Comparison of the Effect of Repeated-Sprint Training Combined With Two Different Methods of Strength Training on Young Soccer Players

Miguel A. Campos-Vazquez,[1] Sergio Romero-Boza,[2] Francisco J. Toscano-Bendala,[3] Juan A. Leon-Prados,[1] Luis J. Suarez-Arrones,[1] and Jose A. Gonzalez-Jurado[1]

[1]*Faculty of Sport Sciences, Pablo de Olavide University, Seville, Spain;* [2]*Faculty of Education Sciences, University of Seville, Seville, Spain;* [3]*Faculty of Sport Sciences, San Antonio Catholic University, Murcia, Spain*

Abstract

Campos-Vazquez, MA, Boza, SR, Toscano-Bendala, FJ, Leon-Prados, JA, Suarez-Arrones, L, and Gonzalez-Jurado, JA. Comparison of the effect of repeated-sprint training combined with two different methods of strength training on young soccer players. *J Strength Cond Res* 29(3): 744–751, 2015—The aim of this study was to assess the effect of combining repeated-sprint training with 2 different methods of muscle strength training on physical performance variables in young players. Twenty-one soccer players with mean (±*SD*) age of 18.1 (±0.8) years, weight 69.9 (±6.5) kg, and height 177.1 (±5.7) cm, and competing in U-19 category, were randomly assigned to 2 experimental groups: squat group (SG: $n = 10$) and take-off group (TG: $n = 11$). Intervention in both groups consisted of the combination of a weekly session of repeated-sprint training (the same for both groups), with 2 weekly sessions of strength training (different for each group), for 8 weeks in the final period of the season. The strength sessions for the SG consisted of conducting a series of full squats executed at maximum velocity in the concentric phase. Intervention in the TG was the performance of 2 specific strength exercises (take-offs and change of direction), with measurements taken before and after consideration of the following variables: repeated-sprint ability (RSA), yo-yo intermittent recovery test level 1 (YYIRT1), countermovement jump (CMJ), and average velocity in full squat progressive loads test. The SG improved CMJ height in 5.28% ($p \leq 0.05$) and $FS_{37.5\text{-}47.5\text{-}67.5}$ ($p \leq 0.05$), whereas the TG improved $FS_{17.5\text{-}27.5\text{-}37.5\text{-}47.5\text{-}67.5}$ ($p \leq 0.05$). There were no significant changes in the values of RSA or YYIRT1 in either group. The results seem to show that the combination of a weekly session of repeated-sprint training with 2 weekly sessions of strength training could be an insufficient stimulus to improve RSA in the final period of the season.

Key Words full squat, repeated-sprint ability, performance, CMJ, yo-yo intermittent recovery test

Introduction

Soccer is a team sport where performance depends on several physical abilities, as well as other technical and tactical skills (35). The physiological requirements of competition are of an intermittent nature (13,39) and of high intensity (20). Furthermore, because of match duration, soccer is a sport that is dependent on aerobic metabolism (3). However, despite this aerobic context, the most decisive actions of the competition (short sprints, tackles, jumps, shots and kicks, or individual confrontations) occur at the expense of the anaerobic metabolism (19,21,34). On average, during competition, there are 2–4 seconds of sprint time every 90 seconds (34), yet this sprint density would be insufficient to compromise performance because recovery time is quite broad. However, other types of exertion are required in these recoveries, such as eccentric contractions, changes of direction, or running at different intensities, which can lead to fatigue (32).

Moreover, because of the unpredictable nature of the dynamics of effort in competition (14), these actions cannot occur in isolation during a match, so that short periods where several sprints may occur in the same short period can have a potential impact on the result if the body is not prepared for it (32). Therefore, and as a result of the analysis of the characteristics of competition, in recent years, a new method of training in team sports has begun to show its effectiveness on improving specific performance. This is the so-called repeated-sprint ability (RSA). The study of this performance variable is relatively new because the first publications concerning scientific knowledge of RSA (1,36), evaluation protocols (5,38), and training for improvement in sports populations (33) date back to the past 10–15 years. The method is based on the execution of several short sprints (<6 seconds) with very short recovery periods

Address correspondence to Jose A. Gonzalez-Jurado, jagonjur@upo.es.

29(3)/744–751

Journal of Strength and Conditioning Research

(<30 seconds) (28), although some authors considered sprints up to 10 seconds with recovery periods lower than 60 seconds (16). The RSA method seeks a metabolic response similar to that which occurs during a soccer game, such as a decrease in the pH, Phosphocreatine (PC) and Adenosine Triphosphate (ATP), activation of anaerobic glycolysis, and a significant participation of anaerobic metabolism (15).

To achieve a good performance in soccer, power and muscular strength, aerobic endurance, and RSA have to achieve optimal development (29). To date, no working method that can be considered the best for increasing performance in RSA (4) has been found because of the high number of factors (of both neural and muscular origin) involved in the fatigue of this type of activity (16). A recent publication (4) recommends the concurrent implementation of different forms of training, among which are training exercises to improve sprint performance (specific sprint training, strength/power training), and programs of high-intensity interval training to improve recovery ability between sprints. However, there is some controversy as to whether proposals of repeating sprint prove successful in improving RSA (4,7). The similarity between the protocols of assessment and training could overestimate improvements in RSA, possibly obtained by improving the skill of change of direction (COD), included in many training protocols and assessment of RSA (7). Therefore, a new research field was required for fitness coaches and sports scientists to enable them to find the most efficient combination of training methods (muscle/power strength training, high-intensity interval training, repeated-sprint training) for improving RSA and other physical performance variables in soccer players.

Because maximum strength has a high correlation with performance in sprints of 10 m ($r = 0.94$; $p < 0.001$) and 30 m ($r = 0.71$; $p < 0.01$) in elite soccer players (37), training programs to improve strength could help to improve levels of speed and even RSA in soccer players. Some studies with soccer players have used various training protocols to improve strength, which included exercises, such as half squat (6,11,30); the combination of full squat (FS) and different types of jumps (17,24); or explosive exercises conducted on the field of play (8). Most of these studies were conducted during preseason or in the initial phase of the competition period.

The aim of our study was to assess the effect of combining repeated-sprint training with 2 different methods of muscle strength training on RSA and other physical performance variables in elite youth soccer players.

Methods

Experimental Approach to the Problem

We used a quasi-experimental design in which participants were assigned to 2 experimental groups by balanced randomization according to the average time obtained in the RSA test (given the importance of this variable in the study and their acceptable reliability, both absolute and relative) (22): squat group (SG, $n = 10$) and take-off group (TG, $n = 11$).

The intervention program of each group was added to the usual training routines. Teams trained for 4 sessions (1.5–2 hours) a week. The intervention period lasted for 8 weeks: the last 2 weeks of official competitions plus 6 weeks in the postcompetition period. All measurements were taken before and after the intervention period and were performed in the gym and on an artificial turf field (depending on the test). Three sessions a week, during 2 consecutive weeks to perform all assessments were carried out.

Subjects

The study initially involved 21 players, with mean ($\pm SD$) age of 18.1 ($\pm$0.8) years (range: 16–19 years), weight 69.9 ($\pm$6.5) kg, height 177.1 ($\pm$5.7) cm, and $\sum$6 skinfolds 53.7 ($\pm$11.7). Players belonged to a youth team that competes in the top Spanish U-19 category, with all players having a minimum experience of 5 seasons in official competitions. The anthropometric characteristics of the subjects in each group are presented in Table 1.

All subjects and their parents were informed in advance about the purpose of the study and the type of evidence to be submitted. Each of the players and their parents or guardians gave their informed consent following the recommendations of the Declaration of Helsinki. The study was approved by the IRB.

Procedures

Training Intervention. Both groups performed a weekly session of repeated-sprint training (the same for both groups) and 2 weekly sessions of strength training (different for each experimental group) detailed below.

The repeated-sprint training consisted of sets of 30- or 40-m shuttle sprints (20 + 20 m or 15 + 15 m, depending on the moment of the intervention period), with 20 seconds of passive recovery between sets and 3 minutes between blocks of sets. The total volume per session progressed from 360 to 720 m in the last training sessions (Table 2).

The strength sessions for the SG were held in the gym and consisted of performing FS sets (on a Smith machine).

Table 1. Anthropometric characteristics of the players.*

Variables	SG ($n = 10$)	TG ($n = 11$)
Age (y)	18.0 ± 0.9	18.2 ± 0.7
Height (cm)	177.9 ± 4.8	176.2 ± 6.8
Body mass (kg)	70.6 ± 5.0	69.4 ± 7.8
Skinfolds (mm)	56.4 ± 11.1	50.9 ± 12.5

*SG = group squat; TG = group take-offs; skinfolds = sum of 6 skinfolds (triceps, subscapular, suprailiac, abdominal, front thigh, and medial calf).

TABLE 2. Training program during the intervention period.*

	RSE (All)	Strength training (SG)		Strength training (TG)	
	Wednesday	Tuesday and Thursday		Tuesday and Thursday	
	(S × R × D)	FS, velocity (m·s^{-1})	S × R	COD (kg/S × T)	TO (kg/S × D)
Wk 1	2 × 6 × 30	1.1	3–4 × 6	0/2-3 × 5	5/2–3 × 15
Wk 2	2 × 6 × 40	1.1	4–5 × 6	0/3 × 5	5/2–3 × 15
Wk 3	3 × 6 × 30	1.0	4 × 6	5/2–3 × 5	7.5/2–3 × 15
Wk 4	3 × 6 × 40	1.0	5 × 6	5/3 × 5	7.5/3 × 15
Wk 5	2 × 8 × 30	0.9	4 × 4	7.5/3 × 5	10/2 × 15
Wk 6	3 × 8 × 30	0.9	4–5 × 4	7.5/3 × 5	10/3 × 15
Wk 7	3 × 6 × 40	0.8	4 × 3	10/2–3 × 5	10/2 × 20
Wk 8	3 × 6 × 40	0.8	4 × 3	10/2–3 × 5	10/3 × 20

*SG = squat group; TG = take-off group; S × R × D = sets × repetitions × distance (m); FS = full squat; S × R = sets × repetitions; COD (kg/S × T) = changes of direction (kg/sets × time [s]); TO (kg/S × D) = take-offs (kg/sets × distance [m]).

Players were required to execute the concentric phase in an explosive manner at the maximum possible velocity (37). The proposed loads were individualized for each subject from his individual load-velocity profile (data from test "Mean Velocity in Full Squat," explained below), progressing from loads of 1.1 m·s^{-1} mean velocity to loads of 0.8 m·s^{-1} in the last weeks of training (Table 2). A specific warm-up was followed by the number of sets and repetitions scheduled for each week, with 3 minutes of recovery between sets.

The strength session for the TG took place on the training field (artificial turf) and consisted of 2 specific strength exercises: displacements with loads with COD and take-offs with resisted sled towing (TO), in that order. Changes of direction were performed on 2 attached squares of 8 m side length. Within this area, the subjects had to perform displacements at maximum speed (running forward or backward), changing direction at each corner of the square for 5 seconds.

The proposed loads for these exercises progressed from 0 to 10 kg in COD and from 5 to 10 kg in the TO exercises (Table 2). Specific warm-ups were followed by the number of sets and repetitions scheduled for each week, with 2.5 minutes of recovery between sets. The duration of strength training was the same for both groups (SG and TG).

Players had no previous experience either in RSA training or in the performance of the strength exercises proposed for each of the groups. In addition, no specific training to improve strength qualities or endurance was carried out, apart from what was included in the intervention. The rest of the daily training was completed exclusively with technical and tactical content tasks for the whole team: small-sided games with goals and goal keepers (5 vs. 5/6 vs. 6) and tactical training (11 vs. 11) in a regulation soccer field with the aim of assimilating the game model implemented by the team coach.

Tests. ***Anthropometric Assessments.*** Body weight, height, and the sum of 6 skinfolds (27) (Harpenden Skinfold Caliper; Holtain, Crosswell, Wales, United Kingdom) were assessed in the medical ward before the first fitness test session.

Countermovement Jump Test. After a specific warm-up, 3 unique jumps were performed on the dynamometric platform (Quattro Jump; Kistler, Amherst, NY, USA) with approximately a 2-minute rest between each jump. The mean of the 3 jumps performed was taken so as to minimize the possible error of incorrectly executed jumps because of lack of previous experience in this exercise. If, in the judgment of the evaluator, any of the jumps were executed with obvious technical inaccuracies, the exercise was repeated after the advised recovery time.

Repeated-Sprint Ability. The RSA test on artificial turf was proposed by Impellizzeri et al. (22). After countermovement jump (CMJ) test, the players had a 15- to 30-minute rest, then performed a specific warm-up and after a 5-minute recovery they performed the RSA test, which consisted of six 40 m (20 + 20) shuttle sprints with 20 seconds of passive recovery between each (22). Each of the repetition times was measured by a photoelectric cell system (Polifermo Light Radio; Microgate, Bolzano-Bozen, Italy), and subsequently, the best time registered in any of the 6 sprints (RSA_{best}) and the mean time (RSA_{mean}) were calculated. It was decided not to use the $RSA_{decrement}$ because of its high coefficients of variation (CV = 30.2%) and low intraclass correlation coefficient (ICC = 0.17) (22).

Yo-Yo Intermittent Recovery Test Level 1. To assess the intermittent exercise capacity of the players, the Yo-Yo Intermittent Recovery Test Level 1 (YYIRT1) (2) was performed. Every player was monitored with a heart rate monitor (Polar Team Sport System; Polar Electro, Kempele, Finlandia), and maximal heart rate was assessed at the conclusion of the test (Pretest: 193.5 ± 8.7 b·min^{-1}; Posttest: 195.1 ± 7.5 b·min^{-1}), and the total distance covered, including the last non-completed period.

Mean Velocity in Full Squat. The average velocity in the concentric phase of the FS for each of the loads used was measured. The reliability of the test (ICC) ranged between 0.76 for the lower loads (FS 17.5) and 0.91 for the higher

TABLE 3. Intragroup differences (squat group).*

Variables	*n*	Pre (mean ± *SD*)	Post (mean ± *SD*)	Change† (mean ± *SD*)	95% CI	Effect size	Magnitude
YYIRT1 (m)	7	2297 ± 302	2377 ± 548	80 ± 324.1	−219.8 to 379.8	0.15	Trivial
RSA_{best} (s)	9	6.99 ± 0.11	6.97 ± 0.09	−0.02 ± 0.07	−0.07 to 0.03	−0.21	Small
RSA_{mean} (s)	9	7.40 ± 0.18	7.36 ± 0.14	−0.04 ± 0.14	−0.15 to 0.07	−0.29	Small
CMJ (cm)	9	43.8 ± 6.9	45.9 ± 5.8	2 ± 2.6†	−0.002 to 4.07	0.36	Small
FS 17.5 ($m \cdot s^{-1}$)	8	1.26 ± 0.06	1.28 ± 0.06	0.02 ± 0.06	−0.03 to 0.08	0.31	Small
FS 27.5 ($m \cdot s^{-1}$)	8	1.18 ± 0.05	1.20 ± 0.05	0.03 ± 0.06	−0.02 to 0.07	0.34	Small
FS 37.5 ($m \cdot s^{-1}$)	8	1.07 ± 0.04	1.12 ± 0.07	0.06 ± 0.05†	0.01 to 0.1	0.74	Medium
FS 47.5 ($m \cdot s^{-1}$)	8	0.98 ± 0.03	1.03 ± 0.06	0.06 ± 0.04†	0.02 to 0.09	0.77	Medium
FS 57.5 ($m \cdot s^{-1}$)	8	0.88 ± 0.06	0.92 ± 0.08	0.04 ± 0.05	−0.004 to 0.08	0.47	Medium
FS 67.5 ($m \cdot s^{-1}$)	7	0.77 ± 0.06	0.83 ± 0.07	0.06 ± 0.04†	0.02 to 0.1	0.9	Large
FS 77.5 ($m \cdot s^{-1}$)	3	0.72 ± 0.08	0.75 ± 0.1	0.02 ± 0.1	−0.24 to 0.28	0.29	Small
∑Skinfolds (mm)	9	56.4 ± 11.1	53.4 ± 11.5	−3.9 ± 4.58	−7.42 to −0.38	−0.26	Small
Weight (kg)	9	70.6 ± 5.02	69.6 ± 4.63	−1.28 ± 1.65	−2.25 to −0.01	−0.22	Small

*CI = confidence interval; YYIRT1 = distance covered in yo-yo intermittent recovery test level 1; RSA = repeated-sprint ability; RSA_{best}/RSA_{mean} = time in RSA_{best}/RSA_{mean}; CMJ = height achieved in countermovement jump; FS "X" = average velocity in full squat with "X" load; ∑skinfolds = summation of 6 skinfolds; weight = body weight.
†$p \leq 0.05$ (*T*-test of Wilcoxon).

ones (FS 77.5). The CV ranged between 2.6 and 3.7%. This was evaluated by a lineal velocity encoder (SmartCoach Power Encoder; SmartCoach Europe AB, Stockholm, Sweden) commonly used for strength training monitoring (25,26). The device has a throughput data rate of 100 Hz, and each sample has a measurement error below 0.5% for velocities between 0 and 3 $m \cdot s^{-1}$. The test was performed in the gym, on a Smith Machine, and was preceded by a warm-up (continuous on field running, joint mobility, and 1 set of 6 repetitions of FS with low load: 17.5 kg) followed by 4-minute recovery. Initial load was 17.5 kg for all players and was gradually increased in loads of 10 kg until the mean velocity of the concentric phase was less than 0.8 $m \cdot s^{-1}$. Players were required to execute the concentric phase in

TABLE 4. Intragroup differences (take-off group).*

Variables	*n*	Pre (mean ± *SD*)	Post (mean ± *SD*)	Change† (mean ± *SD*)	95% CI	Effect size	Magnitude
YYIRT1 (m)	8	2145 ± 461.5	2055 ± 571.3	−90 ± 200.3	−257.4 to 77.4	−0.16	Trivial
RSA_{best} (s)	9	7.07 ± 0.18	7.06 ± 0.14	−0.01 ± 0.14	−0.12 to 0.1	−0.07	Trivial
RSA_{mean} (s)	9	7.42 ± 0.15	7.39 ± 0.16	−0.03 ± 0.08	−0.09 to 0.03	−0.19	Trivial
CMJ (cm)	10	43.3 ± 4.33	44.8 ± 5.21	1.4 ± 3.1	−0.8 to 3.68	0.29	Small
FS 17.5 ($m \cdot s^{-1}$)	10	1.19 ± 0.08	1.28 ± 0.06	0.09 ± 0.08†	0.04 to 0.15	1.36	Large
FS 27.5 ($m \cdot s^{-1}$)	10	1.13 ± 0.07	1.19 ± 0.09	0.06 ± 0.08†	0.003 to 0.12	0.67	Medium
FS 37.5 ($m \cdot s^{-1}$)	10	1.04 ± 0.07	1.10 ± 0.06	0.06 ± 0.07†	0.01 to 0.11	0.57	Medium
FS 47.5 ($m \cdot s^{-1}$)	10	0.92 ± 0.08	0.99 ± 0.1	0.07 ± 0.05†	0.04 to 0.1	0.67	Medium
FS 57.5 ($m \cdot s^{-1}$)	9	0.87 ± 0.07	0.92 ± 0.1	0.05 ± 0.06	−0.00 to 0.09	0.48	Medium
FS 67.5 ($m \cdot s^{-1}$)	7	0.80 ± 0.07	0.86 ± 0.08	0.06 ± 0.06†	0.01 to 0.11	0.69	Medium
FS 77.5 ($m \cdot s^{-1}$)	4	0.81 ± 0.04	0.84 ± 0.07	0.03 ± 0.04	−0.03 to 0.09	0.44	Medium
∑Skinfolds (mm)	11	50.9 ± 12.5	49.3 ± 9.9	−1.57 ± 5.15	−5.03 to 1.89	−0.16	Trivial
Weight (kg)	11	69.4 ± 7.8	68.9 ± 7.4	−0.48 ± 1.76	−1.67 to 0.7	−0.07	Trivial

*CI = confidence interval; YYIRT1 = distance covered in yo-yo intermittent recovery test level 1; RSA = repeated-sprint ability; RSA_{best}/RSA_{mean} = time in RSA_{best}/RSA_{mean}; CMJ = height achieved in countermovement jump; FS "X" = average velocity in full squat with "X" load; ∑skinfolds = summation of 6 skinfolds; weight = body weight.
†$p \leq 0.05$ (*T*-test of Wilcoxon).

TABLE 5. Between-group differences.*

Variables	Change SG (mean ± *SD*)	Change TG (mean ± *SD*)	Difference† (mean ± *SE*)	95% CI	Effect size	Magnitude
YYIRT1 (m)	80 ± 324.1	−90 ± 200.3	170 ± 137	−126 to 466	0.60	Medium
RSA_{best} (s)	−0.02 ± 0.07	−0.01 ± 0.14	−0.01 ± 0.05	−0.12 to 0.1	−0.09	Trivial
RSA_{mean} (s)	−0.04 ± 0.14	−0.03 ± 0.08	−0.01 ± 0.06	−0.13 to 0.11	−0.08	Trivial
CMJ (cm)	2 ± 2.6	1.4 ± 3.1	0.59 ± 1.34	−2.23 to 3.42	0.19	Trivial
FS 17.5 ($m \cdot s^{-1}$)	0.02 ± 0.06	0.09 ± 0.08	−0.07 ± 0.03	−0.14 to 0.00	−0.92	Large
FS 27.5 ($m \cdot s^{-1}$)	0.03 ± 0.06	0.06 ± 0.08	−0.03 ± 0.03	−0.11 to 0.04	−0.39	Small
FS 37.5 ($m \cdot s^{-1}$)	0.06 ± 0.05	0.06 ± 0.07	−0.01 ± 0.03	−0.07 to 0.06	−0.00	Trivial
FS 47.5 ($m \cdot s^{-1}$)	0.06 ± 0.04	0.07 ± 0.05	−0.01 ± 0.02	−0.06 to 0.03	−0.21	Small
FS 57.5 ($m \cdot s^{-1}$)	0.04 ± 0.05	0.05 ± 0.06	−0.01 ± 0.03	−0.07 to 0.05	−0.17	Trivial
FS 67.5 ($m \cdot s^{-1}$)	0.06 ± 0.04	0.06 ± 0.06	0.00 ± 0.03	−0.05 to 0.06	0.00	Trivial
FS 77.5 ($m \cdot s^{-1}$)	0.02 ± 0.1	0.03 ± 0.04	0.00 ± 0.06	−0.24 to 0.23	0.12	Trivial
∑Skinfolds (mm)	−3.9 ± 4.58	−1.57 ± 5.15	−2.33 ± 2.2	−6.96 to 2.31	−0.45	Small
Weight (kg)	−1.28 ± 1.65	−0.48 ± 1.76	−0.8 ± 0.77	−2.41 to 0.82	−0.44	Small

*SG = squat group; TG = take-off group; CI = confidence interval; YYIRT1 = distance covered in yo-yo intermittent recovery test level 1; RSA = repeated-sprint ability; RSA_{best}/RSA_{mean} = time in RSA_{best}/RSA_{mean}; CMJ = height achieved in countermovement jump; FS "X" = average velocity in full squat with "X" load; ∑skinfolds = summation of 6 skinfolds; weight = body weight; *SE* = difference standard error.

†Showed no statistically significant differences between groups (*T*-test or Mann-Whitney *U*-test).

an explosive manner at maximal possible velocity. The number of repetitions for each load varied, depending on the velocity with which the first repetition was performed. If it was greater than 0.9 $m \cdot s^{-1}$, 3 repetitions were performed, and if it was less, 2 repetitions were performed (24). The best of them, according the criteria of fastest mean velocity, were considered for subsequent analysis. Recovery time between loads was 4 minutes Table 2 shows in detail the training velocities that were applied during the intervention period.

Players were warned not to do any vigorous exercise 24 hours in advance of the assessment sessions. For FS test, a mid-assessment intervention protocol was executed to adjust the workload's progression in the final phase of the investigations for SG, in line with possible improvements achieved in the first weeks of training.

Statistical Analyses

Statistical Analyses were conducted with the PASW Statistics 18 software. The Shapiro-Wilk test was performed to establish the normality of each variable and the Levene's test for homogeneity of variance in intergroup comparison. To compare the differences between pretest and posttest, a paired sample *T*-test was conducted (when the variables were consistent with a normal distribution) or, otherwise, the nonparametric Wilcoxon test. For intergroup comparisons, an independent sample *T*-test was conducted for the variables consistent with a normal distribution and homoscedasticity condition, whereas for all other variables, the Mann-Whitney *U*-test was conducted. The effect size (ES) was calculated for all comparisons made, according to the procedure proposed by Cohen (12), considering the following criteria: >0.2 (small), >0.5 (medium), and >0.8 (large). The significance level was set to a value of $p \leq 0.05$, and the confidence limits of 95% were calculated for all measures.

RESULTS

The results of intragroup comparison are shown in Tables 3 and 4. In the SG, significant improvements were obtained for the following variables: CMJ ($p = 0.050$); $FS_{37.5}$ ($p = 0.018$); $FS_{47.5}$ ($p = 0.007$); and $FS_{67.5}$ ($p = 0.008$, large ES) (Table 3).

In the TG, significant improvements were obtained in the following cases: $FS_{17.5}$ ($p = 0.004$; large ES); $FS_{27.5}$ ($p = 0.040$); $FS_{37.5}$ ($p = 0.019$); $FS_{47.5}$ ($p = 0.001$); and $FS_{67.5}$ ($p = 0.035$) (Table 4).

The results of the intergroup comparisons showed no statistically significant differences, with the exception of $FS_{17.5}$, which was substantially greater in the TG (large ES) (Table 5).

DISCUSSION

The aim of the present study was to assess the effect of combining repeated-sprint training with 2 different methods of muscle strength training on RSA. The main findings of the present study were that similar results were obtained in both groups in almost all variables. This may show that despite using different strength training methods, the adaptations achieved were very similar.

The research results showed no statistically significant changes in RSA_{best} and RSA_{mean} for either of the 2 groups (Tables 3 and 4). A similar study published recently also failed to improve RSA_{mean} through 1 weekly repeated-sprint training program in female soccer players during the in-season period (31). The ineffectiveness of repeated-sprint training to improve RSA (4,7) has recently been discussed, although some studies have shown that training with repeated sprints showed important improvements in RSA_{mean} achieved through once- (35) or twice-weekly repeated-sprint training sessions (15); also, statistically significant improvements are achieved in both variables (RSA_{mean} and RSA_{best}) through a single weekly session (8). All these studies were conducted in the initial phase of the competitive season, whereas ours took place in the postcompetition period. It is possible that fatigue accumulated in the first part of the competitive season could reduce performance in RSA (22), in conjunction with the end of the competitive period, which would explain the lack of significant improvement in our study.

According to Ferrari Bravo et al. (15), improvements in RSA_{mean} could reflect increases in the anaerobic metabolism as a determining factor of performance in RSA. In our study, the overloads demanded in strength training were low to medium, and recovery periods between sets were long (ranging from 2.5 to 3 minutes, to allow full recovery of PC deposits), and it is possible than these overloads are not sufficient to improve RSA. Strength training that has shown its effectiveness in improving RSA was performed with high overload (4). Moreover, the authors of the aforementioned systematic RSA review comment on the possibility of reducing recovery time between sets (up to 20 seconds), with the aim of including a high metabolic load (blood lactate concentration greater than 10 $mmol \cdot L^{-1}$), to stimulate a significant RSA improvement in the regulations of H^+. However, the training effects of the different proposals could be determined by the period of the season in which they are applied.

Despite repeated-sprint training seeming unable to improve jumping ability in soccer players (15), the training program applied in this research included explosive strength exercises in both groups. However, only the SG managed to improve its CMJ in a statistically significant way (5.28%; $p \leq 0.05$). These improvements in the SG were similar to those obtained by other studies with young players (17,24) using as a training tool the FS with low-to-medium load mobilized at maximum velocity in its concentric phase. The TG included explosive strength exercises such as TO and COD overloaded, but none specifically for improving the jumps, which could limit possible improvements in the CMJ.

One of the findings of this study was the improvement in both experimental groups in virtually all loads mobilized in the squat exercises. The SG improved average velocities in 3 loads ($FS_{37.5\text{-}47.5\text{-}67.5}$, Table 3), a fact which could be expected given the high volume of training with the squat exercise included in the weekly routine. Improvements in this group were always higher for loads that were mobilized at velocities less than 1 $m \cdot s^{-1}$, being less effective when high concentration velocities were required. This may be because of the fact that during the 8-week intervention, there was a higher squat training volume at velocity equal to or less than 1 $m \cdot s^{-1}$. López-Segovia et al. (24) obtained different results with a similar protocol study, significantly improving the loads that were mobilized at velocities higher than 1 $m \cdot s^{-1}$. It is also important to consider that the aforementioned study included not only training with squat exercises but also exercises to improve acceleration ability as TO and COD with overload for the full team. However, the TG improved significantly up to 5 loads ($FS_{17.5\text{-}27.5\text{-}37.5\text{-}47.5\text{-}67.5}$, Table 4), even though this exercise was not included in the training routines. These results were not expected, and they could demonstrate that it is possible to improve displacement velocity in the FS exercise through other exercises, discarding a learning effect in this group. Improvements were shown both for the loads lifted above and below 1 $m \cdot s^{-1}$. As for intergroup comparison, there was a substantial difference in improvement for $FS_{17.5}$ load (ES = −0.92) favorable to TG. These results could be because of the overload used by these groups during the experimental period, which ranged between 5 and 10 kg.

Strength improvements were not accompanied by increase in body weight in either of the 2 groups (Tables 3 and 4). In a sport such as soccer, which involves displacement of the full body weight and where accelerations can be decisive in performance, the ability to increase player strength without an increase in body weight should be considered a priority. These gains in strength may have been because of improved neural factors. Studies have reported that this type of adaptation has improved strength levels in soccer players (assessed by 1RM test) (11,18). Although these studies influenced (similarly to our research) load displacement at maximum velocity in the concentric phase, they differed in the application of high loads performed by our protocol (70–100% 1RM). However, increases in the application of strength achieved in our study were not accompanied by improvements in RSA as expected before the intervention. The fact of having completed the competition period could have restricted the potential gains.

Because the ability to perform high-intensity intermittent exercise evaluated by YYIRT1 is not closely associated with the performance in RSA ($r^2 = 0.19$) (10), similar results were not expected in the performance in both tests. Possible positive results were expected in YYIRT1 because of the improvements in the anaerobic systems for the supply of power in both groups because the result in YYIRT1 seems to be influenced both by the aerobic and the anaerobic performance of the athletes (9). However, the results in YYIRT1 of our study did not show significant improvements for either of the 2 groups. There is some controversy regarding the correlation between the performance in YYIRT1 and in $\dot{V}O_2max$ (9,23). Despite the fact that our research did not include training tasks for improving $\dot{V}O_2max$, a previous study did manage to improve both $\dot{V}O_2max$ and performance in YYIRT1 by RSA training twice a week (15). The fact that this training was executed at the beginning of the competition season could have facilitated such improvement probably because of the low fitness level of the players in this period. The volume of RSA training included in our study was well below the aforementioned study (15); moreover, the lack of any official competition could explain the absence of any improvement in YYIRT1.

Practical Applications

According to our results and the analysis of the literature, the weekly combination of a single session of repeated-sprint training with 2 strength sessions seems to be a sufficient stimulus to maintain RSA and the capability to perform high-intensity intermittent exercises; however, it is not enough for improving these capabilities in the final period of the season. The absence of official tournament matches in this phase of the season could have conditioned the results obtained with the training programs carried out. However, the weekly combination of repeated-sprint training with FS in this period did produce a significant statistical improvement in the jumping capacity of the soccer players. Nevertheless, it would be interesting to repeat the study with a larger sample to generalize these conclusions.

References

1. Aziz, AR, Chia, M, and Teh, KC. The relationship between maximal oxygen uptake and repeated sprint performance indices in field hockey and soccer players. *J Sports Med Phys Fitness* 40: 195–200, 2000.
2. Bangsbo, J, Iaia, FM, and Krustrup, P. The yo-yo intermittent recovery test: A useful tool for evaluation of physical performance in intermittent sports. *Sports Med* 38: 37–51, 2008.
3. Bangsbo, J, Mohr, M, and Krustrup, P. Physical and metabolic demands of training and match-play in the elite football player. *J Sports Sci* 24: 665–674, 2006.
4. Bishop, D, Girard, O, and Mendez-Villanueva, A. Repeated-sprint ability–Part II: Recommendations for training. *Sports Med* 41: 741–756, 2011.
5. Bishop, D, Spencer, M, Duffield, R, and Lawrence, S. The validity of a repeated sprint ability test. *J Sci Med Sport* 4: 19–29, 2001.
6. Bogdanis, GC, Papaspyrou, A, Souglis, AG, Theos, A, Sotiropoulos, A, and Maridaki, M. Effects of two different half-squat training programs on fatigue during repeated cycling sprints in soccer players. *J Strength Cond Res* 25: 1849–1856, 2011.
7. Buchheit, M. Should we be recommending repeated sprints to improve repeated-sprint performance? *Sports Med* 42: 169–172, 2012; author reply 172–163.
8. Buchheit, M, Mendez-Villanueva, A, Delhomel, G, Brughelli, M, and Ahmaidi, S. Improving repeated sprint ability in young elite soccer players: Repeated shuttle sprints vs. explosive strength training. *J Strength Cond Res* 24: 2715–2722, 2010.
9. Castagna, C, Impellizzeri, FM, Chamari, K, Carlomagno, D, and Rampinini, E. Aerobic fitness and yo-yo continuous and intermittent tests performances in soccer players: A correlation study. *J Strength Cond Res* 20: 320–325, 2006.
10. Chaouachi, A, Manzi, V, Wong del, P, Chaalali, A, Laurencelle, L, Chamari, K, and Castagna, C. Intermittent endurance and repeated sprint ability in soccer players. *J Strength Cond Res* 24: 2663–2669, 2010.
11. Chelly, MS, Fathloun, M, Cherif, N, Ben Amar, M, Tabka, Z, and Van Praagh, E. Effects of a back squat training program on leg power, jump, and sprint performances in junior soccer players. *J Strength Cond Res* 23: 2241–2249, 2009.
12. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). Hillsdale, NJ: Erlbaum Associates, 1988. p. 567.
13. Di Salvo, V, Baron, R, Tschan, H, Calderon Montero, FJ, Bachl, N, and Pigozzi, F. Performance characteristics according to playing position in elite soccer. *Int J Sports Med* 28: 222–227, 2007.
14. Di Salvo, V, Gregson, W, Atkinson, G, Tordoff, P, and Drust, B. Analysis of high intensity activity in Premier League soccer. *Int J Sports Med* 30: 205–212, 2009.
15. Ferrari Bravo, D, Impellizzeri, FM, Rampinini, E, Castagna, C, Bishop, D, and Wisloff, U. Sprint vs. interval training in football. *Int J Sports Med* 29: 668–674, 2008.
16. Girard, O, Mendez-Villanueva, A, and Bishop, D. Repeated-sprint ability–Part I: Factors contributing to fatigue. *Sports Med* 41: 673–694, 2011.
17. Gorostiaga, EM, Izquierdo, M, Ruesta, M, Iribarren, J, Gonzalez-Badillo, JJ, and Ibanez, J. Strength training effects on physical performance and serum hormones in young soccer players. *Eur J Appl Physiol* 91: 698–707, 2004.
18. Helgerud, J, Rodas, G, Kemi, OJ, and Hoff, J. Strength and endurance in elite football players. *Int J Sports Med* 32: 677–682, 2011.
19. Hoff, J and Helgerud, J. Endurance and strength training for soccer players: Physiological considerations. *Sports Med* 34: 165–180, 2004.
20. Hoff, J, Wisloff, U, Engen, LC, Kemi, OJ, and Helgerud, J. Soccer specific aerobic endurance training. *Br J Sports Med* 36: 218–221, 2002.
21. Iaia, FM, Rampinini, E, and Bangsbo, J. High-intensity training in football. *Int J Sports Physiol Perform* 4: 291–306, 2009.
22. Impellizzeri, FM, Rampinini, E, Castagna, C, Bishop, D, Ferrari Bravo, D, Tibaudi, A, and Wisloff, U. Validity of a repeated-sprint test for football. *Int J Sports Med* 29: 899–905, 2008.
23. Krustrup, P, Mohr, M, Amstrup, T, Rysgaard, T, Johansen, J, Steensberg, A, Pedersen, PK, and Bangsbo, J. The yo-yo intermittent recovery test: Physiological response, reliability, and validity. *Med Sci Sports Exerc* 35: 697–705, 2003.
24. López-Segovia, M, Palao Andres, JM, and Gonzalez-Badillo, JJ. Effect of 4 months of training on aerobic power, strength, and acceleration in two under-19 soccer teams. *J Strength Cond Res* 24: 2705–2714, 2010.
25. Lundberg, TR, Fernandez-Gonzalo, R, Gustafsson, T, and Tesch, PA. Aerobic exercise alters skeletal muscle molecular responses to resistance exercise. *Med Sci Sports Exerc* 44: 1680–1688, 2012.
26. Lundberg, TR, Fernandez-Gonzalo, R, Gustafsson, T, and Tesch, PA. Aerobic exercise does not compromise muscle hypertrophy response to short-term resistance training. *J Appl Physiol (1985)* 114: 81–89, 2013.
27. Mujika, I, Santisteban, J, and Castagna, C. In-season effect of short-term sprint and power training programs on elite junior soccer players. *J Strength Cond Res* 23: 2581–2587, 2009.
28. Mujika, I, Spencer, M, Santisteban, J, Goiriena, JJ, and Bishop, D. Age-related differences in repeated-sprint ability in highly trained youth football players. *J Sports Sci* 27: 1581–1590, 2009.
29. Owen, AL, Wong del, P, Paul, D, and Dellal, A. Effects of a periodized small-sided game training intervention on physical performance in elite professional soccer. *J Strength Cond Res* 26: 2748–2754, 2012.
30. Ronnestad, BR, Nymark, BS, and Raastad, T. Effects of in-season strength maintenance training frequency in professional soccer players. *J Strength Cond Res* 25: 2653–2660, 2011.
31. Shalfawi, SA, Haugen, T, Jakobsen, TA, Enoksen, E, and Tonnessen, E. The effect of combined resisted agility and repeated sprint training vs. strength training on female elite soccer players. *J Strength Cond Res* 27: 2966–2972, 2013.
32. Spencer, M, Bishop, D, Dawson, B, and Goodman, C. Physiological and metabolic responses of repeated-sprint activities: Specific to field-based team sports. *Sports Med* 35: 1025–1044, 2005.

33. Spencer, M, Bishop, D, and Lawrence, S. Longitudinal assessment of the effects of field-hockey training on repeated sprint ability. *J Sci Med Sport* 7: 323–334, 2004.

34. Stolen, T, Chamari, K, Castagna, C, and Wisloff, U. Physiology of soccer: An update. *Sports Med* 35: 501–536, 2005.

35. Tonnessen, E, Shalfawi, SA, Haugen, T, and Enoksen, E. The effect of 40-m repeated sprint training on maximum sprinting speed, repeated sprint speed endurance, vertical jump, and aerobic capacity in young elite male soccer players. *J Strength Cond Res* 25: 2364–2370, 2011.

36. Wadley, G and Le Rossignol, P. The relationship between repeated sprint ability and the aerobic and anaerobic energy systems. *J Sci Med Sport* 1: 100–110, 1998.

37. Wisloff, U, Castagna, C, Helgerud, J, Jones, R, and Hoff, J. Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *Br J Sports Med* 38: 285–288, 2004.

38. Wragg, CB, Maxwell, NS, and Doust, JH. Evaluation of the reliability and validity of a soccer-specific field test of repeated sprint ability. *Eur J Appl Physiol* 83: 77–83, 2000.

39. Ziogas, GG, Patras, KN, Stergiou, N, and Georgoulis, AD. Velocity at lactate threshold and running economy must also be considered along with maximal oxygen uptake when testing elite soccer players during preseason. *J Strength Cond Res* 25: 414–419, 2011.