

Running-based high-intensity interval training vs. small-sided game training programs: effects on the physical performance, psychophysiological responses and technical skills in young soccer players

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ABSTRACT: This study aimed to compare the effects of 5-week running-based high-intensity interval training (HIIT) vs. small-sided game training (SSG) on the physical performance, psychophysiological responses and technical skills in young soccer players. Twenty young male soccer players (age: 14.2 ± 0.5 years, height: 161.8 ± 7.9 cm) participated in this study and were assigned to two groups: the HIIT group ($n=10$) and SSG group ($n=10$). Both groups trained twice per week with a similar total training duration. The SSG consisted of two 5–9 minutes of 2-a-side with 2-minute passive rest periods, whereas the HIIT consisted of 12–20 minutes of continuous runs at intensities (90 to 95%) related to the velocity obtained in the 30–15 intermittent fitness test. Before and after the 5-week training periods the following tests were completed: maximum oxygen consumption (VO_{2max}) from the Yo-Yo Intermittent Recovery Test level 1 (YYIRT-1), 10–30-m sprint test, countermovement jump [CMJ], squat jump [SJ], and drop jump [DJ]), 1000-m run test, zigzag agility, repeated sprint ability, 30–15 intermittent fitness test and speed dribbling ability test. Our results revealed meaningful improvements in YYIRT-1 performance (SSG: +12.8%, standardized effect size [d]=-1.46; HIIT: +16.4%, $d=3.27$ and VO_{2max} (SSG: +3.3%, $d=-1.48$; HIIT: +4.3%, $d=2.61$). There was a meaningful greater improvement in agility and technical test performances following the SSG training compared with the HIIT ($p \leq 0.05$, d =ranging from 0.92 to 1.99). By contrast, the HIIT group showed meaningfully higher performance responses in terms of the 1000-m running time and repeated sprint test ability ($p \leq 0.05$, d =ranging from 0.90 to 2.06). These results confirmed that SSG training might be a more effective training regime to improve technical ability and agility with greater enjoyment, whereas HIIT might be more suitable for speed-based conditioning in young soccer players.

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INTRODUCTION

Physical demands in soccer are characterized by a mixture of short-duration sprints, high-intensity running at different speeds, jumping, tackling, shooting, and controlling the ball under pressure, with an average game intensity ranging from 80% to 90% of players' individual maximum heart rate (HR_{max}) [1, 2]. In the particular case of young soccer players (14 years old) distances of 8.3 km can be covered while performing approximately 1 km (16% of total distance covered) in high-intensity activity ($>13 \text{ km} \cdot \text{h}^{-1}$) during an official match [3]. Consequently, superior aerobic endurance and anaerobic capacity are required for players to be successful in soccer [4, 5]. Recently, coaches have used various training regimes and strategies to improve players' physical capacity required for soccer matches,

such as aerobic endurance, technical skills and anaerobic capacity [6].

One of the training strategies used is aerobic high-intensity interval training ($>85\% \text{ HR}_{max}$), which may improve 5%–11% of the maximum oxygen consumption (VO_{2max}) [7]. However, such improvements may depend on the baseline fitness level of athletes and, for that reason, the distance covered obtained from the Yo-Yo Intermittent Recovery Test level 1 (YYIRT-1) has been used to assess the soccer-specific physical performance [8]. Numerous studies have demonstrated the effect of high-intensity interval training (HIIT) on the performance of young soccer players [7, 9]. Sperlich et al. [10] evaluated HIIT effects among young (Under-14) soccer players. The

players performed the HIIT three times a week for 5 weeks during the winter preparation period. The HIIT consisted of different durations of running intervals at a 90%–95% HR_{max} intensity with various rest durations between sets. The results indicated that players' VO_{2max} improved by 7% from 55.1 ± 4.9 to 58.9 ± 4.7 $ml \cdot min^{-1} \cdot kg^{-1}$.

Another popular strategy to improve cardiovascular fitness is to use small-sided game training (SSG), which involves the actual movement patterns and types widely used in soccer [11]. SSG is a time-efficient training regime and it simultaneously involves technical skill, tactical awareness and physical fitness [5, 11, 12]. Consequently, some studies [13, 14] have demonstrated the positive training effect of SSG among young soccer players in improving their VO_{2max} compared to running-based HIIT, which is directly related to endurance performance and high-intensity activity during a match. Hill-Haas *et al.* [15] executed an SSG programme for 7 weeks in pre-season, consisting of 3×6 and 6×13 minutes of SSG intervals at $>80\%$ HR_{max} with 1–2 minutes of rest between bouts. Contrary to the mixed generic fitness training programme, YYIRTL-1 performance increased by 17.1% in the SSG training group.

While some studies investigated the long-term (7–8 weeks) training effects of HIIT and SSG programmes in pre-season [15, 16, 17], other limited research (two studies) examined the short term (4–6 weeks) during the competitive season [18, 19] with regard to the performance, psychophysiological responses and technical abilities of young soccer players, especially when the total training durations of both training modalities were matched. To the best of our knowledge, this study is the first to examine these variables in detail in youth soccer players. Therefore, this study aimed to investigate the effects of 5-week HIIT vs. 5-week SSG on the physical performance, psychophysiological responses and technical skills in young soccer players and to clarify which training strategy is more effective in improving these variables. We hypothesized that SSG training programmes are as effective as HIIT in order to improve aerobic fitness without any negative effects on jumping and sprinting ability and that the SSG training includes higher physical enjoyment responses than HIIT. The results of this research would provide soccer coaches with empirical evidence to justify their selection between SSG and HIIT training modalities.

MATERIALS AND METHODS

Experimental Approach to the Problem

A parallel matched-group design was used to compare performance, psychophysiological responses and technical skills, including pre-intervention testing, intervention and post-intervention testing in the present study. The present study was conducted during the first half of the junior soccer season period (4 weeks after the beginning of the season). The study design lasted 8 weeks and consisted of 1.5 weeks of tests (pre-testing), 5 weeks of supervised training intervention, and 1.5 week of tests (post-testing). The players were assigned to the SSG ($n=10$) or the HIIT group ($n=10$) according to their aerobic fitness (YYIRTL-1) and technical skill

rankings to avoid having unbalanced groups and to begin statistically equally. Each of these training regimes was performed twice a week and each session was separated by at least 48 hours. During the entire duration of the present study, the players had the same type of soccer training and SSG or HIIT was added to their training sessions. To reduce the potential influence of minutes played in official matches on aerobic fitness, the team was established with the same number of players from the SSG and HIIT groups (~ 37 and 33 minutes played respectively). In addition, the players not playing in official matches performed combined training (SSG + HIIT training according to the week of the present study) in order to simulate the internal and external loading in official soccer matches. Each training session started with a 15 min standardized warm-up, consisting of low-intensity running and stretching with integration of soccer-specific actions. The players completed a VO_{2max} , sprint, jump, agility, repeated sprint ability, technical test, 1000-m run test and 30–15 intermittent fitness test (30–15 IFT). All tests took place at a similar time of day (between 5 and 7 PM) with the same order of tests and players.

Subjects

Twenty young male soccer players (age: 14.2 ± 0.5 years, height: 161.8 ± 7.9 cm, weight: 50.8 ± 0.5 kg, body fat % 13.8 ± 2.0) participated in this study. All the players were members of the same young soccer team competing in an academy league (U-15 regional development league). They were accustomed to a training workload of >4 training units per week (~ 90 minutes each session) and had been involved in soccer training and matches for at least 3 years (Table 1). The players were assigned to two groups: the SSG group ($n=10$, VO_{2max} : 47.2 ± 1.3 $ml \cdot min^{-1} \cdot kg^{-1}$) and the HIIT group ($n=10$, VO_{2max} : 46.6 ± 0.9 $ml \cdot min^{-1} \cdot kg^{-1}$). During the 5-week training period, none of the subjects in the study were excluded (due to injuries, sickness or drop-out). All players and parents were notified regarding the research procedures, requirements, benefits, and risks and written informed consent was obtained prior to the study. The study was approved by the Ankara Yildirim Beyazit University Ethics Committee (09/19-249) and was conducted in a manner consistent with the institutional ethical requirements for human experimentation in accordance with the Declaration of Helsinki.

Procedures

Pre- and Post-testing Sessions. Body mass and body fat percentage were measured using the bioelectrical impedance measurement (BC-418, Tanita, Tokyo, Japan). Both body mass and fat percentage were assessed in the morning before breakfast. The remaining tests were conducted at 5 to 7 p.m. after a 15-min standardized warm-up consisting of low-intensity running, striding, and dynamic stretching. The tests occurred 2 days after the last match and 3 days after the last training session. After the test assessments in pre- and post-intervention, players played soccer-specific games involving both technical and tactical tasks for a total of 20–25 minutes.

TABLE 1. Subjects' characteristics and the internal load measure

	SSG (n=10)		HIIT (n=10)	
	Pre	Post	Pre	Post
Age (years)	14.4±0.5	14.5±0.5	14.1±0.6	14.2±0.6
Years of experience	3.4±0.3	3.5±0.3	3.3±0.3	3.4±0.3
Weight (kg)	52.4±7.2	51.2±7.6	49.3±4.9	48.3±4.7
Height (cm)	163.0±6.9	163.8±6.8	160.7±9.0	161.5±8.8
Average time in minutes during the sessions (5 weeks)	90±10			
Average internal training load during the 5 weeks	266.2±6.3*		219.3±4.9	
Average RPE during the 5 weeks	16.6±0.4		18.3±0.4*	
Average enjoyment during the 5 weeks	30.6±1.0*		16.9±1.1	

Data are presented as mean±SD. * Significant difference between SSG and HIIT groups, p < 0.05.

Each player performed a 10-m, 20-m and 30-m sprint test, zig-zag agility test (with and without ball), speed dribbling ability, repeated sprint ability and 1000-m run test as fast as possible. Each player had three trials separated by 2 minutes of passive resting for these tests except for repeated sprint ability and the 1000-m run test. All these test times were measured using a portable wireless photocell system connected to an electronic timer (Witty, Microgate, Bolzano, Italy). The testing procedure is summarized in Figure 1.

On the first day, after the anthropometric measurements, the YYIRTL-1 was administered according to the procedures suggested by Bangsbo et al. [20]. Test reliability was established in a previous study [21]. After the test, the estimated VO_{2max} was calculated using the following formula: [20]:

$$VO_{2max} = 36.4 + (0.0084 \times \text{covered distance in YYIRTL-1})$$

On the third day, players performed a 10-m, 20-m and 30-m sprint test and speed dribbling ability test as fast as possible. As

a soccer technical test, the speed dribbling ability test was used to assess speed and coordinated dribbling under time pressure. The players started with the ball from behind the line. After 5 min, the players dribbled to the right, around the first post of a triangle. Following the set order, the players dribbled around the other posts. After 10 min, they dribbled around a block. Then, after 8 min, the players dribbled the ball around one side of a square and ran around the other side to collect the ball. Afterward, they sprinted through a gate and placed their foot on the ball [22].

On the fifth day, for jumping, the players performed the counter-movement jump (CMJ), squat jump (SJ), and 30-cm drop jump (DJ) tests, with hands kept on the hips to minimize the contribution of the upper limbs. Each player had 3 attempts at all the jumping tests and these attempts were separated by 2 minutes of passive resting between consecutive trials. All jumping tests were separated by 5 minutes of passive rest to avoid fatigue and injury. Jump performances were assessed using a portable force plate (Optojump, Microgate, Bolzano, Italy). Players were familiarized with the proper

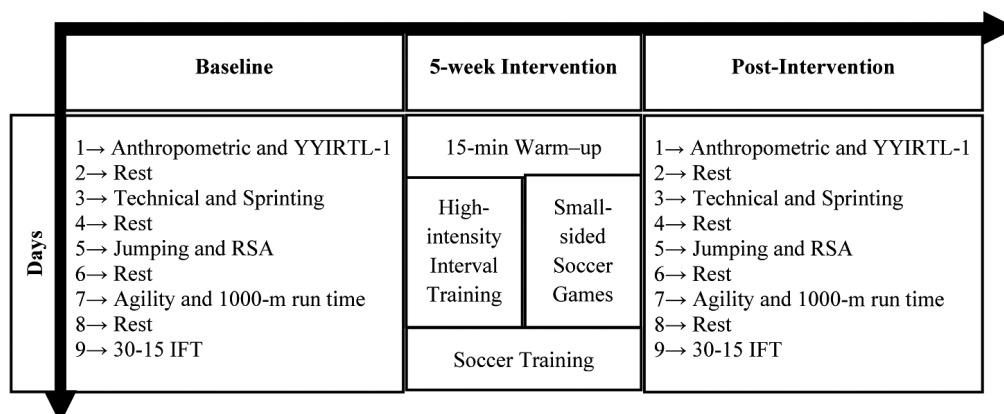


FIG. 1. Study design.

jumping technique before being tested. After jumping tests, the players performed the repeated sprint ability (RSA) test involving 6 repetitions of maximal 2 x 15-m shuttle sprints (~6 seconds) departing every 20 seconds [23].

On the seventh day, the agility performances of the players were evaluated using a zigzag agility test [24]. A zigzag test consisting of 4- to 5-m sections was set out at 100° angles. This test was based on rapid deceleration, acceleration, and balance control required for a short running time, which demonstrated the result of the test [25]. Each player had three trials separated by 2 minutes of passive resting between trials. After the agility test, each player performed a 1000-m run test as fast as possible [10, 26].

On the ninth day, in order to determine the running speed for the HIIT, the 30–15 intermittent fitness test, which has been shown to be reliable, was performed as previously described by Buchheit [27]. The speed was noted as velocity obtained in the 30–15 intermittent fitness test (V_{IFT}) during the last completed stage of the test.

All the players were familiar with all tests used in this study and were verbally encouraged by their team coach to exert maximal efforts during the testing and training sessions. All tests were performed on a synthetic grass pitch at a similar time of the day (between 5 p.m. and 7 p.m.) for similar chronobiological characteristics [28].

Training Interventions. The 5-week training programme took place in the first half of the junior soccer season period (4 weeks after the beginning of the season). During the study, players performed 2 specific training (HIIT or SSG) sessions per week, in addition to their sport-specific team training for a total of 5 consecutive weeks. A soccer training week consisted of 4 times 1–1.5 hours of practice and 1 soccer match. Except for the 2 specific training sessions, the coach mainly focused on developing aerobic and anaerobic

fitness and technical-tactical skills during the present study. Each training session started with a 15 min standardized warm-up, consisting of low-intensity running and stretching with integration of soccer-specific actions. Subsequently, the players performed SSG or HIIT. Both training programmes were structured according to a gradual progress plan designed to maximize final performance. The total training time of sessions was equally distributed for both groups in accordance with their in-season periodization. The SSG group performed various types of the 2-a-side SSG, including possession, goalkeeper, small goal, two floaters off the pitch (Table 2) lasting for 10 and 18 min per training session. Two-a-side SSG were selected because this game has been shown to have similar exercise intensity as the HIIT types (>85% of their individual HR_{max}) [29, 30]. The 2-a-side SSG with possession and small goal were played with pitch size of 20x15 m, whereas the 2-a-side SSG with goalkeeper and two floaters were played on 25x18-m pitch size. The relative pitch size was fixed with 75 m² per person in all SSG. To minimize interruption when the ball left the field of play, spare balls were kept all around the pitch and four supporting players were stationed around the outside of the playing area ready to return the ball to play when necessary. The HIIT sessions, interval training without a soccer ball, consisted of intermittent running at 90–95% of players' V_{IFT} for 15 seconds (around the pitch), followed by 15 seconds of passive recovery, as described in Table 2. The rating of perceived exertion (RPE) was determined using the category level (CR-20) Borg scale immediately after the completion of each session. The players answered individually to avoid hearing the scores of the colleagues. Moreover, the CR-20 was introduced before aiming to familiarize the players and increase the accuracy of the answers. All players also completed the short form of the physical activity enjoyment scale (PACES) [31]. This scale

TABLE 2. Description of the 5 weeks of HIIT and SSG training programme and features of each session.

Week	Sessions	SSG	HIIT
1			Pre-intervention testing
2	1 2	2 x (2 x 2.30 min POS), 2 min rest	2 x (6 min of 15''-15'' at 90% of V_{IFT})
3	3 4	2 x (2 x 3 min GK), 2 min rest	2 x (7 min of 15''-15'' at 90% of V_{IFT})
4	5 6	2 x (2 x 3.30 min SG), 2 min rest	2 x (8 min of 15''-15'' at 90% of V_{IFT})
5	7 8	2 x (2 x 4 min GK), 2 min rest	2 x (9 min of 15''-15'' at 95% of V_{IFT})
6	9 10	2 x (2 x 4.30 min F_{out}), 2 min rest	2 x (10 min of 15''-15'' at 95% of V_{IFT})
7			Post-intervention testing

POS: possession; GK: goalkeeper; SG: small goal; F_{out} : two floater off pitch VIFT: Maximum speed reached in the last stage of the 30–15 intermittent fitness test.

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includes 5 items scored on a 1–7 Likert scale and has been validated as a marker of enjoyment level in activity in Turkish youths [32]. The players were familiar with all the tests and training methods, and they were instructed to maintain their habitual lifestyle and normal dietary intake before and during the study.

Statistical Analyses

Data were represented as mean \pm SD. Within-group differences in psychophysiological responses between pre- and post-test results were assessed using the paired sample t-test. Between-group

differences were analysed using a 2-factor repeated-measures analysis of variance with 1 “between” factor (group: SSG vs. HIIT) and 1 “within” factor (time: pre vs. post). Effect sizes (Cohen’s *d*) were also calculated to provide an estimate of meaningfulness of comparisons between pre- and post-test results. The thresholds for effect size statistics were as follows: <0.20=trivial, 0.20–0.59=small, 0.6–1.19=moderate, 1.2–1.99=large; \geq 2.0=very large [33]. Statistical analyses were performed with SPSS software version 16.0 (SPSS, Inc., Chicago, IL, USA). The level of statistical significance was set at $p \leq 0.05$.

TABLE 3. Effect of both training methods on anthropometric and performance responses of the participants.

	SSG (<i>n</i> =10)							HIIT (<i>n</i> =10)						
	Pre	CV (%)	Post	CV (%)	%Change	Cohens <i>d</i>	Magnitude	Pre	CV (%)	Post	CV (%)	%Change	Cohens <i>d</i>	Magnitude
Body mass (kg)	52.4 \pm 7.2	13.7	51.2 \pm 7.6	14.8	-2.3	0.16	trivial	49.3 \pm 4.9	9.9	48.2 \pm 4.7	9.7	-2.3	0.23	small
Fat percentage (%)	14.2 \pm 1.9	13.4	13.6 \pm 1.9	13.9	-4.4	0.32	small	13.4 \pm 2.2	16.4	12.8 \pm 2.0	15.6	-4.7	0.28	small
YYIRTL-1 (m)	1284 \pm 152	11.8	1472 \pm 99*	6.7	12.8	1.46	large	1240 \pm 75	6.4	1484 \pm 74*>	4.9	16.4	3.27	very large
VO _{2max} (ml. min ⁻¹ .kg ⁻¹)	47.2 \pm 1.3	2.7	48.8 \pm 0.8*	1.6	3.3	1.48	large	46.8 \pm 0.6	1.3	48.9 \pm 0.9*>	1.8	4.3	2.61	very large
1000-m time (s)	236 \pm 17	7.2	230 \pm 15*	6.5	-2.6	0.37	small	243 \pm 17	6.9	229 \pm 14*	6.1	-6.1	0.90	moderate
CMJ (cm)	28.5 \pm 2.5	8.8	31.3 \pm 1.9*	6.1	8.9	1.26	large	28.2 \pm 2.0	7.1	30.6 \pm 1.8*	5.9	7.8	1.26	large
SJ (cm)	30.1 \pm 1.5	4.9	33.1 \pm 1.4*>	4.2	9.1	2.07	very large	31.2 \pm 2.2	7.0	33.9 \pm 1.4*	4.1	7.9	1.46	large
DJ (cm)	27.9 \pm 1.7	6.1	29.9 \pm 1.8*	6.0	6.7	1.14	moderate	27.7 \pm 1.7	6.1	29.6 \pm 1.5*	5.1	6.4	1.18	moderate
10- Sprint (s)	2.15 \pm 0.12	5.6	2.03 \pm 0.08*	3.9	-5.9	1.77	large	2.09 \pm 0.07	3.3	1.99 \pm 0.04*	2.0	-5.0	1.75	large
20- Sprint (s)	3.79 \pm 0.23	6.1	3.51 \pm 0.16*	4.6	-7.9	1.41	large	3.55 \pm 0.16	4.5	3.33 \pm 0.12*	3.6	-6.6	1.55	large
30- Sprint (s)	5.15 \pm 0.32	6.2	4.81 \pm 0.31*	6.4	-7.1	1.08	moderate	5.00 \pm 0.34	6.8	4.66 \pm 0.29*	6.2	-7.3	1.08	moderate
ZAWB (s)	8.85 \pm 0.54	6.1	8.36 \pm 0.53*	6.3	-5.9	0.92	moderate	8.56 \pm 0.34	3.9	8.45 \pm 0.36*	4.3	-1.3	0.31	small
ZAWOB (s)	6.92 \pm 0.19	2.7	6.68 \pm 0.15*	2.2	-3.6	1.40	large	7.09 \pm 0.20	2.8	6.91 \pm 0.16*	2.3	-2.6	0.99	moderate
SDA (s)	25.3 \pm 0.9	3.6	23.6 \pm 0.8*	3.4	-7.2	1.99	large	25.1 \pm 1.2	4.8	24.0 \pm 0.8*	3.3	-4.6	1.08	moderate
RSA _{total} (s)	37.8 \pm 1.5	3.9	35.6 \pm 1.2*	3.4	-6.2	1.67	large	38.2 \pm 1.7	4.4	34.9 \pm 1.5*>	4.3	-9.4	2.06	very large

Data presented as mean \pm SD. YYIRTL-1: Yo-Yo Intermittent Recovery Test level 1; VO_{2max}: maximal oxygen uptake; CMJ: counter-movement jump; SJ: squat jump; DJ: drop jump; ZAWB: zigzag agility with the ball; ZAWOB: zigzag agility without the ball; SDA: speed dribbling ability; RSA_{total}: total time during repeated sprint ability test; CV: coefficient of variation > very large effect size. * Significant difference between pre- and post-training.

RESULTS

RPE responses to HIIT sessions were significantly larger than those to SSG sessions (18.3 ± 0.4 vs. 16.6 ± 0.5 ; $p \leq 0.05$, $d=3.75$ [very large effect]). Conversely, PACES scores from the SSG were significantly higher than those from the HIIT over the 10 sessions (30.6 ± 1.0 vs. 16.5 ± 0.9 ; $p \leq 0.05$, $d=14.82$ [very large effect]). No significant within-group differences were found in body weight or body fat percentage when comparing the effect of the two training methods ($p > 0.05$, trivial to small effect). In addition, there were significant improvements in agility test performances in terms of zigzag agility with the ball (ZAWB) (SSG: -5.9% , $p \leq 0.05$, $d=0.92$ [moderate effect]; HIIT: -1.3% , $p \leq 0.05$, $d=0.31$ [small effect]) and zigzag agility without the ball (ZAWOB) (SSG: -3.6% , $p \leq 0.05$, $d=1.40$ [large effect]; HIIT: -2.6% , $p \leq 0.05$, $d=0.99$ [moderate effect]) and technical test performance (SSG: -7.2% , $p \leq 0.05$, $d=1.99$ [large effect]; HIIT: -4.6% , $p \leq 0.05$, $d=1.08$ [moderate effect]) in both the SSG and HIIT groups (Figure 2).

Conversely, significant changes were observed in the 1000-m running time (HIIT: -6.1% , $p \leq 0.05$, $d=0.90$ [moderate effect]; SSG: -2.6% , $p \leq 0.05$, $d=0.37$ [small effect]) and total time of repeated sprint test ability (HIIT: -9.5% , $p \leq 0.05$, $d=2.06$ [very large effect]; SSG: -6.2% , $p \leq 0.05$, $d=1.67$ [large effect]). Furthermore, no significant between-group differences were found in any anthropometric or performance responses ($p > 0.05$) (Table 3).

DISCUSSION

The aim of the present study was to compare the effects of 5-week HIIT vs. 5-week SSG on the physical performance, psychophysiological responses and technical skills in young soccer players and to show which of these training programmes is more effective in the preparation period. In agreement with our hypothesis, our results showed that both the HIIT and SSG training methods are effective

at improving body composition and aerobic and anaerobic fitness variables in young soccer players. Furthermore, SSG training might be a more effective training strategy to improve soccer-specific ability, which includes agility and technical ability, with greater physical enjoyment. Conversely, the HIIT training might be more suitable for speed-based conditioning in young soccer players.

Heart rate monitoring, although it has some important limitations [34], is a very common method to measure the intensity of physical activity, especially in games involving high-intensity activity. For this reason, RPE is also considered a viable measurement tool for tracking internal loads using low cost and easily accessible procedures which determine individuals' perceived exertion of training. Recently, many studies have increasingly reported the psycho-physiological scales used in sports to measure levels of enjoyment related to a given activity [19, 35]. Many studies have also indicated the positive effect of motivation and enjoyment, which are directly related to effort expenditure and participation in sports, particularly in young players [19, 36]. As expected, the results of this study showed that the SSG group had higher PACES scores with lower RPE responses than the HIIT, which is consistent with some studies in the literature [19, 35].

One of the main findings of the present study was that both SSG and HIIT training significantly increased the aerobic capacity of the players. Our results are consistent with previous studies comparing HIIT and SSG, showing that both training methods result in similar changes in aerobic fitness not only in young soccer players [15, 16], but also in different team and individual players such as basketball [37], futsal [38], handball [39] and tennis [35]. An increase in VO_{2max} values of the young soccer players after HIIT with different intensities ($>85\% HR_{max}$) and durations (5–12 weeks) has been observed in numerous studies [7, 10]. Evidently, VO_{2max} increased from $58.1 \text{ ml} \cdot \text{min}^{-1} \cdot \text{kg}^{-1}$ to $64.3 \text{ ml} \cdot \text{min}^{-1} \cdot \text{kg}^{-1}$ with an increase of 11% after HIIT with 18-year-old elite soccer players for a period

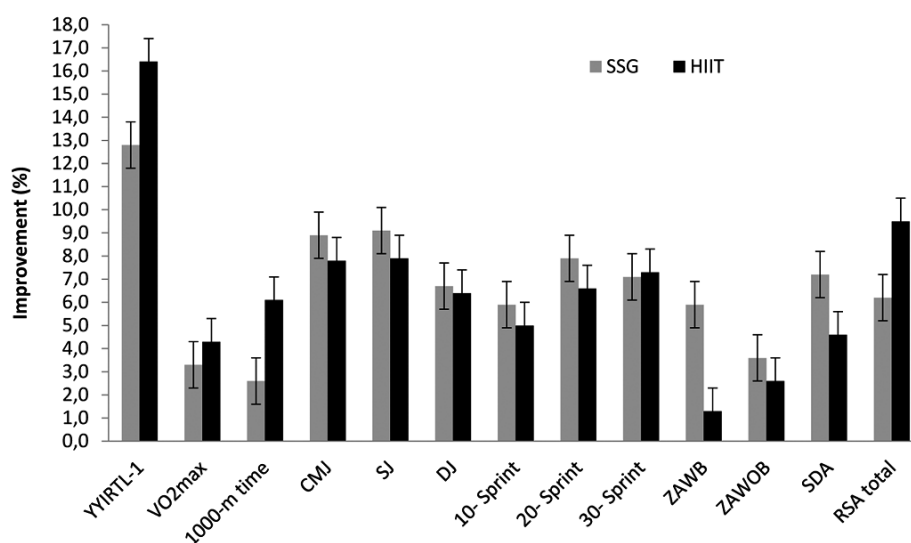


FIG. 2. Improvement in performance, psychophysiological responses and technical skills following the different training interventions.

of 8 weeks [13]. Another study proved that VO_{2max} increased by $6.4 \text{ ml}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$ or 9% after HIIT with U-17 aged soccer players for a period of 10 weeks [39]. In another study, Sperlich et al. [10] observed that the VO_{2max} increased from $55.1 \pm 4.9 \text{ ml}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$ to $58.9 \pm 4.7 \text{ ml}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$ with an increase of 7% after HIIT among 14-year-old soccer players for a period of 5 weeks. Clearly, our results are similar to those of previous studies. Several studies also confirmed the changes in the maximum aerobic power and capacity values of young soccer players after SSG performed with different numbers of players, different field dimensions, and different rules. For example, the VO_{2max} values of the young soccer players increased from $57.7 + 4.2 \text{ ml}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$ to $61.8 + 4.5 \text{ ml}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$ in a percentage of 7% after SSG lasting 12 weeks in total (4 weeks pre-season + 8 weeks within season) [16]. Another comparable study indicated that neither VO_{2max} values nor sprint values of 15-year-old soccer players changed after SSG for a period of 7 weeks in the percentage of 90%–95% HR_{max} [15]. Such differences between changes might be explained by the training duration, training period and age of the participants.

In accordance with the VO_{2max} results from our study, there was a significant decrease of 14 seconds or in the percentage of 6.1% in their 1000-m running time and a significant increase in repeated sprint ability performance of 9.5% after the 5-week HIIT. In another study with similar results, the VO_{2max} of young soccer players increased by 5.2% after high-intensity running training for a period of 8 weeks prior to the season, whereas an enhancement by 2.2% in their 300-yard shuttle run test performances occurred [41]. Another study supporting our study confirms a decrease of 10 seconds or in the percentage of 4.2% in their 1000-m running time after the 5-week HIIT [10]. Taking these results into consideration, clearly, increasing VO_{2max} values in young soccer players after HIIT of different durations cause a decrease in running time of different field lengths. From a practical point of view, these results will be beneficial for young players' coaches in planning field applications, especially sprint training with and without balls (agility) as well as endurance workouts.

Performance indicators, such as agility and technical skills, which require both acceleration and soccer-specific technical skills, are significantly better in the SSG than in the HIIT. Jumping and sprinting ability improved significantly in both groups after the 5-week HIIT vs. the 5-week SSG in the young soccer players. This result also supports other similar studies in the literature [10, 13, 15, 40]. Furthermore, the ability of speed dribbling, which includes sprinting and soccer-specific elements, is enhanced further with the help of SSG (-1.7 s or -7.2%). In a study which supports these results, Chamari et al. [42] observed a decrease of 9.6% in the Hoff test completion time (which requires swinging sprint and dribbling abilities), as a result of regular soccer training with the ball for a period of 8-weeks. Impellizzeri et al. [16] reported a decrease of approximately 16% in the duration of the Ekblom test, which is a soccer-specific test, after an SSG training period of 12 weeks in total (4 weeks pre-season + 8 weeks within season). In another study carried out

with soccer players, Little and Williams [25] found that a medium level of relationship exists between the acceleration and agility test performances of the soccer players (respectively $r=0.35$, $p < 0.05$). Considering these results, we believe that ball usage is of high importance, especially in training which involves acceleration and agility to be performed in a limited period of time, because this usage can generate progress not only in accelerating but also in soccer technique and in the ability of making decisions and predicting the activities in the game (reading the game) in SSG games jointly applied with a ball and with a teammate.

The main limitations of the present study included a relatively small sample size of young male soccer players, a short training period, and the lack of external loading. Because of these, our results may not generalise to players of different sex, level or age groups. Another limitation is the synthetic grass pitch, affecting the movement patterns and technical standards of players.

In conclusion, this study led to a considerable increase in aerobic capacity through HIIT performed 2 days a week for a period of 5-weeks during the preparation period of the season while causing a considerable improve in speed-based demands such as 1000-m running time (-6.1%) and total duration of repeated sprint ability (-9.5%). However, much more progress is observed in agility, and soccer technique in SSG with similar total duration of HIIT. The majority of the children at this age spend most of their time at school and they have little spare time outside of their studies, so they cannot spend much time on soccer training. Therefore, SSG seems to be specifically effective in conditioning the game-based abilities such as agility, and soccer-specific technique. For further investigations it would be interesting to allocate players to groups according to their initial performance [43].

PRACTICAL APPLICATIONS

This study showed the effects of two different and popular training interventions, i.e. HIIT and SSG, on young soccer players. This study also demonstrated a considerable increase in technical test score of -7.2% and a significant decrease in agility test time after 5 weeks of SSG. However, the HIIT group showed significant improvement in 1000-m running time and repeated sprint ability performance with similar total duration of HIIT in young soccer players. Time-efficient training strategies, especially in young players, are necessary to increase technical capacity, which is directly related to agility and match performance. The majority of young soccer players spend most of their time at school and have little spare time outside of their studies, which means that they cannot spend a great deal of time on soccer training. Therefore enjoyable, effective, and easier to practice training strategies in soccer are preferable to focus on improving game-based demands. Considering these factors, it seems possible to conclude that SSG is a more effective training method than HIIT for youth soccer players. The present study suggests that coaches can successfully use time-efficient and soccer-specific training in order to improve desired physical conditioning of young soccer players.

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Conflict of interest declaration

The authors declare no conflict of interests regarding the publication of this manuscript.

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