. It is worth noting that the degree of change is associated with sex, a factor that coaches should carefully consider, particularly when implementing SSG. The varied stimuli experienced by players during SSG may result in different effects. However, additional research is necessary to integrate the parameters of training load for a better understanding of the potential mechanisms and factors that may influence the effects based on gender. Furthermore, it is crucial to note that this study was conducted among regional-level players. Therefore, factors such as trainability and competitive level may influence the extrapolation of results to other contexts. Given the diversity of individual responses, for women, opting for running-based HIIT might be more advantageous in reducing adaptation variability, potentially leading to a more consistent degree of adaptation among all participants. Nevertheless, such recommendations are subject to the limitations of the current study methodology, and thus, further research is warranted to confirm that similar trends are observed under comparable study conditions.

Conclusion

This study indicates that both men and women experienced similar effects when exposed to SSG and HIIT training interventions, conducted twice a week. These effects were observed in terms of their adaptations in VIFT and CMJ. However, changes in acceleration and COD deficit were contingent upon the specific group and sex. Men exhibited significantly greater changes than women when exposed to SSG, particularly in terms of CMJ, acceleration time, and aerobic performance. Hence, SSG seems to impact these components in men. Conversely, for women, it is recommended to utilize HIIT to achieve more homogeneous levels of adaptations, with the aim of preventing non-response patterns as observed in SSGs.

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Key points

- This study is the first to compare physical fitness adaptations between men and women concerning the use of small-sided games (SSG) and high-intensity interval training (HIIT) in soccer players.
- Men in SSG groups appear to be more favored in improving jumping performance, acceleration, change of direction, and aerobic performance than women.
- It is possible that HIIT is a more favorable training approach for ensuring a homogeneous level of adaptation in women.

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