

Short-term effects of on-field combined core strength and small-sided games training on physical performance in young soccer players

AUTHORS: Ersan Arslan¹, Yusuf Soylu², Filipe Manuel Clemente³, Tahir Hazir⁴, Ayse Kin Isler³, Bulent Kilit⁵

¹ Siirt University, School of Physical Education and Sports, Siirt, Turkey

² Tokat Gaziosmanpasa University, Faculty of Sport Sciences, Tokat, Turkey

³ Escola Superior Desporto e Lazer, Instituto Politécnico de Viana do Castelo, Rua Escola Industrial e Comercial de Nun'Álvares, 4900-347, Viana do Castelo, Portugal

⁴ Hacettepe University, Faculty of Sport Sciences, Ankara, Turkey

⁵ Tekirdag Namik Kemal University, School of Physical Education and Sports, Tekirdag, Turkey

ABSTRACT: This study aimed to compare the effects of 6-weeks combined core strength and small-sided games training (SSG_{core}) vs. small-sided games (SSG) training on the physical performance of young soccer players. Thirty-eight amateur soccer players (age: 16.50 ± 0.51 years) were randomly assigned to either a SSG_{core} (*n* = 20) or a SSG group (*n* = 18). The SSG_{core} group performed upper and lower body core strength exercises combined with SSG including 2-, 3- and 4-a-sided soccer games third a week. The SSG group performed only the SSG periodization. Baseline and after the 6-week training period the Yo-Yo Intermittent Recovery Test level 1 (YYIRT-1), 5–20-m sprint test, countermovement jump (CMJ), squat jump (SJ), triple-hop distance (THD), zigzag agility with ball (ZAWB) and without ball (ZAWOB), three corner run test (TCRT) and Y-balance test. The SSG_{core} group demonstrated meaningful improvements in 20 m sprint time (SSG_{core}: -9.1%, *d* = 1.42; SSG: -4.4%, *d* = 0.76), CMJ (SSG_{core}: 11.4%, *d* = 2.67; SSG: -7.7%, *d* = 1.43), SJ (SSG_{core}: 12.0%, *d* = 2.14; SSG: 5.7%, *d* = 1.28), THD (SSG_{core}: 5.0%, *d* = 1.39; SSG: 2.7%, *d* = 0.52) and TCRT (SSG_{core}: -3.7%, *d* = 0.69; SSG: -1.9%, *d* = 0.38). Furthermore, the SSG_{core} group demonstrated meaningfully higher improvement responses in both leg balance score (*d* = ranging from 2.11 to 2.75) compared with SSG group. These results suggest that the inclusion of core strength training to a SSG periodization is greatly effective to improve speed and strength-based conditioning in young soccer players.

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Corresponding author:

Ersan Arslan

School of Physical Education and Sports
Siirt University, Kezer Yerleşkesi
Siirt, Turkey
Tel.: +90 484 212 11 11
Email: ersanarslan1980@hotmail.com

ORCID:

Ersan Arslan
0000-0002-2933-6937

Yusuf Soylu
0000-0003-0609-0601

Filipe Manuel Clemente
0000-0001-9813-2842

Tahir Hazir
0000-0002-0048-0281

Ayşe Kin-İsler
0000-0001-9651-2067

Bulent Kilit
0000-0002-9061-0691

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INTRODUCTION

High level performance in competitive soccer depends heavily on aerobic energy metabolism and short-time high-intensity intermittent activities such as running at different speeds, shooting and tackling, with an average game intensity ranging from 80% to 90% of players' individual maximum heart rate (HR_{max}) [1–3]. Furthermore, previous studies have shown that young soccer players cover a distance between 6.5 km and 9.9 km and that very high-intensity activity (> 16 km·h⁻¹) accounts for approximately 7–14% of the total distance covered during the official competitive matches [4, 5]. Therefore, many sport scientists and coaches have recently focused on the improvement of young soccer players' aerobic fitness by using various popular training methods such as high-intensity interval training (HIIT) [6], small-sided games (SSG) [7, 8] and speed-based training [9, 10]. However, young

soccer players need to possess soccer-specific physical characteristics such as speed, agility and strength to perform sprinting, dribbling and shooting during the matches [3].

One of the more enjoyable, effective and time-efficient training strategies to improve players' aerobic endurance performance is small-sided games training (SSG), which simultaneously involves actual movement patterns and types, technical-tactical awareness and physical fitness under simulated game conditions [7, 11, 12]. Recently, numerous studies have showed the variety term (ranging from 5 to 8 weeks) training effect of SSG on physical performance, psychophysiological responses and technical skills in young soccer players [6, 7, 13, 14]. Arslan et al. [6] performed a SSG two times a week for 5 weeks during the first half of the season, lasting of 10 and 18 minutes of SSG intervals at > 85% HR_{max} with 2 minutes

of rest between bouts. The study results demonstrated that the players' physical fitness, anaerobic test performances and technical skills are higher in the SSG training group.

It is well known that soccer players perform numerous strength-based activities during the matches. Consequently, core muscle strength is not only critical skill-related component of physical fitness such as coordination, balance and speed, but also important indicator of health-related components of young players [15]. Numerous studies have demonstrated that the considerable positive training effect of core strength in young soccer players improved sport-specific performances, including balance [15], endurance [16] and agility [17]. Furthermore, concurrent training method, combining strength and endurance [18] or strength and SSG [19], has also more effective

training strategy to increase soccer-specific strength and endurance performances in young soccer players. Consequently, this training strategy may be a part of strength and conditioning program as a time-efficient alternative training method for improving physical conditioning during the preseason period.

While some previous studies examined the long-term (8–12 weeks) on-field training effects of core strength training programs [17, 20], other recent studies investigated the effects of strength training on physical performance responses in young soccer players [18, 21]. To our knowledge, no study has performed regarding the short-term effects of combined core strength and small-sided games training on physical performance responses in young soccer players during the off-season period. Therefore, this study aimed to compare the

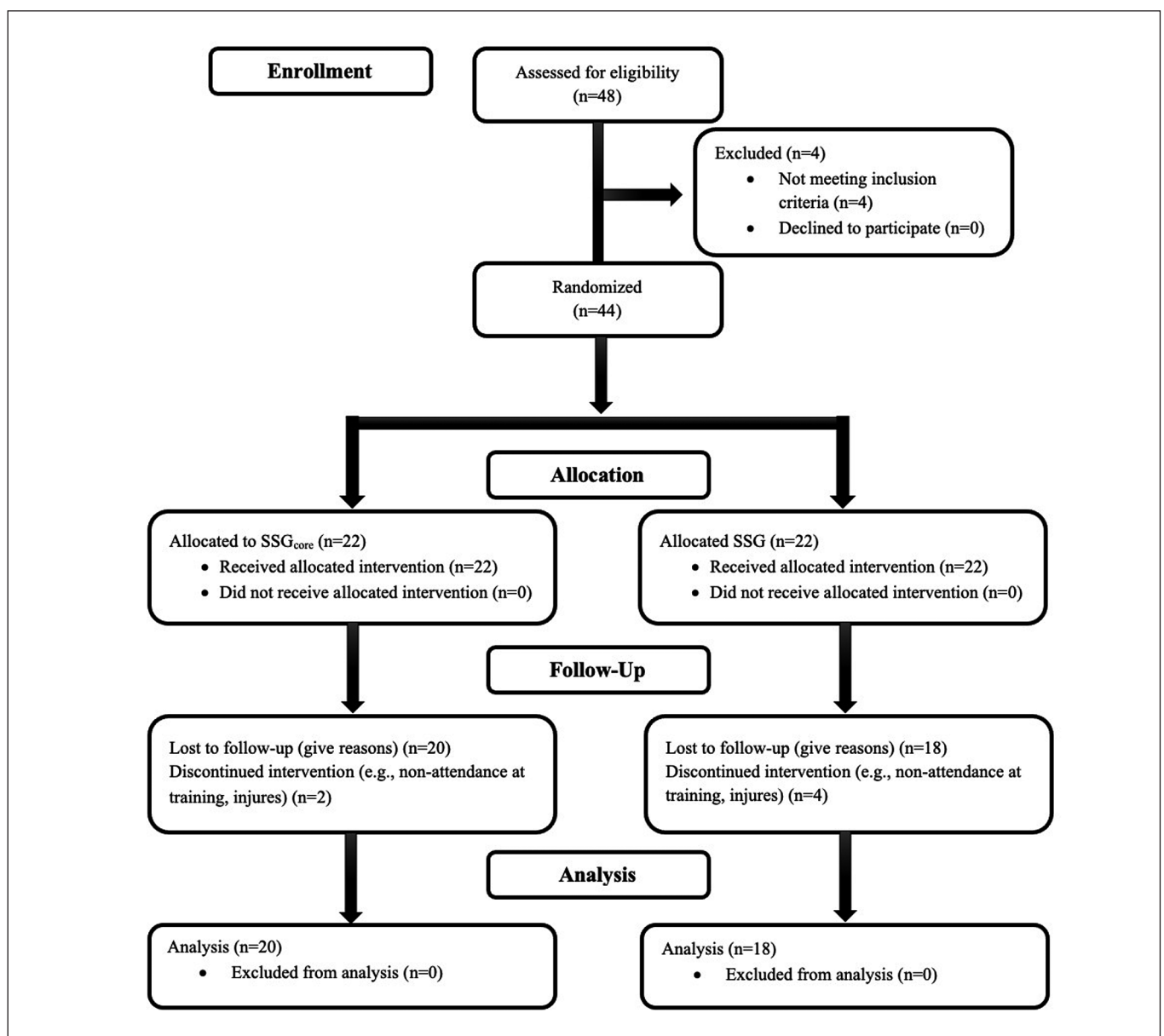


FIG. 1. CONSORT study flow chart.

short-term effects of on-field combined core strength and small-sided games training (SSG_{core}) vs. small-sided games (SSG) training on aerobic, anaerobic and balance performance responses in young soccer players. We hypothesized that the SSG_{core} training will lead to greater improvement in speed and strength-based performance responses such as sprinting, jumping and balance.

MATERIALS AND METHODS

Experimental Approach to the Problem

A parallel group controlled design was used in order to compare short-term effects of on-field SSG_{core} vs. SSG training on aerobic, anaerobic and balance performance responses in young soccer players during the off-season period. The study design consisted of 1-week of baseline test, 6-weeks of training intervention (3 times per week) and 1-week of post intervention tests. All players completed maximal oxygen consumption ($\dot{V}O_{2max}$), 5–20 m sprint test, countermovement jump (CMJ), squat jump (SJ), triple-hop distance (THD), zigzag agility with ball (ZAWB) and without ball (ZAWOB), three corner run test (TCRT) and Y-balance test measurements with same order before and after the 6-weeks intervention period. In this study, we especially preferred these performance determinant tests that have been shown high relationship with match performance of young soccer players [4, 22]. The players were already familiar with all the tests and SSG trainings. Each training session started with a 15-min standardized warm-up and consisting of low-intensity running and stretching with integration of soccer-specific actions. The SSG_{core} group performed dynamic and static core strength training involving upper and lower body exercises with different formats of SSGs 3 times per week. The SSG training group maintained their normal training which consists of small-sided games without core strength training. All tests and training sessions were performed on a natural grass pitch at a similar time of the day with the same order of tests and players. The players were instructed to maintain their normal dietary intake and habitual lifestyle during the study.

Subjects

Forty-four young male soccer players agreed to participate at the beginning of this study (Figure 1). During the study, a total of 6 players (2 players from the SSG_{core}, 4 players from the SSG) were excluded due to dropouts (e.g., non-attendance at training, injuries, failing to attend test sessions). Consequently, 38 players participated in this study voluntarily. The players were divided into two groups: the SSG_{core} group ($n = 20$, age: 16.30 ± 0.47 years, height: 171.80 ± 6.56 cm, weight: 62.18 ± 7.41 kg, training age: 4.15 ± 0.59 years) and the SSG group ($n = 18$, age: 16.50 ± 0.51 years, height: 174.67 ± 5.58 cm, weight: 62.58 ± 6.08 kg, training age: 4.11 ± 0.58 years). These players were members of a regional amateur U-17 league teams and they were also familiar with training workload of ≥ 3 training units per week (~ 100 minutes) and have been involved in training and competitive soccer matches at least 3 years. All players were performing

3 training sessions which includes low to moderate aerobic training, plyometric and small-sided games without core strength training at the time of the study. Players were not familiar with upper and lower core strength training. They and their parents were notified of the research requirements, procedures, risks and benefits before being given the informed consent forms. Written these forms were then obtained from all the players and their parents. The present study was approved by the Research Ethics Committee of the local university and was conducted in accordance with the Declaration of Helsinki.

Procedures

Testing Procedure. Body weight and body fat percentage were measured using the bioelectrical impedance measurement (BC-418, Tanita, Tokyo, Japan) before breakfast. Each player performed vertical jump height in terms of the CMJ and SJ tests with hands kept on the hips to minimize the contribution of the upper limbs. Jump performances were assessed using a portable force plate (Newtest, Finland). A standard tape measure was used for measuring the maximum distance in the TDH, which is a valid test for evaluation of lower limb strength and power, is to reach maximum distance with 3 consecutive hops without losing balance and touching the ground with the any hands or other leg [23]. Each player performed a 20-m sprint test (with 5-m and 10-m splits), ZAWB, ZAWOB and TCR. A zigzag agility test consisting of 4- to 5-m sections was set out at 100° angles [24]. The selection of this test was based on rapid acceleration, deceleration, and balance control required for a short running time, which represented the result of the test [25]. The TCR test was used to evaluate the speed and anaerobic endurance of the players. After the starting command, the players ran to flag post (1) 80-m away from the start. Then, they turned to the left-hand side and ran to flag post (2) 20-m away from flag post (1). Subsequently, the players ran back to flag post (3) 82.4-m away from the start. Finally, the players turned to the right-hand side, ran to the finish line (4), and crossed it [26]. The times for these tests were measured and recorded using photocells (Newtest, Finland). Before the Y balance test, each players' length of the both legs were assessed with a standard tape measure from the anterior superior iliac spine to the most distal aspect of the medial malleolus during supine lying position. The test, consisting three different movement directions such as anterior, posteromedial and posterolateral) was used to evaluate the dynamic balance with single leg stance whilst reaching in those direction. After six trials on each foot for familiarization, each player had three successful reaches separated by 15 seconds [27]. After the test, a composite score (CS) was calculated using the following formula [28]:

$$CS = [(maximum\ anterior\ reach\ distance + maximum\ posteromedial\ reach\ distance + maximum\ posterolateral\ reach\ distance) / (leg\ length \times 3)] \times 100$$

To evaluate of aerobic capacity, The YYIRT-1, which is a reliable and acoustically progressive test [29] was performed on a natural grass pitch and according to procedures were described by Bangsbo

TABLE 1. The 6-week training program.

Trainings	Sessions	Training Program																		
		1-week			2-week			3-week			4-week			5-week			6-week			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Core Strength Training	Exercise Type	Dynamic			Static			Dynamic			Static			Dynamic			Static			
	Sets × Duration	3 × 25-s			3 × 30-s			3 × 35-s			3 × 40-s			3 × 45-s			3 × 50-s			
	Work:Rest ratio	1:1																		
	Rest Interval	90-s																		
	Exercises	Push-up	Push-up			Plank			Push-up			Plank			Push-up			Plank		
		Push-up with rotation	Push-up with rotation			Plank one-side			Push-up with rotation			Plank one-side			Push-up with rotation			Plank one-side		
		Crunch	Crunch			Crunch			Crunch			Crunch			Crunch			Crunch		
		Bird-dog	Bird-dog			Bird-dog			Bird-dog			Bird-dog			Bird-dog			Bird-dog		
		Scissor kick	Scissor kick			Plank			Scissor kick			Plank			Scissor kick			Plank		
		Mountain climber	Mountain climber			leg-raised			Mountain climber			leg-raised			Mountain climber			leg-raised		
Full Squat		Full Squat			Full Squat			Full Squat			Full Squat			Full Squat			Full Squat			
Small-sided Games Training	SSGs Formats	2-a-side	3-a-side	4-a-side	2-a-side	3-a-side	4-a-side	2-a-side	3-a-side	4-a-side	2-a-side	3-a-side	4-a-side	2-a-side	3-a-side	4-a-side	2-a-side	3-a-side	4-a-side	
	Pitch Dimension (m × m)	12 × 24	18 × 30	24 × 36	12 × 24	18 × 30	24 × 36	12 × 24	18 × 30	24 × 36	12 × 24	18 × 30	24 × 36	12 × 24	18 × 30	24 × 36	12 × 24	18 × 30	24 × 36	
	Bout Duration (min)	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	
	Number of Bouts	4																		
	Resting Duration (min)	3																		
	Goalkeeper	Yes																		
	Coach Encouragement	Yes																		

et al. [30]. After the test, the estimated $\dot{V}O_{2max}$ was calculated using the following formula

$$\dot{V}O_{2max} = 36.4 + (0.0084 \times \text{covered distance in YYIRT-level 1})$$

Training Interventions. The training procedure is summarized in Table 1. The 6-week training program took place during the preseason period and our players were not involved in any matches. Each training session started with a 15-min standardized warm-up and consisting of low-intensity running and stretching with integration of soccer-specific actions. The SSG_{core} group performed dynamic and static core strength training involving 7 popular upper and lower body exercises [16, 17, 20] with different formats of SSGs (2-, 3- and 4-aside games) 3 times per week. The core strength training was

structured according to a gradual progress plan designed to increase core strength performance. The SSG training group maintained their normal training which consists of game-based training without core strength training. During the study, trainings were supervised an expert with a certified strength and conditioning. All the players were verbally encouraged by their team coach to exert maximal efforts during the training sessions.

Statistical Analyses

Data were expressed as mean ± standard deviation (SD). Between-group differences were analyzed using a 2-factor repeated-measures analysis of variance with 1 “between” factor (group: SSG_{core} vs. SSG) and 1 “within” factor (time: baseline vs. post). Effect sizes (Cohen’s

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d) were calculated for each dependent variable. The thresholds for effect size statistics were as follows: 0.2, trivial; 0.6, small; 1.2, moderate; 2.0, large; and .2.0, very large [31]. Statistical analyses were performed with SPSS software version 16.0 (SPSS, Inc., Chicago, IL, USA). The level of statistical significance was set at $p \leq 0.05$.

RESULTS

Baseline and the short-term effects of on-field combined core strength training on anthropometric and performance responses of the participants are summarized in Table 2. No significant within-group differences were found in anthropometric measurements such as body mass and body fat percentage following training in both groups

($p > 0.05$, $d =$ ranging from 0.07 to 0.43 [trivial to small effect]). Furthermore, The YYIRT-1 performance (SSG_{core}: -13.66%, $d = 1.44$ [large effect]; SSG: -11.49%, $d = 1.56$ [large effect]) and $\dot{V}O_{2max}$ responses (SSG_{core}: -3.17%, $d = 1.44$ [large effect]; SSG: -2.64%, $d = 1.55$ [large effect]). Sprinting performances including 5-m (SSG_{core}: 8.31%, $d = 1.12$ [moderate effect]; SSG: 5.07%, $d = 0.90$ [moderate effect]) and 10-m (SSG_{core}: 7.08%, $d = 1.26$ [large effect]; SSG: 4.70%, $d = 0.59$ [small effect]). ZAWB and ZAWOB performances increase in both groups from pre-testing to post-testing ($p \leq 0.05$, $d =$ ranging from 0.73 to 1.59 [moderate to large effect]).

TABLE 2. Effect of both training methods on performance responses of the participants.

	SSG _{core}					SSG				
	Pre	Post	%Change	d	Descriptor	Pre	Post	%Change	d	Descriptor
Body mass (kg)	62.18 ± 7.41	61.47 ± 7.01*	-1.06	0.09	trivial	62.58 ± 6.08	62.15 ± 5.95*	-0.67	0.07	trivial
Fat percentage (%)	15.39 ± 2.86	14.27 ± 2.23*	-6.67	0.44	small	15.12 ± 1.81	14.38 ± 1.63*	-4.48	0.43	small
YYIRT-1 (m)	1325 ± 123	1504 ± 125*	13.66	1.44	large	1311 ± 97	1460 ± 94*	11.49	1.56	large
$\dot{V}O_{2max}$ (ml.min ⁻¹ .kg ⁻¹)	47.53 ± 1.03	49.03 ± 1.05*	3.17	1.44	large	47.41 ± 0.82	48.66 ± 0.79*	2.64	1.55	large
CMJ (cm)	33.56 ± 1.44	37.39 ± 1.43*¥	11.43	2.67	very large	33.00 ± 1.81	35.52 ± 1.70*	7.68	1.43	large
SJ (cm)	30.71 ± 1.69	34.40 ± 1.75*¥	12.03	2.14	very large	30.32 ± 1.69	32.46 ± 1.64*	5.72	1.28	large
THD (cm)	583 ± 0.23	613 ± 0.20*¥	5.06	1.39	large	572 ± 0.29	587 ± 0.29*	2.72	0.52	small
5- Sprint (s)	1.01 ± 0.09	0.92 ± 0.07*	-8.31	1.12	moderate	0.97 ± 0.06	0.92 ± 0.05*	-5.07	0.90	moderate
10- Sprint (s)	1.68 ± 0.10	1.56 ± 0.09*	-7.08	1.26	large	1.67 ± 0.14	1.59 ± 0.13*	-4.70	0.59	small
20- Sprint (s)	2.96 ± 0.20	2.69 ± 0.18*¥	-9.13	1.42	large	3.03 ± 0.17	2.90 ± 0.17*	-4.45	0.76	moderate
ZAWB (s)	7.31 ± 0.57	6.84 ± 0.42*	-6.25	0.94	moderate	7.25 ± 0.39	6.96 ± 0.40*	-4.00	0.73	moderate
ZAWOB (s)	5.98 ± 0.23	5.50 ± 0.36*	-8.05	1.59	large	5.86 ± 0.19	5.53 ± 0.23*	-5.55	1.56	large
TCRT (s)	34.55 ± 1.97	33.27 ± 1.71*¥	-3.67	0.69	moderate	35.60 ± 1.99	34.89 ± 1.76*	-1.95	0.38	small
Y-Balance Right Leg Score	98.96 ± 6.69	113.78 ± 7.33*¥	15.07	2.11	very large	97.76 ± 5.54	106.73 ± 4.14*	9.34	1.83	large
Y-Balance Left Leg Score	98.70 ± 5.19	113.72 ± 5.73*¥	15.33	2.75	very large	97.38 ± 5.46	106.88 ± 5.45*	9.82	1.74	large

Note: Data are Mean ± SD. YYIRT-1: Yo-Yo Intermittent Recovery Test level 1; $\dot{V}O_{2max}$: maximal oxygen uptake; CMJ: counter-movement jump; SJ: squat jump; THD: triple hop distance; ZAWB: zigzag agility with the ball; ZAWOB: zigzag agility without the ball; TCRT: three corner run test. * Significant difference between pre- and post-training. ¥ Significant difference between groups.

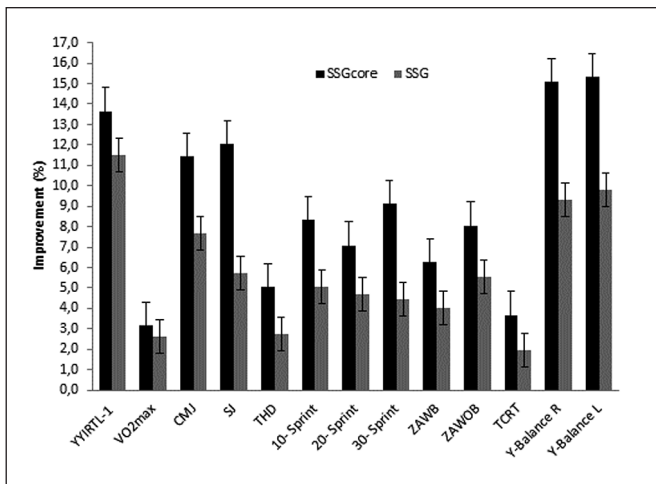


FIG. 2. Improvement in performance responses following the different training interventions.

Between-group comparison results showed that the SSG_{core} group demonstrated greater improvement in the CMJ (SSG_{core}: +11.43%, standardized effect size [d] = -2.67 [very large effect]; SSG: +7.68%, d = 1.43 [large effect]) and SJ (SSG_{core}: +12.03%, d = -2.14 [very large effect]; SSG: +5.72%, d = 1.28 [large effect]) compared with SSG group. In addition, the SSG_{core} group demonstrated higher THD (SSG_{core}: 5.06%, standardized effect size [d] = -1.39 [large effect]; SSG: 2.72%, d = 0.52 [small effect], 20-m sprint time (SSG_{core}: -9.13%, standardized effect size [d] = -1.42 [large effect]; SSG: -4.45%, d = 0.76 [moderate effect] and TCRT performances (SSG_{core}: +3.67%, standardized effect size [d] = -0.69 [moderate effect]; SSG: +1.95%, d = 0.38 [small effect]). The SSG_{core} group demonstrated significant higher improvement responses in both leg balance score ($p \leq 0.05$, d = ranging from 2.11 to 2.75 [very large effect]) compared with SSG group (Figure 2).

DISCUSSION

The purpose of this study was to analyse the effects of two SSGs-based programs (SSG_{core} and SSG) on fitness levels after a 6-week period of intervention. Within group analysis revealed that aerobic performance, linear sprinting and change of direction performance measured at zig-zag tests were significantly and largely improved by both SSG-based groups. Between groups analysis revealed greater improvements of CMJ, SJ, linear sprint at 20-m, three corner run test and both leg balance in SSG_{core} comparing to SSG group.

The combining of SSGs with other training methods have been tested. Some articles revealed beneficial effects of combining SSGs with high-intensity running-based interval training [32, 33] in aerobic capacity. A more recent study combining SSGs and strength training (in weight room) also showed beneficial effects in neuromuscular fitness [19]. However, from these three studies, only one have used a parallel design [32], while one tested the same protocol with a vari-

ation in the order of exercises [33] and one have used a cohort approach [19]. In our study, a parallel design tested a combination of SSGs and core training against only SSGs, with a clear benefit to those who experienced the combination. Specifically, in the current study aerobic performance was largely improved by both groups. The improvement is in line with findings revealed by meta-analysis [34, 35]. In fact, SSGs assumes an high-intensity interval training modality and it is one of the suggested approaches for improving capacity to repeatedly perform high-intensity efforts with changes of direction [36, 37]. The capacity to stress both aerobic and anaerobic systems [36], while promote some muscular tension and load can justify the benefits in field-based aerobic tests as YYIRT. In this field, none of the groups took advantage, since both meaningfully improved the aerobic capacity with no significant changes between groups.

In neuromuscular-based tests as CMJ and SJ, players experiencing the combination of SSG and core training revealed significant benefits comparing to those only performed SSGs. The SSG_{core} group had average improvements of 11 and 12% respectively for CMJ and SJ, while the group with only SSG improved 8 and 6%, respectively. The core performance it seems to play a beneficial effect on vertical jump performance since studies have reporting large correlations between both outcomes [38] or revealing the benefits of adding core training to regular field-based sessions [39]. Improvements in 20-m linear sprinting were also significant in SSG_{core} comparing to SSG. This is also interesting, since a previous study establishing relationships between core performance and linear sprinting revealed large magnitudes (dependency relationship) between both [38]. Finally, balance capacity was also significantly improved by SSG_{core} comparing to SSG, thus suggesting that core training can be highly interesting to promote balance as demonstrated in previous studies [40].

CONCLUSIONS

This study is not absent of limitations. The sample size is not large enough to generalize the findings and no control group was used to compare the effects. Additionally, quantifying the volume of strength training and field-based training should be considered in future studies and used as a covariable for the pre-post analysis. However, despite the limitations, the present findings are interesting and suggest that combining SSG and core training can be highly beneficial for fitness performance. With the exception of aerobic performance, those who experienced core training were significantly benefited by core training in important performance outcomes and this suggests that core training should be implemented as complementary training. Future studies should compare core training, with other strength-based training programs or even combinations, aiming to determine the more appropriate complementary approach for field-based training.

Practical applications

Numerous training articles have examined the effect of strength training on neuromuscular fitness in soccer players. This study also

confirms that short-term core strength training has an important role in speed and strength-based conditioning during the preseason period. From a practical point of view, this type of combined training (core strength + SSG) is effective, time-efficient and cost-effective for team sports especially soccer. From a coach's point of view, sport scientists and coaches should use the combined core strength with different game-based training without any expensive training equipment or weight room to improve strength levels, aerobic capacity and technical performances of young soccer players during the preseason period. Further research is required to compare potential effect of combined strength training such as free weight, elastic band

or weighted vest with different game format SSG training in the preseason period 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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