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Comparing the physical effects of combining small-sided games with short high-intensity interval training or repeated sprint training in youth soccer players: A parallel-study design

Hadi Nobari[1,2,3], Ana Filipa Silva[4,5,6], Norodin Vali[7], and Filipe Manuel Clemente[4,5,8]

Abstract

Most of the research combining small-sided games (SSGs) with high-intensity interval training (HIIT) is using the short or long forms of HIIT. However, other types of HIIT as repeated sprint training (RST) could enhance different stimuli. The purpose of the current research was to analyze the within- and between-group variations of physical fitness and body composition of two combined training interventions: (i) SSGs combined with a short high intensity interval training (sHIIT); and (ii) SSGs combined with a RST. This study followed a randomized parallel study design. Twenty-eight youth soccer players (age: 17.3 ± 0.5) belong to the same team were assigned equally to two intervention groups: SSG + sHIIT *versus* SSG + RST. Training intervention lasted 4 weeks, with a 2-session/week frequency. The players were tested twice, once before and after the intervention with the following tests: skinfolds (fat mass); Sargent jump test (SJT); standing long jump; sprinting time at 10-, 20-, or 30-m; 5-0-5 for time and deficit; 30-15 intermittent fitness test (30-15IFT) based on the final velocity, and repeated sprint ability (RAST) for peak, minimum, average power, and fatigue index. A mixed analysis of variance was conducted to considering factor × time effect. Between-group analysis revealed no significant differences at baseline and post-intervention period for fat mass, sprinting time at 10-, 20-, and 30-m, change-of-direction (COD) time and deficit, SJT and standing long jump, final velocity at 30-15IFT and RAST peak, average power, and fatigue index ($p > 0.05$). Within-group analysis revealed that both groups significantly reduced fat mass ($p \leq 0.001$), SJT ($p \leq 0.001$), standing long jump ($p \leq 0.001$), sprint time at 10- and 20-m ($p \leq 0.001$), 30-m ($p = 0.002$), COD time ($p \leq 0.001$) and deficit ($p < 0.05$), RAST average ($p < 0.05$), and final velocity 30-15IFT ($p \leq 0.001$). Only SSG + RST had significant improvements on COD deficit and peak

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power ($p < 0.05$). The result of the current research suggests that either SSG + sHIIT or SSG + RST are effective for improving physical fitness in youth soccer players, with a multiple beneficial effect on locomotor profile, speed and COD, jumping performance and repeated sprint ability.

Keywords
Association football, change of direction, fatigue index, peak power, speed, standing long jump

Introduction

High-intensity interval training (HIIT) is one of the common training methods used in soccer for developing the locomotor profile and physical fitness of players.[1] The HIIT training seeks to provide an impacting and intermittent metabolic and neuromuscular stimulus on the players aiming to be as much as efficient as possible for changing mitochondrial protein content, muscle oxidative capacity, and the maximal activity of key enzymes while trying to reproduce some of the intermittent demands of the match.[2,3] Thus, the HIIT training can stimulate both energetic systems (metabolism) and neuromuscular readiness of the players.[4] For those reasons, the HIIT training holds a multidirectional impact on the players which catches the attention of the soccer coaches for using in the regular weekly programming process.[5,6]

Although not consensual across different researchers, one possible way to look into HIIT possibilities is to organize in five main types[2,3]: (i) short HIIT (sHIIT), which implies sub-maximal efforts <45 s; (ii) long HIIT which implies sub-maximal efforts from 2 to 4 min; (iii) repeated sprint training (RST), which consists in <10 s repeated all-out short sprint sequences; (iv) sprint interval training which consists >20–30 s of long all-out sprint with long rest periods; and (v) game-based training (e.g. small-sided games (SSGs) usually using training regimens similar to long HIIT). Those HIIT types imply a different metabolic and neuromuscular cost (considering the acute responses), while may affect differently the further adaptations that can appear after training interventions.[7,8]

The sHIIT is focusing on eliciting a greater contribution of the oxidative system, with some participation of anaerobic systems and neuromuscular strain while RST is more focused on greater participation of the anaerobic system and locomotor stress.[2,3] However, the training regimen may affect those acute responses, with possible consequences for adaptations. As example, variations of frequency, number of sets, the number of bouts, bout duration, the density (work-to-rest ratio), the number and extension of changes-of-direction, or the overall duration of training may change the acute responses.[9,10] Thus, pending the prescription of regimen, the stimulus between sHIIT and RST can be more or less similar with natural impacts on the adaptations.[2,3] Interestingly, and despite the lack of parallel study designs comparing both, there is some evidence regarding similar positive and significant effects of using either sHIIT or RST for developing aerobic power, aerobic capacity, and repeated-sprint ability, although no significant beneficial effects on sprinting performance or vertical jump on soccer players.[1]

While sHIIT or RST is a running-based training approach, most soccer training contexts require game-based drills which can be also interesting for targeting some of the metabolic and neuromuscular stimuli presented in HIIT training.[11,12] The SSGs can allow a good metabolic stimulus with an bonus of reproducing some technical and tactical demands occurring in the real match.[13,14] Some researches show the effectiveness of SSGs-based approach for developing aerobic power and capacity with no significant differences with running-based HIIT.[15] However, running-based HIIT seems to elicit a meaningful improvement in sprinting performance or change-of-direction (COD) compared to SSGs.[16] These facts allowed to understand that possible a combined approach could be of higher interest for the players.[17] Thus, combinations between SSGs and HIIT training in the same intervention have been tested and reported, with interesting results in which combination seems to be more effective than only SSGs for the improvement of aerobic power, and some neuromuscular-based variables.[18,19] However, most the combinations are based on SSGs and a sHIIT or long HIIT[19,20] which does not allow to identify how a different target as RST can help players to enhance a different adaptation profile. Possibly, considering that RST may be closely related to anaerobic and neuromuscular stimulus than short-intervals, it is possibly a more suitable combination than sHIIT to supplement the lack of anaerobic stimulus presenting in SSGs. However, such a hypothesis is not confirmed and the absence of research testing discloses the relevance of the topic.

Characterizing the effects of two different combinations (SSG + sHIIT vs SSG + RST) may help coaches to find the most appropriate approach for targeting specific adaptations, while may help to identify if meaningful changes can occur based on the training orientation. The particular research in youth players may also improve the comprehension of coaches about the optimal strategies to implement in this specific population. Considering the absence of

research focusing on those combinations, we do believe that the experiment may provide an interesting contribution to the state-of-the-art of HIIT training in soccer while combining SSGs with different HIIT types. Therefore, the purpose of this study was two-fold: (i) analyze the within-group variations of SSG + sHIIT and SSG + RST interventions lasting 4 weeks on physical fitness of youth soccer players; (ii) analyze the between-group differences of both training interventions on physical fitness of youth soccer players. We hypothesize that both groups will enhance body composition and physical fitness, although significance between groups will occur in between groups after intervention.

Methods

Study design

This study followed a randomized parallel study design. The players were recruited from the same team and then randomized was made before the trial begun. The study was conducted in the pre-season. Participants were randomly assigned to two training interventions (each one with a *N* of 14). Simple randomization was made consisting in a single sequence of random assigns. Equal number of letters were prepared for each group (SSG + sHIIT and SSG + RST) and the researchers selected the letters in blind considering the list of participants to include.

Setting

The study occurred from 22/6/2021 to 29/7/2021, in a team of Iranian competition. The study begun after 4 weeks of the beginning of the season training sessions. As context, 24 number of training sessions were performed before the study begun, and 2 matches occurred before the study begun. The training intervention occurred over 4 weeks, on Mondays and Wednesdays after the last match.

Participants

A priori sample size was calculated using G*Power software based on the F tests—analysis of variance (ANOVA): Repeated measures, within-between interaction (G-Power, version 3.1.9.2, University of Dusseldorf, Dusseldorf, Germany). The input variables were: For an effect size of 0.28 (we entered the amount of variability in the outcome that was accounted for by the interaction between groups and time), power (1-β err prob) of 0.8, *p*-value (α err prob) of 0.05 (2 groups and 2 number of measurements), and correlation of 0.5. According to this, there is an 81.4% chance of correctly rejecting the null hypothesis of no significant effect of the interaction between groups for a total of 28 subjects. In the current research, 28 participants were recruited from the same **** team (Figure 1).

Participants demographic description can be found in Table 1. The eligibility and exclusion criteria for the study were: (i) participants had no injuries, illness, or any limitation during the period of the study; (ii) participants had part of the all-intervention sessions (100% adherence and frequency) during the 4-week period; (iii) participants were part of the two moments of assessment (pre-post). The team trained by 4–6 days in the week plus an additional match at the weeks. Each training lasted on average 90 min. The participants were firstly asked to their voluntary participation. After presenting the intervention protocol, risks and benefits, they were asked to sign a free consent. The parents were also informed and signed the same consent. The study design and protocol was analyzed and approved by an ethical committee at the University of ****. The study also followed ethical guidelines of Declaration of Helsinki for the study in humans.

Testing procedures

The pre- and post-intervention assessments started after 2 days of rest, considering the last training session. For each assessment period (pre and post), four days of assessments were made. On the 1st day, anthropometric and body composition assessments (e.g. height, body mass, and body fat %) were performed in the morning. Then, in the afternoon, we assessed the horizontal and vertical jumps by standing long jump and Sargent jump test (SJT), respectively and also 5-0-5 test for COD ability. On the 2nd day, the maximum sprint time was evaluated at different distances (i.e. 30, 20, or 10-m). On the 3rd day, repeated sprint ability was assessed with a running-based anaerobic sprint test (RAST). Ultimately, on the 4th day, the 30-15 intermittent fitness test (30-15IFT) was performed with a heart rate sensor for the locomotor profile of players. The test steps were performed for approximately 24 h and with the recommendations of previous studies.[21–23]

Both assessments (pre- and post) occurred from Saturday to Wednesday. The assessments started at 16-17 pm. The tests were developed in a week without competition and training sessions. Players were asked to have a regular dietary intake and no ingestion of stimulating drinks on the day of the assessments. The players were familiarized with the tests protocol and then were organized by groups. Each group started all performance measurements, following a standardized warm-up protocol consisting of the FIFA 11 + warm-up program (see Table 2).

Anthropometry

The height and body mass were assessed 8–10 am after the waking up. The assessments were made by the same observer. The height was assessed using a stadiometer (Seca 217 Stable stadiometer, Hamburg, Germany), with players using shorts, t-shirt, and no shoes. The same for body mass. The body fat was assessed using Harpenden skinfold

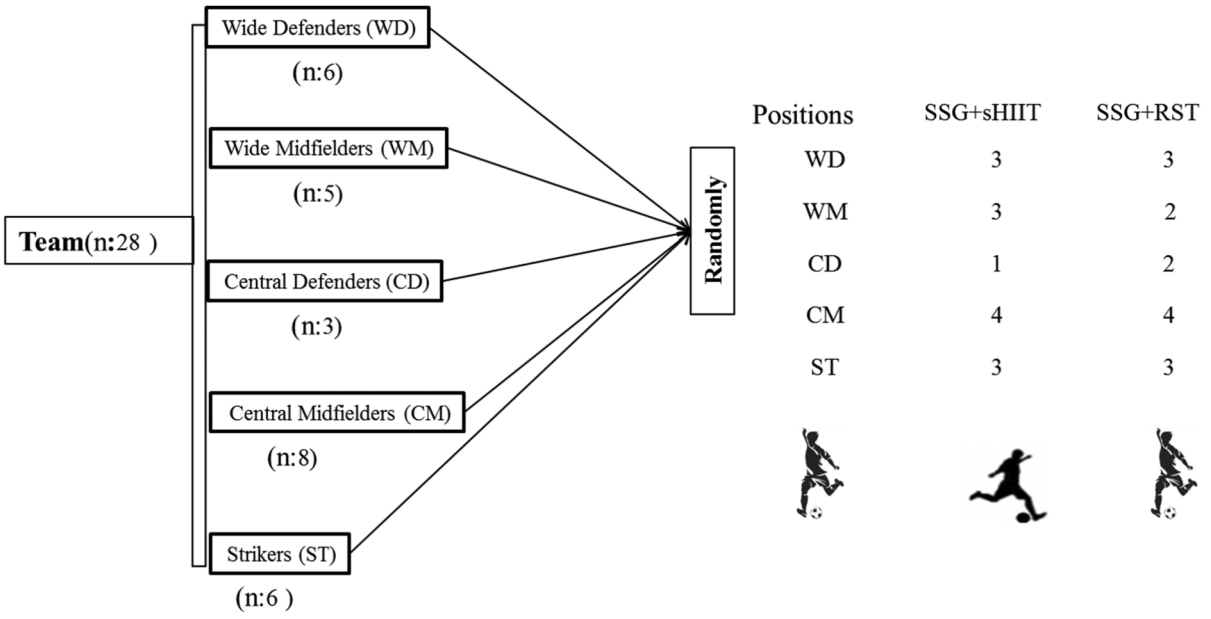


Figure 1. How to recruited participants to each group.

Table 1. Demographic information.

Characteristics	SSG + sHIIT group	SSG + RST group	Overall
Participants (*n*)	14	14	28
Age (years)	17.2 ± 0.4	17.2 ± 0.4	17.3 ± 0.5
Experience (years)	5.7 ± 1.2	5.4 ± 1.5	5.9 ± 1.4
Height (cm)	176.5 ± 5.0	179.6 ± 6.9	177.6 ± 5.8
Body mass (kg)	63.1 ± 7.2	69.6 ± 9.6	63.7 ± 8.6
Body mass index (kg/m^2)	20.2 ± 1.9	21.5 ± 2.1	20.1 ± 2.0
Defenders (*n*)	4	5	9
Midfielders (*n*)	7	6	13
Attackers (*n*)	3	3	6

Abbreviations: SSGs: small-sided games; sHIIT: short high intensity interval training; RST: repeated sprint training.

caliper, UK (0.1 cm error of measurement). The body fat percentage was assessed Jackson and Pollock seven-point formula as follows names: 1-pectoral, 2-midaxillary, 3-triceps, 4-subscapular, 5-abdominal, 6-suprailiac, and 7-thigh.[24] All the measures were made by the same observer on the right side of the body. The outcome extracted from height assessment was the height itself in centimeters. For the body mass was the mass in kilograms. For the case of fat mass, was collected the fat mass in percentage.

Vertical jump

The SJT was used to estimate the vertical jumping performance of the participants. The depth of the squat was self-adjusted by the participants, although a trial of familiarization was given to each of one as well as identification of the key aspects related with the movement. It was not allowed to stop the movement across the unweighting phase to braking phase or from this last to the propulsive phase. The SJT was measured using a tap measure in a wall. After preparing the setup, the athlete was measured standing side onto the wall, reaching up as high as possible the wall with the tips of the fingers. From the standing position, the player jumped as high as possible and marks the wall with the chalk on his finger and the measure was taken recording the distance from the standing position until the mark after jumping. Each player was assessed two times, with a rest period (passive) of 120 s between them. The estimated height of jump was recorded in each trial. The highest trial (cm) was recorded in each player and used for further data treatment. The intra-class coefficient (ICC) in this test was 0.88.

Horizontal jump

The standing long jump was employed for estimating the horizontal jump performance. The player stands behind a

Table 2. Exercise programs performed in FIFA 11 + warm-up.

No	Section I: Running movements (8–10 min)	
1	Straight ahead	5 min
2	Hip out	10 reps
3	Hip in	10 reps
4	Circling partner	5 reps
5	Shoulder contact	6 reps
6	Quick forwards or backwards	7 reps
Section II: Plyometric, strength, and balance movements (10–12 min)		
7	Plank with alternating leg	3 set × 20s
8	Sideway plankwith leg lift	3 set × 15s
9	Nordic hamstring curl	2 set × 10 reps
10	Single leg stance	2 set × 30s
11	Walking lunges	2 set × 8 reps
12	One leg squats	1 set × 8 reps
13	Vertical jumps	2 set × 6 reps
14	Lateral jumps	2 set × 6 reps
Section III: Running ABC (2–3 min)		
15	Running across the pitch	Approximately with 70–80% maximum pace × 3 reps
16	Running bounding	2 set × 16 reps
17	Running plant or cut	2 set × 4 step

line marked in on the ground with feet slightly apart. Parallel feet were requested during take-off and landing. Players used a stock shoes. The jump was measured using a long jump map marked from one-to-one centimeter and the measure was taken in the nearest point of contact of the landing (back of the heels). Each player had a trial of familiarization. After that, two trials were made, and the longest performance was collected for further data treatment. There was a 3 min break between each attempt. The longest distance was used for further data treatment. The ICC in this test was 0.87.

Sprint test

A sprint linear test three different distances at 10-m, 20-m, and 30-m were used to determine the sprinting time of the players. The sprint tests started in a split position of the foot always with the same preferable leg for the player. The starting point position was 70 cm behind the first pair of photocells that marked the starting line.[25,26] Four pairs of photocells were used (starting line, 10-m, 20-m, and 30-m). The photocells (Newtest Powertimer 300-series testing system, Finland) height was positioned based on the player's hips. Players performed two trials, interspaced by 120 s of rest. The shortest time (s) to perform in each linear sprint test was used for further data treatment. The ICC for the test was 0.84.

Change-of-direction test

The 5-0-5 test protocol was employed to measure the COD time and deficit of the players. The test consists of starting in standing position (foot split) and accelerating over a 10-m distance and to perform an additional 10-m trajectories with a COD of 180° (5 + 5 meters).[27] The time from the latest 10-m (5 + 5 meters) are counted using two pair of photocells (Newtest Powertimer 300-series testing system, Finland). The photocells height was adjusted based on the height of the players's hip. The players were allowed to use the preferred leg for braking and turning moment, however, they were asked to use always the same. Similarly, approach was made for the foot in front of the starting position. Each participant performed two trials, with a rest period of 3 min.[26] The COD time (s) was obtained for each trial. The smallest time was used for further statistical procedures. The COD deficit was used by subtracting the COD time by the linear speed time at 10-m.[28] The ICC for the test was 0.81.

Repeated sprint ability

The running based anaerobic sprint test (RAST) was used to determine the repeated sprint ability of the players. The RAST consists in performing six sprints of 35-m interspaced by a 10 s period of recovery. The sprints are linear and with no COD. The sprint tests started in a split position of the foot always with the same preferable leg for the player. The starting point position was 70 cm behind the first pair of photocells that marked the starting line. The photocells were positioned at the starting line and at the ending line. The time to perform the 35 m was counted using two pair of photocells (Newtest Powertimer 300-series testing system, Finland). The power output in each trial was then calculated based on: (body mass ×

Table 3. Training intervention details.

Dates	SSGs	Group sHIIT	Group RST
Week 1–4 (session 1–8)	2v2 20 × 25 m Encourage No-goals (aim: possession of the ball) No offside Work: 120s Rest: 120s Repetitions: 2	Sets: 2 Repetitions: 5 Work: 15 s Rest: 15 s Work intensity: 90–95%V_{IFT} Rest intensity: 0%V_{IFT}	Sets: 2 Repetitions: 4 distance: 30 m Rest: 20 s Work intensity: ≤100% Rest intensity: 0%

Abbreviations: SSGs: small-sided games; sHIIT: short high intensity interval training; RST: repeated sprint training.

distance^2)/time^3.[29] The average power over the six trials, and the peak power (maximum power over the six trials) were collected for further data treatment. Moreover, the fatigue index was also calculated based on: (highest power−lowest power)/(sum of the time over the six sprints). The ICC was used to calculate the test-retest reliability, which was found to be 0.85.

Locomotor profile

The 30-15IFT was implemented to classify the locomotor profile of players.[30] The original test (40-m) was used, thus consisting in 30 s shuttle runs interspaced by 15 s periods of passive recovery. The test starts with a velocity of 8 km/h and progressively increases at each stage of running by 0.5 km/h until the exhaustion of participants. The pace is regulated by an audio beep. The protocol was followed strictly in accordance to the original report of the proponent of the test.[30] The test ended in the case of a player could not ensure the imposed running speed or fail to be in the 3-m zone around each line for three consecutive times. The final velocity (km/h) attained during the last completed stage was collected for each player and considered the outcome related with the test. The ICC was used to calculate the test-retest reliability, which was found to be 0.90.

Training intervention

The training intervention occurred in days Monday and Wednesday of the week. The training sessions occurred at 16 h of the day, under an average temperature condition of 35°C and 26% relative humidity. The training intervention was employed immediately after a standardized warm-up protocol that consists in FIFA 11 + warm-up program (Table 2). After the warm-up the groups were organized and started the training protocol. The first players of 2v2 groups were unstable in any session, and their opponents and teams were randomly selected in each session. The participants allow started with SSGs following after for running-based HIIT or RST after a 2–3 min period of recovery (Table 3).

In Figure 2, training protocol descriptions are presented in full.

Training intensity during intervention

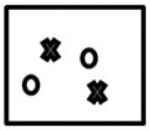
The training intensity was monitored in all intervention sessions using the CR-10 Borg's scale.[31] The players had previous familiarization with the scale. After the end of each period of intervention, the players scored individually the perceived level of effort performed over the intervention. The recorded were registered in a sheet and after an individual question of "how intense was the session?".

Statistical procedures

Normality and homogeneity of the sample were preliminary tested using Shapiro-Wilk test and Levene's test, respectively. The normality of the outcomes was explored individually and for each group revealing a p-value > 0.05 for all the outcomes considered. The homogeneity of the outcomes was tested using the Levene's presenting values above $p > 0.05$, thus confirming homogeneity. No significant outlier was found. A mixed ANOVA (factor × time) was executed for controlling the between and within-group analysis for the physical outcomes considered. Interaction was reported in the format of p-value and partial eta squared. Within-group variations and between-group variations were tested after confirmation of no interaction (time × factor). Within-group variations were tested using t-paired sample test, while between-group differences for baseline and post-intervention moments were tested using independent t-test. Magnitude of differences were tested using the standardized effect size of Cohen, with the equation ((mean post−mean pre)/(pool standard deviation)).[32] The magnitude of differences were interpreted using the following thresholds[32]: [0.0;0.2], trivial; [0.2;0.5], small; [0.5;0.8], medium; [>0.8], large.

Results

Descriptive statistics of pre and posttest values, within-group and between-group analysis can be found in Table 4.

Group	Formats	SF	APP(m2)	Regimen	Exercise form
Group sHIIT+ Group RST	2vs2	20×15	75	2× 2 min/2 min rest	

SF: Size of the field (m); APP: Area per player

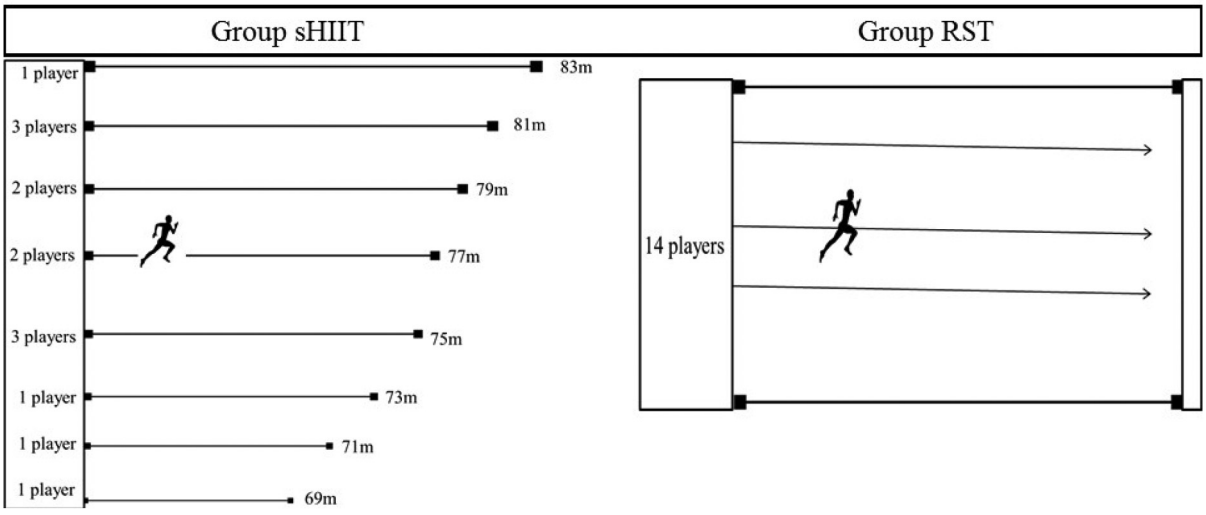


Figure 2. The training intervention protocol in the sHIIT group is the distance set for each player based on the 90–95% IFT test speed. In the RST group, all players cover a fixed distance of 30 m with maximum speed.

Significant interactions were found between groups and time (pre-post) in the mixed ANOVA conducted for COD time ($p = 0.048$; $\eta_p^2 \leq 0.143$). No significant interactions between groups and time (pre-post) were found in mixed ANOVA for the case of 10-m time ($p = 0.266$; $\eta_p^2 = 0.047$), 20-m time ($p = 0.956$; $\eta_p^2 \leq 0.001$), 30-m time ($p = 0.7206$; $\eta_p^2 = 0.005$), COD deficit ($p = 0.618$; $\eta_p^2 = 0.010$), standing long jump ($p = 0.926$; $\eta_p^2 \leq 0.001$), RAST peak power ($p = 0.555$; $\eta_p^2 = 0.014$), RAST average power ($p = 0.430$; $\eta_p^2 = 0.024$), RAST fatigue index ($p = 0.065$; $\eta_p^2 \leq 0.125$), V_{IFT} ($p = 0.292$; $\eta_p^2 = 0.043$), SJT ($p = 0.308$; $\eta_p^2 = 0.040$), and fat mass ($p = 0.224$; $\eta_p^2 = 0.056$).

Figure 3 presents the within- and between-group variations and intra-individual variations for the sprinting and COD tests. Between-group variations revealed no significant differences in any of the baseline and post-interventions ($p > 0.05$), thus both interventions had similar effects on sprinting and COD abilities. Considering the within-group variations, both groups conducted to significant beneficial effects on sprinting time (10-, 20-, and 30-m), COD time, and COD deficit ($p < 0.05$).

Figure 4 presents the between and within-group variations, as well as intra-individual variations, for SJT and standing long jump. No significant differences were found between groups in baseline and post-intervention ($p > 0.05$). The within-group changes revealed that both interventions conducted to significant improvements in jumping performances of youth soccer players ($p < 0.05$).

Figure 5 presents the within- and between-group variations, as well as intra-individual variations, for final velocity at 30-15 IFT and RAST peak power. No significant differences were found between groups in the baseline and after training interventions ($p > 0.05$). However, only SSG + RST conducted to significant improvements of peak power during RAST test ($p \leq 0.001$). Both groups conducted to significant improvements in VIFT ($p < 0.05$).

The training intensity registered using the CR-10 Borg's scale was recorded over the eight training sessions (Figure 6). The SSG + RST (6.77 A.U.) was less intense in average (−5.13%) than SSG + sHIIT (7.13 A.U.). Small magnitude of differences were found between the average of intensities ($d = -0.45$) between SSG + RST and SSG + sHIIT.

Table 4. Descriptive statistics (mean and standard deviation), within and between-group analysis.

	SSG + sHIIT (within-group analysis)					SSG + RST (within-group analysis)					Between-group differences (pre)		Between-group differences (post)	
Variables	Pre	Post	% change (post-pre)	*p*	*d*	Pre	Post	% change (post-pre)	*p*	*d*	*p*	*d*	*p*	*d*
Fat mass (%)	11.2 ± 3.5	9.6 ± 2.5	−14.5	≤0.001*	−0.54	14.9 ± 6.0	12.8 ± 4.9	−14.3	≤0.001*	−0.39	0.053	−0.767	0.042	−0.824
SJT (cm)	45.2 ± 5.9	55.3 ± 6.8	22.3	≤0.001*	1.59	48.1 ± 7.9	56.2 ± 7.8	16.8	≤0.001*	1.03	0.276	−0.421	0.741	−0.126
SLJ (cm)	219 ± 9	229 ± 9	4.6	≤0.001*	1.09	215 ± 14	225 ± 13	4.8	≤0.001*	0.74	0.360	0.353	0.345	0.363
10-m (s)	1.79 ± 0.14	1.70 ± 0.13	−5.3	≤0.001*	−0.69	1.83 ± 0.15	1.76 ± 0.12	−3.9	≤0.001*	−0.53	0.482	−0.269	0.205	−0.491
20-m (s)	3.09 ± 0.23	2.90 ± 0.13	−6.4	≤0.001*	−1.11	3.09 ± 0.28	2.90 ± 0.18	−6.3	≤0.001*	−0.84	0.982	0.008	0.991	−0.005
30-m (s)	4.17 ± 0.33	3.81 ± 0.31	−8.5	0.002*	−1.12	4.18 ± 0.54	3.89 ± 0.30	−7.0	0.002*	−0.70	0.923	−0.037	0.496	−0.261
COD time (s)	3.98 ± 0.29	3.84 ± 0.29	−3.5	≤0.001*	−0.48	4.04 ± 0.21	3.79 ± 0.26	−6.1	≤0.001*	−1.07	0.526	−0.243	0.662	0.167
COD deficit (s)	2.18 ± 0.28	2.14 ± 0.27	−2.1	0.042*	−0.17	2.20 ± 0.13	2.03 ± 0.22	−8.0	≤0.001*	−1.00	0.790	−0.102	0.259	0.436
RAST PP (W)	731 ± 172	778 ± 178	6.5	0.134	0.27	744 ± 146	836 ± 153	12.4	≤0.001*	0.62	0.833	−0.080	0.367	−0.347
RAST av (W)	591 ± 112	665 ± 116	12.6	≤0.001*	0.65	630 ± 104	692 ± 120	9.8	0.008*	0.55	0.346	−0.362	0.554	−0.227
RAST FI (A.U.)	8.90 ± 4.25	6.47 ± 4.33	−27.3	0.063	−0.57	7.39 ± 3.41	7.88 ± 3.88	6.6	0.609	0.13	0.309	0.392	0.374	−0.342
V_{IFT} (km/h)	18.2 ± 1.0	20.3 ± 1.1	11.6	≤0.001*	2.01	18.1 ± 0.9	20.1 ± 1.1	10.6	≤0.001*	1.99	0.919	0.039	0.610	0.195

Abbreviations: SSGs: small-sided games; Shiit: short high intensity interval training; RST: repeated sprint training; SJT: Sargent jump test; SLJ: standing long jump; COD: change-of-direction at 5-0-5 test; RAST: running anaerobic sprint test; PP: peak power; av: average; FI: fatigue index; V_{IFT}: final velocity at 30-15 IFT test; *: *p*-value < 0.05.

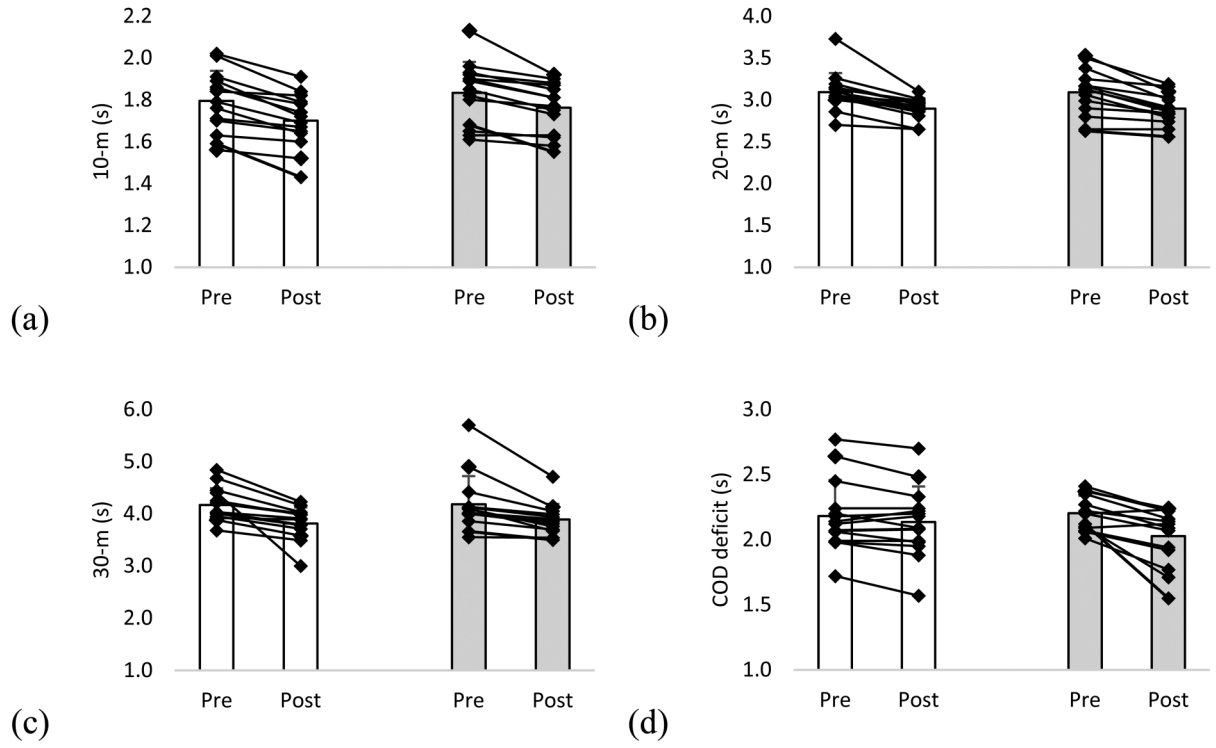


Figure 3. Descriptive statistics (mean and intra-individual variation) of within-group variations. White bars (SSG + sHIIT) and grey bars (SSG + RST). (a) 10-m test; (b) 20-m test; (c) 30-m test; (d) COD deficit at 5-0-5 test.

Discussion

This study tested the effects of combining SSGs with a sHIIT and RST twice a week over 4 weeks on physical fitness of youth soccer players. Main results revealed that no significant differences were found between groups after the training intervention regarding physical fitness. Additionally, both groups were significantly effective in improving locomotor profile, jumping performance, sprinting performance, and repeated sprint ability. The SSG + RST was also significantly beneficial for COD deficit and peak power in repeated sprint ability test. These results are new in the research of SGGs, since so far as we know, no previous studies compared the combination of SSGs with RST. Interestingly, using sHIIT or RST conducted to similar benefits may provide some recommendations for coaches, since RST provides a greater impact on the neuromuscular strain. Thus, coaches may choose to use sHIIT to decrease this strain, without compromising benefits in physical fitness adaptations. Naturally, the main message is: SSGs can be combined with both sHIIT or RST with beneficial effects for the physical fitness of youth players. Coaches should be aware of that and chose the most appropriate combination based on the period of the season and the training status of players.

The use of HIIT type has become one trending approach in soccer to induce a high-intense stimulus in the shortest time possible.[11,33] The benefits as a training method are well-known and using different HIIT types provide to coaches different options to induce variability in training stimulus, while keeping players with a enough stimulus to maintain or improve physical fitness in different moments of the season.[34,35]

In the current research, it was confirmed that using SSGs combined with sHIIT or RST had similar improvements in the order of 10–11% after only eight sessions. More interestingly, all the players improved the ability after the interventions (Figure 3(a)). This allows to understand how effective the combined approaches can be based on different HIIT types for improving locomotor profile of soccer players. These results are somehow in line with other studies which combined combination between SSG and running-based HIIT. As example, with a duration of 4 weeks, a study conducted in semi-professional results in 6% and 7% of improvement in VIFT after using SSGs combined with sHIIT.[19] With a similar approach, a study conducted in youth players lasting 6 weeks also revealed improvements in VIFT around 7%.[36] Those results can provide a general idea that SSGs combined with running based HIIT can enhance locomotor profile with meaningful impact on aerobic performance of players in short periods of time. Considering that sHIIT may target greater oxidative participation, while RST can target oxidative with a greater participation of glycolytic systems,[3] it seems interesting to analyze that both provide similar effects on the adaptations

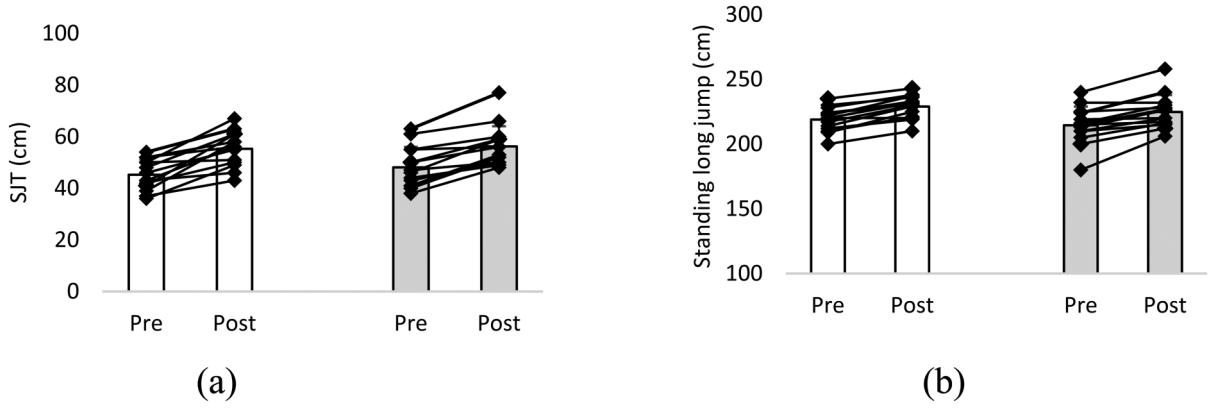


Figure 4. Descriptive statistics (mean and intra-individual variation) of within-group variations. White bars (SSG + sHIIT) and grey bars (SSG + RST). (a) SJT test; (b) standing long jump test.

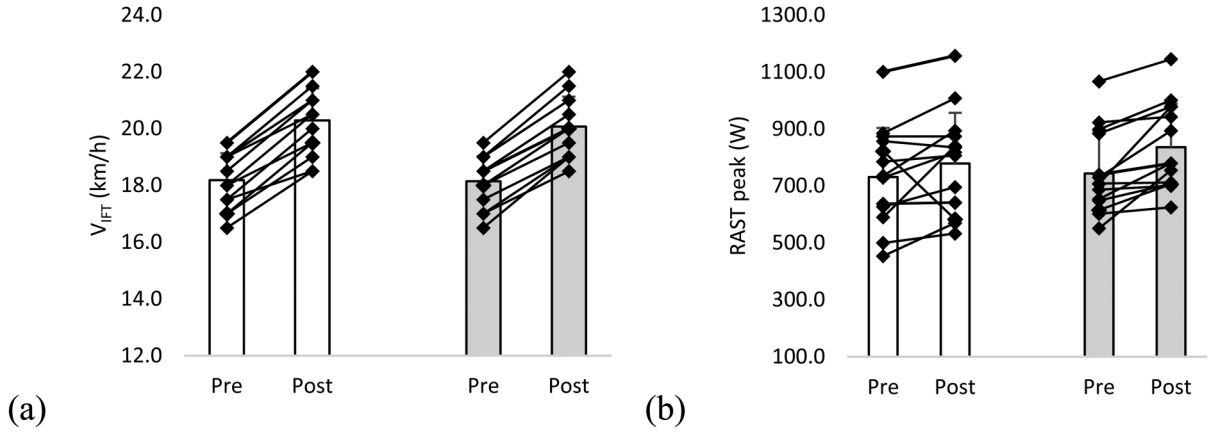


Figure 5. Descriptive statistics (mean and intra-individual variation) of within-group variations. White bars (SSG + sHIIT) and grey bars (SSG + RST). (a) Final velocity at 30-15IFT test; (b) peak power at RAST test.

while combined with SSGs. Thus, coaches may consider using RST if the aim is to target greater glycolytic participation or neuromuscular stress or consider combining with sHIIT if the aim is a greater neuromuscular strain with less load while focusing on the oxidative system.[2]

Using HIIT types can enhance the ability to recover between bouts. Moreover, this can conduct to positive adaptation regarding the power attained in each period of effort.[37] In the current study, it was found that SSG combined with sHIIT conducted to significant improvements on average peak power on RAST, while combining with RST conducted to significant improvements on both peak power and average. This information is of particular interest, since average power is highly associated with aerobic fitness[38,39] and peak power is more associated with neuromuscular and mechanical fitness.[40,41] Considering that RST targets all-out efforts, this may play an important role in ensuring a greater power performed over the bouts with consequences for the ability to reach a highest level in RAST. On the other hand, since RST is targeting similar metabolic load as sHIIT and SSGs targets also an important aerobic power stimulus, possibly combining SSGs with RST can ensure an enhancement in improving average and peak power during repeated sprint ability.

One of the particular interesting findings of the current study was the improvement of both groups in all sprinting time tests and COD time. One of the threats of exclusively using SSGs is the fact of small sizes can affect the capacity of these games to achieve maximal or nearly maximal speed levels which may compromise the stimulus for maintaining or improving sprinting performance.[42] In fact, a meta-analytical comparison revealed the significant benefits of running-based HIIT *versus* SSGs for improving sprinting performance and COD time.[16] Thus, combining HIIT and SSGs may be beneficial, and the current study confirmed that. Improvements between ~4 and 9% on sprinting performance across different distances were observed. These significant improvements are in line with a parallel study comparing the effects of different order of employing combinations between SSG and sHIIT which revealed

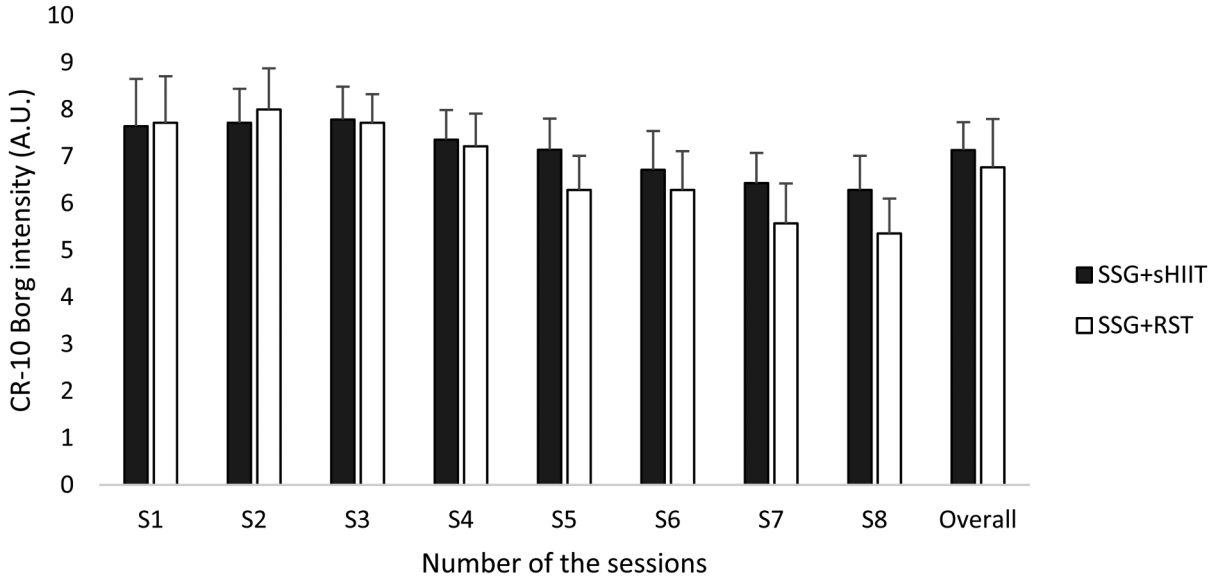


Figure 6. Training intensity (mean and standard deviation) using the CR-10 Borgs scale over the eight training sessions.

improvements in sprinting and COD performances.[20] However, since COD time in 5-0-5 is perfectly related with a linear speed test of 10-m,[43] it is not possible to describe that COD ability was improved. In fact, COD deficit, a better measure of COD ability,[28] was not significantly improved in both groups. In fact, only in the group combining RST it was observed a significant improvement of the COD deficit. The RST is made in an all-out mode which may imply a greater eccentric and concentric strain associated with greater decelerations during braking phase and further accelerations which may induce a greater level of adaptation for COD.[44] Since in the current case the RST had COD during training process, this may justify the RST can be of a higher interest for improving COD.[45]

The neuromuscular and mechanical activity in accelerations/decelerations during SSGs in combination with running based-HIIT may be enough for enhancing jumping performance.[2] In the current study, vertical and horizontal jump performances were significantly improved after both training interventions. This fact was also observed in a previous study combining SSGs and sHIIT.[20] Possibly, the transfer from neuromuscular stimulus may play enough stimulus for improving the stretching shortening cycle.[46] However, the fact of the current research has not been controlled by a third group in a different team, does not allow us to understand the generalization of the current findings.

This study has some limitations. Only one team was considered, thus the evidence of this study cannot be consistently generalized since no other team or context was considered in the comparison as control. Future studies should add more than one team and context aiming to identify if the effects can be replicable across different contexts. Moreover, it would be important to explore in the future the effects of adaptation of the stimulus/intensity based on the anaerobic speed reserve and not based on maximal velocity attained in 30-15IFT, since for the same level, two players can hold different anaerobic speed reserves which may influence the best attunement to a training type. Exploring factors as the most adequate training type, minimal effective dose, and effects across different training contexts are some of the concerns that should be considered in future research. Additionally, exploration of the concurrent effects with other training methods should be considered for a better understanding of how to implement and organize the weekly schedule while minimizing the worst effects of concurrent training. Analysis of training measures as acute and chronic exposure to training demands, the monotony of strain can be interesting to add in future research aiming to identify the long-term effects of these interventions. In addition, there are other limitations to the data collection and analysis process, such as difficulties in collecting data on the number of tests and how to calculate test values between trials. Finally, the transfer of evidence is just allowed for soccer, and this should be stated as a limitation.

Apart from these limitations, this study provides a confident signal to whom in similar conditions want to combine SSGs with other HIIT training types. This study confirms that combining SSG with sHIIT or RST plays a significant improvement role on the player's adaptations and naturally this can provide more options to coaches to explore one or another without limitations for adaptations provided by the HIIT types on most of the key physical parameters. It is important to note that RST conducted to

a significant improvement in COD deficit and peak power in RST, which did not occur in sHIIT. Applying a combination of SSGs and sHIIT or RST twice a week during a short period of 4 weeks was effective for great majority of physical fitness, thus this is a message that combination can be useful and that game-based training and running-based methods had their space in the weekly schedule.

It is recommended that SSGs (particularly those with smaller format 2 vs 2 to 4 vs 4) can be used as an aerobic power stimulus in the beginning of the session, while sHIIT can be supplemented at the end of training sessions (possibly in case of need). However, in the case of using RST, possibly, it is a saver to implement at the beginning of the session, since the muscular strain is high which may conduct to a greater risk in the use as a top-up strategy at the end of the session.

Conclusions

Either SSG + sHIIT or SSG + RST training interventions performed twice over 4 weeks had significant improvements on body composition, sprinting, COD, and jumping performances, repeated sprint ability, and locomotor profile of youth soccer players. Generalization of conclusions is not recommended, since the research was conducted in the same team. However, it can be argued that based on current findings, coaches can use induction status and dose based on the acute effect and interaction with the period of the season. If a particular focus is in COD ability or peak power while performing repeated sprint ability, maybe RST is more recommended for combining with SSGs.

Author contributions

Conceptualization: H.N., F.M.C., A.F.S., and N.V. Methodology: H.N., and F.M.C. Data collection: N.V. Analysis: H.N., F.M.C., A.F.S., and N.V. writing—review and editing original draft preparation: H.N., F.M.C., A.F.S., and N.V. All authors have read and agreed to the published version of the manuscript.

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Consent for publication

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Availability of data and materials

Data are available on reasonable request. Deidentified data are available on reasonable request and in compliance with ethical and legal requirements.

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