COMPARATIVE EFFECTS OF IN-SEASON FULL-BACK SQUAT, RESISTED SPRINT TRAINING, AND PLYOMETRIC TRAINING ON EXPLOSIVE PERFORMANCE IN U-19 ELITE SOCCER PLAYERS

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ABSTRACT

de Hoyo, M, Gonzalo-Skok, O, Sañudo, B, Carrascal, C, Plaza-Armas, JR, Camacho-Candil, F, and Otero-Esquina, C. Comparative effects of in-season full-back squat, resisted sprint training, and plyometric training on explosive performance in U-19 elite soccer players. *J Strength Cond Res* 30 (2): 368–377, 2016—The aim of this study was to analyze the effects of 3 different low/moderate load strength training methods (full-back squat [SQ], resisted sprint with sled towing [RS], and plyometric and specific drills training [PLYO]) on sprinting, jumping, and change of direction (COD) abilities in soccer players. Thirty-two young elite male Spanish soccer players participated in the study. Subjects performed 2 specific strength training sessions per week, in addition to their normal training sessions for 8 weeks. The full-back squat protocol consisted of 2–3 sets × 4–8 repetitions at 40–60% 1 repetition maximum (~1.28–0.98 $m \cdot s^{-1}$). The resisted sprint training was compounded by 6–10 sets × 20-m loaded sprints (12.6% of body mass). The plyometric and specific drills training was based on 1–3 sets × 2–3 repetitions of 8 plyometric and speed/agility exercises. Testing sessions included a countermovement jump (CMJ), a 20-m sprint (10-m split time), a 50-m (30-m split time) sprint, and COD test (i.e., Zig-Zag test). Substantial improvements (likely to almost certainly) in CMJ (effect size [ES]: 0.50–0.57) and 30–50 m (ES: 0.45–0.84) were found in every group in comparison to pretest results. Moreover, players in PLYO and SQ groups also showed substantial enhancements (likely to very likely) in 0–50 m (ES: 0.46–0.60). In addition, 10–20 m was also improved (very likely) in the SQ group (ES: 0.61). Between-group analyses showed that improvements in 10–20 m (ES: 0.57) and 30–50 m (ES: 0.40) were likely greater in the SQ group than in the RS group. Also, 10–20 m (ES: 0.49) was substantially better in the SQ group than in the PLYO group. In conclusion, the present strength training methods used in this study seem to be effective to improve jumping and sprinting abilities, but COD might need other stimulus to achieve positive effects.

KEY WORDS strength training, jumping ability, sprinting ability, change of direction ability

INTRODUCTION

Soccer is an intermittent sport that is characterized by high-intensity actions such as sprinting, changing direction, jumping, tackling, and kicking (14,17). Concurrent with technique, skill, balance, and perception, one of the most important contributing factors of these high-intensity actions is strength (17). As such, it is suggested that soccer players need a high level of explosive muscular strength (10,17,28). In this regard, 83% of goals are preceded by at least 1 powerful action of the scoring or assisting player in a soccer match (11). Therefore, it seems that together with other strength training modalities (i.e., heavy load resistance training) power abilities are relevant in soccer players, and accordingly, the inclusion of different training strategies to improve explosive actions is recommended.

Several training strategies have been included to enhance explosive performance in junior male and female athletes, including soccer players, such as resistance training (6,8,17,23), plyometric training (7,27,30,32,40) or sled towing training (37,41). Resistance training approaches are based on emphasizing the vertical component during the lower body triple extension (i.e., ankle, knee, and hip) such as in different squat exercises (e.g., full-squat), due to the fact that these are deemed closer to explosive actions (i.e., sprinting and jumping actions) (18). Usually, high loads (70–90% 1 repetition maximum [1RM]) are mostly used to improve functional explosive

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actions in soccer players (i.e., sprint, jumps, and change of direction [COD]) (6). However, it seems that actual velocity (high speeds) is crucial to yield positive explosive performance adaptations (26). Furthermore, maximal intended velocity also seems fundamental because greater jumping gains have been reported after a maximal intended velocity training program in comparison with a half-maximal intended velocity training program in the full-squat exercise. (31). From a practical point of view, soccer players, who are required to practice tactical and technical concepts after executing the resistance training workout, need "freshness" and avoid any muscle discomfort, typically manifested after high-intensity resistance training (i.e. 70–90 %RM), throughout the soccer session. In consequence, it is hypothesized that the combination of light loads, high speeds (actual velocity), and maximal intended velocity is a potential stimulus (velocity-specific adaptations) to improve explosiveness. Unfortunately, information about this approach is scarce in young soccer players.

Plyometric training refers to exercises that are designed to enhance muscle power, mostly through the use of jump training. These exercises constitute a natural part of most sports movements (i.e., soccer) because they involve jumping, hopping, and skipping (33). Also, it is characterized by lengthening (eccentric contraction) of the muscle–tendon unit followed directly by shortening action (concentric contraction), which is called a stretch-shortening cycle (25). A plyometric training program should be based on the individual needs of the athlete in relation to the characteristics of the sporting activity that they are involved with (jump, sprint, and COD) (7,27,32), but it should also be performed in an explosive way (7,27,28). As such, to optimize transference to sport, plyometric exercises should reflect the type of the activity implicit in that sport (i.e., soccer), that is, the principle of specificity.

Weight sled towing has increasingly appeared in the literature during the last decade (22). Resisted sprint training provides a greater resistance than normal sprint training and may provide a greater stimulus to the working muscles, optimize training adaptations, and crossover to dynamic athletic performance (16). This type of training is commonly used to increase linear sprinting performance (37) through a muscle force output augment (22), while maintaining a proper sprinting technique (1). As such, a relatively light external resistance (i.e., approximately 10% of body mass [BM]) or those loads that reduce less than or equal to 10% the sprinting times (1,22,37), which have minimal impact on the stride length and frequency during the acceleration phase, are recommended (37). Furthermore, it was reported that additional loads of 12.6% BM improve both jumping and sprinting performance (2); although controversy still exists in this regard (9).

With training time at a premium in a professional soccer context, the search for the best training methods is crucial. To date, the comparison of the effectiveness of these isolated training methods (i.e., full-back squat [SQ], plyometric training with specific drills [PLYO], and sled towing [RS]) has never been assessed. Therefore, the aim of this study was to analyze the effects of 3 different low/moderate strength training methods on sprinting, jumping, and COD abilities in late adolescent soccer players.

METHODS

Experimental Approach to the Problem

Using a nonrandomized study design, 3 previously formed teams were divided into 3 training groups, which performed exclusively full-back squat ($n = 11$), resisted sprint with sled towing ($n = 12$) or plyometric and specific drills ($n = 9$) training. Players were selected from 3 different soccer teams that were competing in the same category (i.e., U-19 Spanish National League). Each participant visited the laboratory at 3 different times (1 familiarization session and 2 testing sessions) separated by at least 48 hours. In the preliminary session, a full explanation of the experimental protocol and recommendations were given to participants, and they were allowed to practice all tests. In addition, SQ participants performed an incremental full-squat load test to individually determine the training loads. To ensure reliability, the tests were performed twice and the values from the second session were used in subsequent analyses. Tests were performed 1

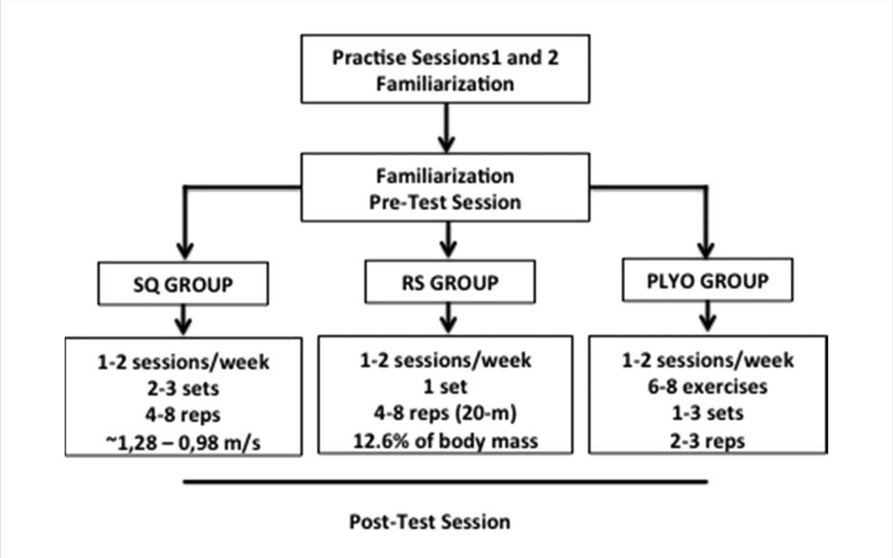

Figure 1. Project design timeline.

TABLE 1. Descriptive data of the subjects (Mean ± *SD*).*

	Age (y)	Height (cm)	Weight (kg)	BMI ($kg\cdot m^{-2}$)
SQ (*n* = 11)	18 ± 1	177.86 ± 3.12	70.87 ± 3.87	18.8 ± 2.2
RS (*n* = 12)	17 ± 1	178.24 ± 1.25	73.12 ± 2.56	19.3 ± 2.5
PLYO (*n* = 9)	18 ± 1	177.45 ± 2.12	72.34 ± 2.55	18.7 ± 2.2

*BMI = body mass index; SQ = back squat group; RS = resisted sprint group; PLYO = plyometric and speed/agility group.

week before the commencement of the training period and 1 week after the intervention. Testing sessions included a countermovement jump (CMJ) test, 20 m (10 m split time) and 50 m sprint (30 m split time) tests, and a COD test (Zig-Zag test). They were not to perform intense exercise on the day before the test and not to consume their last meal at least 3 hours before the scheduled test time. Figure 1 shows the experimental timeline.

Subjects

Thirty-two late adolescents (U-19), highly trained, male Spanish soccer players were recruited to participate in this study. Table 1 shows the descriptive data of the participants who were competing at the national level. All players participated on an average of ~10 hours of combined soccer (4–5 sessions) and conditioning (1 session) training, and 1 competitive match per week. Participants usually performed strength training based on circuit training, which was compounded, by core exercises and full-body exercises. None of the players had already participated in a periodized strength training program. The study was conducted according to the Declaration of Helsinki, and the protocol was fully approved by the local research ethics committee before recruitment. After a detailed explanation about the aims, benefits, and risks involved in this investigation, all participants and their parents gave written informed consent.

PROCEDURES

Training Intervention

Participants performed 2 specific training sessions per week (every Tuesday and Thursday afternoon, at the start of the session, after a standardized warm up routine), in addition to their normal training requirements, for 8 consecutive weeks during the competitive season (February to April). Full-back squat training sessions were developed at the gym, whereas RS and PLYO sessions were performed on artificial grass, with the subjects using appropriate soccer equipment (boots and clothes).

TABLE 2. Descriptive characteristics of the squat training program.*

		Intensity		Volume		
Week	Session	% 1RM	MPV ($m\cdot s^{-1}$)	Sets	Repetitions	Recovery time (min)
1	1	40	~1.28	3	6	3
	2			3	6	3
2	3	40	~1.28	3	8	3
	4			3	8	3
3	5	50	~1.15	3	6	3
	6			3	6	3
4	7	50	~1.15	3	8	3
	8			3	8	3
5	9	55	~1.07	2	5	3
	10			3	5	3
6	11	55	~1.07	3	6	3
	12			3	8	3
7	13	60	~0.98	2	4	3
	14			3	4	3
8	15	60	~0.98	3	6	3
	16			3	6	3

*% 1RM = percentage of 1 repetition maximum; MPV = mean propulsive velocity.

Full-Squat Training Program

The full-squat training consisted of 2–3 full-squat sets × 4–8 repetitions at 40–60% 1RM (~1.28–0.98 $m \cdot s^{-1}$) (Table 2). The concentric phase was performed as fast as possible, and the eccentric phase was executed in a controlled manner (i.e., approximately 2 seconds). The resting period between each set was 3 minutes. At the beginning of every SQ session, the mean propulsive velocity (MPV) was measured to adjust the load to the "real daily" performance within each session. The mean propulsive velocity has been considered as a precise measure of relative load intensity (% 1RM) ($R^2 = 0.98$) to prescribe and monitor the resistance training load (13).

Resisted Sprint Training Program

Resisted sprint training was compounded by 6–10 sets × 20-m loaded sprints. The load corresponded to 12.6% of BM (Table 3). Three minutes of passive recovery between sets were provided.

Plyometric Training Program

Participants performed 2 sessions per week (for 8 weeks) of plyometric training at 100% of their maximum individual effort, starting from 1 set of 2 reps (week 1), progressing to 2 sets of 2 reps (weeks 2 and 3), 2 sets of 3 reps (weeks 4 and 5), and finally 3 sets of 3 reps during the last 3 weeks (weeks 6, 7, and 8). Recovery time between sets and exercises was 3 minutes. Subjects performed combined plyometric and speed/agility training, which consisted of 8 exercises: (a) 8 unilateral crossing jumps + 15-m sprint, (b) 10 lunges + 4 × 3-m zigzag + 10-m sprint, (c) 8 unilateral alternative jumps + 15-m sprint, (d) 10 unilateral lateral jumps (40 cm hurdle) + 4 × 5-m zigzag + 10-m sprint, (e) Speed ladder. Go: Gastrocnemius exercise. Back: Foot exercise, (f) 6 headers + 5-m sprint + deceleration + 2-m back running + 10-m sprint, (g) 8 double lateral jumps (20 cm hurdle) + zigzag + 10-m sprint, and (h) Unilateral lateral jumps + shooting without controlling the ball.

Tests

Physical performance tests were performed on 2 different days and were performed 1 week before starting the training period. On the first day, CMJ, linear sprint, and COD tests were performed. On the second day, the incremental full-squat load test was developed in the SQ group. Every assessment session took place at the same time of the day (6–8 PM), thus minimizing circadian rhythms, and under similar environmental conditions. Players rested at least 48 hours between each testing session.

Countermovement Jump Test. The countermovement jump height was assessed using infrared-ray cells built into the OptoJump System (Microgate, Bolzano, Italy). Five trials of the CMJ, with 60 seconds of rest between trials, without arms (hands on hips), and using a preparatory movement of knee extension, followed by flexion to approximately 90°, and without pausing, jumping upward as high as possible, were allowed. Elevation of the center of gravity (height in meters) was calculated for all jumps as the flight time (t_v) in seconds by applying the laws of ballistics: $H = t_v 2 \cdot g \cdot 8-1$ (m); where H is the height and g is the gravitational acceleration (9.81 $m \cdot s^{-2}$). The best and worst values of the 5 jumps were erased. The mean of 3 CMJs was recorded for subsequent analysis.

TABLE 3. Descriptive characteristics of the resisted sprint training program.*

			Volume			
Week	Session	Intensity (%BW)	Distance (m)	Repetitions	Total distance (m)	Recovery time (min)
1	1	12.6	20	6	120	3
	2			6		
2	3	12.6	20	7	140	3
	4			7		
3	5	12.6	20	8	160	3
	6			8		
4	7	12.6	20	8	160	3
	8			8		
5	9	12.6	20	9	180	3
	10			9		
6	11	12.6	20	9	180	3
	12			9		
7	13	12.6	20	10	200	3
	14			10		
8	15	12.6	20	10	200	3
	16			10		

*%BW = percentage of body mass.

TABLE 4. Changes in performance after squat (SQ, $n = 11$), resisted sprint (RS, $n = 13$), or plyometric and specific drills (PLYO, $n = 9$) training programs.*†‡

	Variables	Pretest	Posttest	Changes (%) (90% CL)	Standardized differences (ES ± 90% CL)	Qualitative assessment	Chances (%)
SQ ($n = 11$)	CMJ (cm)	37.5 ± 4.2	40.0 ± 5.5	6.3 (3.5; 9.2)	0.51 (0.29; 0.73)	Very likely	99/1/0
	0–10 m (s)	1.67 ± 0.05	1.68 ± 0.08	−1.0 (−3.6; 1.5)	−0.31 (−1.10; 0.48)	Unclear	13/27/60
	10–20 m (s)	1.27 ± 0.04	1.25 ± 0.04	1.9 (0.8; 2.9)	0.61 (0.26; 0.96)	Very likely	97/3/0
	0–20 m (s)	2.95 ± 0.09	2.94 ± 0.10	0.2 (−1.4; 1.7)	0.05 (−0.43; 0.54)	Unclear	30/52/18
	0–30 m (s)	4.11 ± 0.12	4.07 ± 0.11	1.0 (−0.2; 2.2)	0.32 (−0.06; 0.70)	Possibly	71/28/2
	30–50 m (s)	2.37 ± 0.09	2.29 ± 0.09	3.4 (1.9; 4.8)	0.84 (0.48; 1.21)	Almost certainly	100/0/0
	0–50 m (s)	6.50 ± 0.20	6.38 ± 0.19	2.0 (0.8; 3.1)	0.60 (0.23; 0.97)	Very likely	96/4/0
	COD (s)	4.99 ± 0.10	4.97 ± 0.14	0.3 (−1.5; 2.2)	0.15 (−0.67; 0.97)	Unclear	46/31/23
RS ($n = 13$)	CMJ (cm)	35.3 ± 2.7	37.0 ± 2.8	4.8 (3.4; 6.3)	0.57 (0.40; 0.74)	Almost certainly	100/0/0
	0–10 m (s)	1.72 ± 0.05	1.71 ± 0.06	0.4 (−0.5; 1.3)	0.11 (−0.16; 0.37)	Possibly	26/71/3
	10–20 m (s)	1.28 ± 0.04	1.27 ± 0.04	0.2 (−1.3; 1.7)	0.06 (−0.39; 0.51)	Unclear	29/54/17
	0–20 m (s)	3.00 ± 0.07	2.99 ± 0.08	0.1 (−0.7; 1.0)	0.05 (−0.25; 0.34)	Unclear	19/74/8
	0–30 m (s)	4.22 ± 0.12	4.19 ± 0.13	0.7 (−0.3; 1.7)	0.21 (−0.11; 0.53)	Possibly	53/45/2
	30–50 m (s)	2.37 ± 0.10	2.33 ± 0.08	1.7 (0.4; 3.1)	0.45 (0.09; 0.81)	Likely	88/11/0
	0–50 m (s)	6.60 ± 0.22	6.53 ± 0.20	1.0 (0.0; 2.0)	0.30 (−0.01; 0.60)	Possibly	70/29/1
	COD (s)	5.26 ± 0.16	5.28 ± 0.17	−0.3 (−1.8; 1.1)	−0.10 (−0.54; 0.35)	Unclear	13/53/34
PLYO ($n = 9$)	CMJ (cm)	35.5 ± 4.3	37.9 ± 3.6	7.2 (2.6; 12.1)	0.50 (0.18; 0.81)	Likely	94/6/0
	0–10 m (s)	1.72 ± 0.07	1.72 ± 0.08	0.1 (−2.4; 2.5)	0.02 (−0.55; 0.60)	Unclear	29/46/25
	10–20 m (s)	1.26 ± 0.04	1.25 ± 0.05	0.4 (−1.2; 1.9)	0.12 (−0.36; 0.60)	Unclear	38/49/13
	0–20 m (s)	2.99 ± 0.08	2.98 ± 0.12	0.3 (−1.5; 2.1)	0.12 (−0.51; 0.74)	Unclear	40/41/19
	0–30 m (s)	4.17 ± 0.11	4.13 ± 0.17	1.0 (−0.6; 2.6)	0.35 (−0.21; 0.90)	Possibly	68/26/5
	30–50 m (s)	2.36 ± 0.09	2.32 ± 0.10	2.0 (0.8; 3.2)	0.50 (0.19; 0.81)	Likely	95/5/0
	0–50 m (s)	6.55 ± 0.20	6.46 ± 0.25	1.5 (0.2; 2.8)	0.46 (0.05; 0.88)	Likely	86/13/1
	COD (s)	4.94 ± 0.18	4.94 ± 0.19	0.1 (−1.1; 1.3)	0.02 (−0.27; 0.32)	Unclear	15/76/10

*Data are mean ± *SD*.

†CL = confidence limits; ES = effect size; CMJ = countermovement jump height; COD = change of direction time; %Difference = percentage difference; Chances = percentage chance of having better/similar/poorer values.

‡For clarity, all differences are presented as improvements (positive), so that negative and positive differences are in the same direction.

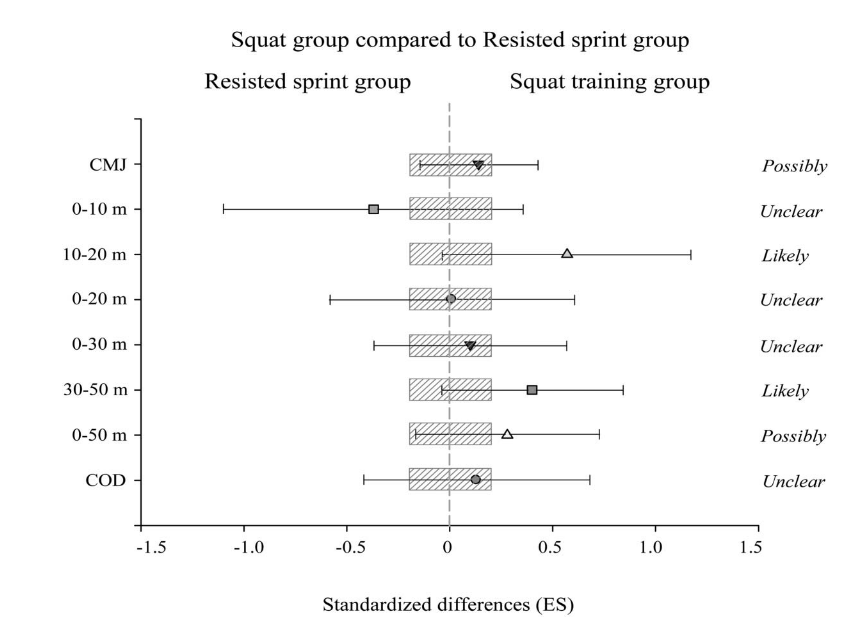

Figure 2. Efficiency of the squat training group (SQ) in comparison with resisted sprint group (RS) to improve the height in countermovement jump (CMJ), the sprint time in 10-m (0–10 m), 10-m flying time (10–20 m), the sprint times in 20-m (0–20 m), and 30-m (0–30 m), 20-m flying time (30–50 m), the sprint time in 50-m (0–50 m), and the change of direction time (bars indicate uncertainty in the true mean changes with 90% confidence intervals). Trivial areas were the smallest worthwhile change (SWC) (see methods).

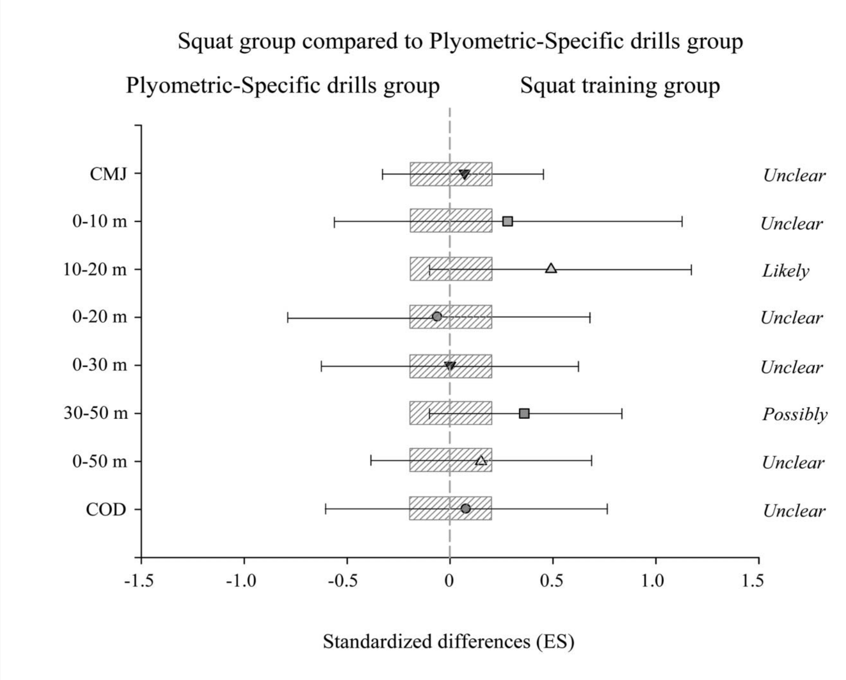

Figure 3. Efficiency of the squat training group (SQ) compared with that of plyometric-specific drills group (PLYO) to improve the height in countermovement jump (CMJ), the sprint time in 10-m (0–10 m), 10-m flying time (10–20 m), the sprint time in 20-m (0–20 m) and 30-m (0–30 m), 20-m flying time (30–50 m), the sprint time in 50-m (0–50 m), and the change of direction time (bars indicate uncertainty in the true mean changes with 90% confidence intervals). Trivial areas were the smallest worthwhile change (SWC) (see methods).

10-, 20-, 30-, and 50-m Sprint Test. Sprint time was measured using a dual-beam electronic timing gate OptoJump System (Polifemo Radio Light, Microgate, Bolzano, Italy). First, a 20-m sprint test with a 10-m split time was evaluated, considering as the outcome the time at 10- and 20-m, but also the intermediate between 10- and 20-m (flying sprinting time). Second, a 50-m sprint test with a 30-m split time was assessed. Again, the times at 50- and 30-m were recorded together with the flying sprinting time between 30- and 50-m. The front foot was placed 1 m before the first/starting timing gate. The photocells were placed at a height of 0.83 m at the start and 1.16 m at the final and intermediate measurements. All sprints were performed on an artificial grass surface, and all participants wore soccer shoes. Both, the 20- and 50-m sprint tests were executed twice, separated by at least 2 and 3 minutes of passive recovery, respectively. In this case, only 2 attempts were permitted to avoid accumulated fatigue and the best time was used in the subsequent analysis.

Zigzag Test. The change of direction was measured through the 20-m zigzag course, which included three 100° turns at 5-m intervals (21). The front foot was placed 1 m before the first/starting timing gate. Each participant performed 3 trials with 3 minutes of passive recovery between trials. The best time was recorded for the subsequent analysis.

Incremental Full-Squat Load Test. An incremental full-squat load test was performed in the SQ group before the training program. The full-squat was performed with plantar flexion to

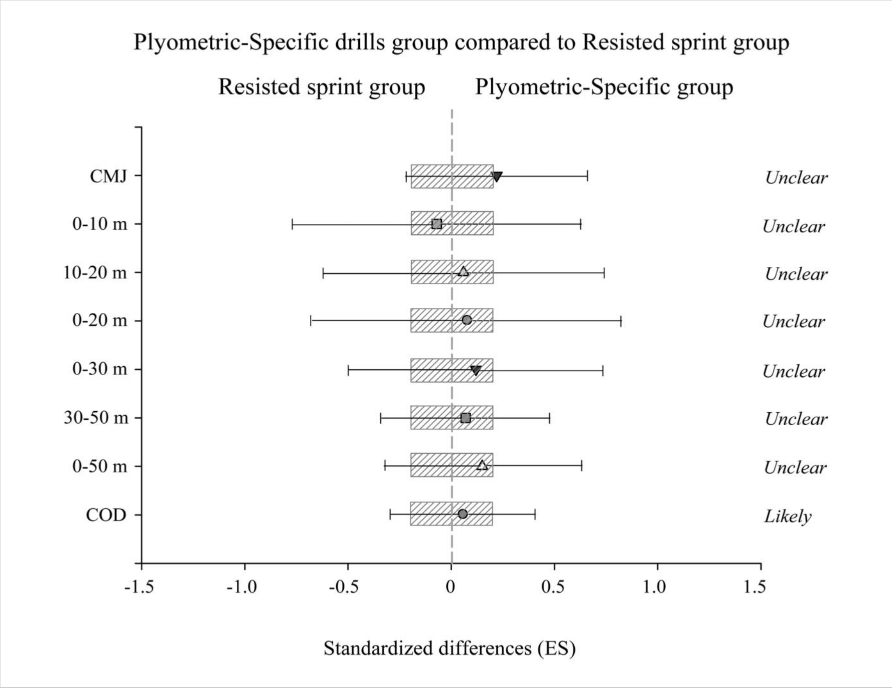

Figure 4. Efficiency of the plyometric and specific drills group (PLYO) compared with that of resisted sprint group (RS) to improve the height in countermovement jump (CMJ), the sprint time in 10-m (0–10 m), 10-m flying time (10–20 m), the sprint time in 20-m (0–20 m) and 30-m (0–30 m), 20-m flying time (30–50 m), the sprint time in 50-m (0–50 m), and the change of direction time (bars indicate uncertainty in the true mean changes with 90% confidence intervals). Trivial areas were the smallest worthwhile change (SWC) (see methods).

finish the movement, but jumping was not allowed. The MPV for each load in the concentric phase of the full squat was measured (Coeficient of variation 2.9–4.0%; Intraclass Coefficient of Correlation 0.92–0.94). This measurement was performed with the Smith machine (Multipower Fitness Line; FITLAND, Seville, Spain) starting with a resistance of 17 kg. An isoinertial dynamometer (T-Force Dynamic Measurement System; Ergotech, Murcia, Spain) was used for mechanical measurements. This system consists of a cable extension linear velocity transducer interfaced to a personal computer by means of a 14-bit resolution analog-to-digital data acquisition board and custom software. The device, at a frequency of 1,000 Hz, directly sampled the vertical instantaneous velocity. The propulsive phase was defined as that portion of the concentric phase, during which the measured acceleration (a) is greater than gravitational acceleration (i.e., $a \geq -9.81$ $m \cdot s^{-2}$) (13). Before testing, a standardized warm up routine that included 5 minutes of jogging, 5 CMJ, 10 full squats without external loads, and 1 set of 5 repetitions with 17 kg of full squats (load of the bar) was performed. After the warm up routine, subjects performed the incremental full-squat test. The testing method was adapted for that purpose by Lopez-Segovia et al. (23). Players were required to always perform the concentric phase of each repetition as fast as possible, whereas the eccentric phase was performed in a controlled manner (~2 seconds). The initial load was set at 17 kg and was progressively increased in 10-kg increments until the MPV was >1.10 $m \cdot s^{-1}$. Thereafter, the load was adjusted in 5-kg increments. The number of repetitions executed by each athlete with each load was determined according to the speed of their first repetition. Three repetitions were performed, with the loads in which the subject moved the bar at a MPV of ≥ 1 $m \cdot s^{-1}$, whereas 2 repetitions were performed if the MPV was ≤ 1 $m \cdot s^{-1}$. Four minutes of passive recovery were allowed between each load. The test ended for each subject when the MPV was less than 0.85 $m \cdot s^{-1}$. Only the best repetition at each load was considered for further analysis (based on the criteria of fastest MPV) (34).

STATISTICAL ANALYSES

Data are presented as mean ± *SD*. All data were log-transformed at first to reduce bias arising from nonuniformity errors. An ANCOVA was conducted to determine the between-group differences using the pretest as a covariate to avoid any difference at the pretest. The standardized difference or effect size (ES, 90% confidence limit) in the selected variables was calculated using the pooled pretraining *SD*. Threshold values for the Cohen ES statistics were >0.2 (small), >0.6 (moderate), and >1.2 (large) (15). For within/between-group comparisons, the chances that the differences in performance were better/greater (i.e., greater than the smallest worthwhile change [SWC] [0.2 multiplied by the between-subject *SD*, based on Cohen's d principle]), similar, or worse/smaller were calculated. Quantitative chances of the beneficial/better or detrimental/poorer effect were assessed qualitatively as follows: <1%, almost certainly not; 1–5%, very unlikely; 5–25%, unlikely; 25–75%, possible; 75–95%, likely; 95–99%, very likely; and >99%, almost certain (15). A substantial effect was set at >75% (38). If the chance of having beneficial/better or detrimental/poorer performances were both >5%, the true difference was assessed as unclear. Otherwise, we interpreted that change as the observed chance (15).

RESULTS

Only subjects who participated in 90% of sessions were included in the subsequent statistical analysis.

Within-Group Analyses

Relative changes and qualitative outcomes resulting from the within-group analyses are shown in Table 4. Substantial improvements in CMJ and 30–50 m sprinting results were found in every group compared with those at the pre-test. Players in both SQ and PLYO also showed substantial enhancements in 0–50 m sprinting results. In addition, 10–20 m sprinting performance was substantially improved in the SQ group.

Between-Group Analyses

Results from the between-group analyses are illustrated in Figures 2–4. The improvements in 10–20 m sprinting results (%: 1.7 [90% CL: −0.1; 3.5], 85/13/2% with chances for greater/similar/lower values, respectively) and 30–50 m sprinting results (%: 1.7 [90% CL: −0.2; 3.7], 78/28/1%) were substantially greater in the SQ group than in the RS group. Also, the 10–20 m sprinting result (%: 1.5 [90% CL: −0.3; 3.3], 80/17/3%) was substantially better in the SQ group than in the PLYO group.

DISCUSSION

The aim of this study was to analyze the effect of different in-season strength training programs (SQ, RS, and PLYO) on several explosive actions in U-19 highly trained soccer players. To the best of our knowledge, this is the first study that has looked at the effectiveness of different low/moderate load training methods (i.e., SQ, RS, and PLYO) in late adolescent soccer players. The main finding was the substantial improvement noted in the jumping height and flying sprinting times in all groups, with slightly better results for the SQ group, which used low/moderate loads (40–60% 1RM) and low training volume (4–8 reps per set). Furthermore, the unclear effect provided on COD performance might suggest that other factors might be taken into account to enhance the ability to rapidly change direction.

The present results indicate that 8 weeks of different training strategies had a beneficial impact on CMJ performance (ES: 0.50–0.57). The CMJ results found in this study are within the range of CMJ results established in the literature (ES: 0.20–0.86) after similar interventions (resistance training, RS, and plyometric training) in young soccer players (6,8,32,37). Previous investigations conducted on young soccer players have reported typically greater training effects [ES: 0.86 (8), ES: 0.62 (6)] after a resistance training program with either moderate or heavy loads, respectively. Other training strategies that included improvements in jumping height (i.e., sled towing or sprinting) have provided small (ES: 0.51) (37) to moderate (ES: 0.69) (39) effects in young soccer players. Conversely, when plyometric training has been included within a soccer training routine, lower effects (ES: 0.20–0.33) have been reported (7,32). The between-results discrepancies might be due to the training performed, player's training background, or total volume. Interestingly, the highest ES is found after a resistance training program, specifically through using the squat exercise. This could be due to the close relationship between the CMJ and the squat exercise in which the vertical component is emphasized during the lower body triple extension (i.e., ankle, knee, and hip) (18). Notwithstanding, the most important findings are that the SQ group in our study used a relatively low load (40–60% 1RM) and lower volume (2–3 sets per session and 4 to 8 repetitions per set) than other studies (7,8). This fact has great practical applications in a context where time is limited and heavy loads are not always well tolerated by soccer players. Despite the fact that differences were presented in the force application (vertical vs. horizontal vs. horizontal/lateral), no substantial between-group differences were found after any training program in our study. These results are in contrast with the principle of specificity needed to enhance any activity. As such, it might be possible that these players were unfamiliar with periodized strength training before starting the intervention, and consequently the knee extensor strength improvement, irrespective of the specificity of training, prompted a CMJ enhancement (3,4). Further studies are needed to know the effect of the training methodology in resistance training for experienced young soccer players.

A 50-m sprint can be divided into 2 parts: the acceleration phase (0–30 m) and the maximum sprinting phase (30–50 m). In this regard, there was only a substantial improvement in the maximum sprinting phase (30–50 m) throughout the whole sprint in all groups. Recently, it was established that force production capability is crucial to enhance sprinting performance over short distances, whereas maximal sprinting speed might depend on velocity factors (5). As such, it seems that exclusively high loads (~30% BM) require more horizontal force application and horizontal impulses in comparison with light loads (~10% BM) during RS (19). These assumptions are in line with the results found in this study and in the literature. For example, Bachero-Mena and González-Badillo (2) reported significant improvements in the initial part of a linear sprint (0–20 m and 0–30 m) after 7 weeks with a load, corresponding to 20% BM while lower loads (12.6% BM) showed significant enhancements in the last phase of the sprint (0–40 m and 20–30 m). While those studies that have used high loads during resistance training (70–90% 1RM) (6) or RS training (20% BM) (2) (30% reduction sprint times) (19) have provided substantial improvements in the acceleration phase, using light loads during either resistance training (40–60% 1RM) (8) or RS training (12.6% BM) or PLYO training (32) might be ineffective to increase the acceleration performance in young team-sports athletes. Thus, it seems that the time allowed to apply force might be the most important variable to improve the acceleration phase. In contrast, our soccer players who performed resistance training (40–60% 1RM) or RS training (12.6% BM) with light loads and PLYO training just got substantial improvements in the maximum sprinting phase (30–50 m and 0–50 m). Notwithstanding, substantial improvements were shown (ES: 0.70) in the 30-m sprint after 16-week of

PLYO training in young elite soccer players (36). As such, it is possible that training durations of less than 16 weeks [8–10 weeks such as our study or Ramirez-Campillo et al. (32)] are insufficient to prompt acceleration adaptations through plyometric training. Hence, it might be suggested that different training strategies should be used depending on the main sprinting phase focus. From the between-group analysis, it can be observed that "likely" differences in the flying times between the 10- and 20-m sprints (SQ group vs. RS group and SQ group vs. PLYO group) were found and "likely" (SQ group vs. RS group) to "possibly" (SQ group vs. PLYO group) were provided in the flying time between the 30 and 50-m sprint, which may indicate better results in the SQ group in comparison with other groups (RS group and PLYO group). In accordance with the previous considerations, it might be possible that the load used in the SQ group lead to a greater overload during the training intervention than RS and PLYO groups, and consequently, it might have produced these between-group differences.

Change of direction is considered as a multifactorial task (35), which depends on different variables to explain its performance, such as technique, straight sprinting speed, leg muscle qualities, and anthropometry. In this sense, our results are in accordance with other studies in highly trained team-sport athletes (12,24,29) in which COD showed no improvements. Nevertheless, Keiner et al. (20) observed substantial improvements in COD performance after a 2-year strength training period. Probably, a long training period is required to yield positive effects in COD through resistance training. Nevertheless, it is worth noting that there may be other considerations (technique), which are even more important than strength training per se, when several CODs are involved within a test. Thus, strength training might only be a small piece within these improvements, and when "optimal" COD performance is acquired greater force development might have a marginal effect.

Several limitations should be mentioned in this study: (a) we did not use a control group to compare the effect of the current experimental protocols, (b) we did not compare against the heavy resistance training group; and (c) we used a relatively short training intervention and did not examine the maintenance of training effects in each group. Despite these limitations, all training interventions proposed in this study similarly affected the jumping height and the flying sprinting times, although the results of SQ training showed a slightly better performance (10–20 m and 30–50 m) in young soccer players. Furthermore, COD might need to improve other factors than lower-body strength, such as techniques to increase its performance.

Practical Applications

This study showed that all the present low/moderate strength training strategies are useful to increase jumping and sprinting performance in the maximum sprinting phase in late adolescent soccer players. As such, any of these training modalities could be used to increase the CMJ and sprinting performance in young soccer players with low experience in strength training. Interestingly, a new training approach based on performing full squats with low loads executed as fast as possible, and low volume to obtain positive effects in explosive actions, could be used as part of a systematically varied and multidimensional training program for youth athletes. In contrast, strength and conditioning coaches who want to improve the acceleration phase should use higher loads or augment the training duration. However, decision-making should always be completed in accordance with the needs of individual athletes. Finally, the inclusion of other training methods (technique) seems to be the rationale to improve the ability to rapidly change direction.

References

1. Alcaraz, PE, Palao, JM, and Elvira, JL. Determining the optimal load for resisted sprint training with sled towing. *J Strength Cond Res* 23: 480–485, 2009.
2. Bachero-Mena, B and González-Badillo, JJ. Effects of resisted sprint training on acceleration with three different loads accounting for 5, 12.5, and 20% of body mass. *J Strength Cond Res* 28: 2954–2960, 2014.
3. Berthoin, S, Dupont, G, Mary, P, and Gerbeaux, M. Predicting sprint kinematic parameters from anaerobic field tests in physical education students. *J Strength Cond Res* 15: 75–80, 2001.
4. Bret, C, Rahmani, A, Dufour, AB, Messonnier, L, and Lacour, JR. Leg strength and stiffness as ability factors in 100m sprint running. *J Sports Med Phys Fitness* 42: 274–281, 2002.
5. Buchheit, M, Samozino, P, Glynn, JA, Michael, BS, Al Haddad, H, Mendez-Villanueva, A, and Morin, JB. Mechanical determinants of acceleration and maximal sprinting speed in highly trained young soccer players. *J Sports Sci* 32: 1906–1913, 2014.
6. 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.
7. Chelly, MS, Ghenem, MA, Abid, K, Hermassi, S, Tabka, Z, and Shephard, RJ. Effects of in-season short-term plyometric training program on leg power, jump and sprint performance of soccer players. *J Strength Cond Res* 24: 2670–2676, 2010.
8. Christou, M, Smilios, I, Sotiropoulos, K, Volaklis, K, Pilianidis, T, and Tokmakidis, SP. Effects of resistance training on the physical capacities of adolescent soccer players. *J Strength Cond Res* 20: 783–791, 2006.
9. Cronin, J and Hansen, KT. Resisted sprint training for the acceleration phase of sprinting. *Strength Cond J* 28: 42–51, 2006.
10. Ellis, L, Gastin, P, Lawrence, S, Savage, B, Buckeridge, A, Stapff, A, Tumilty, D, Quinn, A, Woolford, S, and Young, W. Protocols for the physiological assessment of team sports players. In: *Physiological Tests for Elite Athletes.* C.J. Gore, ed. Champaign, IL: Human Kinetics, 2000. pp. 128–144.
11. Faude, O, Koch, T, and Meyer, T. Straight sprinting is the most frequent action in goal situations in professional football. *J Sports Sci* 30: 625–631, 2012.
12. Gabbett, TJ, Johns, J, and Riemann, M. Performance changes following training in junior rugby league players. *J Strength Cond Res* 22: 910–917, 2008.
13. González-Badillo, JJ and Sánchez-Medina, L. Movement velocity as a measure of loading intensity in resistance training. *Int J Sports Med* 31: 347–352, 2010.

14. Hoff, J and Helgerud, J. Endurance and strength training for soccer players. Physiological considerations. *Sports Med* 34: 165–180, 2004.
15. Hopkins, WG, Marshall, SW, Batterham, AM, and Hanin, J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc* 241: 3–13, 2009.
16. Hrysomallis, C. The effectiveness of resisted movement training on sprinting and jumping performance. *J Strength Cond Res* 26: 299–306, 2012.
17. Jullien, H, Bisch, C, Largouet, N, Manouvrier, C, Carling, CJ, and Amiard, V. Does a short period of lower limb strength training improve performance in field-bases tests of running and agility in young professional soccer players? *J Strength Cond Res* 22: 404–411, 2008.
18. Kawamori, N and Haff, GG. The optimal training load for the development of muscular power. *J Strength Cond Res* 18: 675–684, 2004.
19. Kawamori, N, Newton, R, and Nosaka, K. Effects of weighted sled towing on ground reaction force during the acceleration phase of sprint running. *J Sports Sci* 32: 1139–1145, 2014.
20. Keiner, M, Sander, A, Wirth, K, and Schmidtbleicher, D. Long-term strength training effects on change-of-direction sprint performance. *J Strength Cond Res* 28: 223–231, 2014.
21. Little, T and Williams, AG. Specificity of acceleration, maximum speed, and agility in professional soccer players. *J Strength Cond Res* 19: 76–78, 2005.
22. Lockie, RG, Murphy, AJ, and Spinks, CD. Effects of resisted sled towing on sprint kinematics in field-sport athletes. *J Strength Cond Res* 17: 760–767, 2003.
23. López-Segovia, M, Palao, JM, and González-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.
24. Maio Alves, JM, Rebelo, AN, Abrantes, C, and Sampaio, J. Short-term effects of complex and contrast training in soccer players' vertical jump, sprint, and agility abilities. *J Strength Cond Res* 24: 936–941, 2010.
25. Markovic, G and Mikulic, P. Neuro-Musculoskeletal and performance adaptations to lower-extremity plyometric training. *Sports Med* 40: 859–896, 2010.
26. McBride, JM, Triplett-McBride, T, Davie, A, and Newton, RU. The effect of heavy- vs. light-load jump squats on the development of strength, power, and speed. *J Strength Cond Res* 16: 75–82, 2002.
27. Meylan, C and Malatesta, D. Effects of in-season plyometric training within soccer practice on explosive actions of young players. *J Strength Cond Res* 23: 2605–2613, 2009.
28. Michailidis, Y, Fatouros, IG, Primpa, E, Michailidis, C, Avloniti, A, Chatzinikolaou, A, Barbero-Alvarez, JC, Tsoukas, D, Douroudos, II, Draganidis, D, Leontsini, D, Margonis, K, Berberidou, F, and Kambas, A. Plyometrics' trainability in pre-adolescent soccer athletes. *J Strength Cond Res* 27: 38–49, 2013.
29. 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.
30. Ozbar, N, Ates, S, and Agopyan, A. The effect of 8-week plyometric training on leg power, jump and sprint performance in female soccer players. *J Strength Cond Res* 28: 2888–2894, 2014.
31. Pareja-Blanco, F, Rodríguez-Rosell, D, Sánchez-Medina, L, Gorostiaga, EM, and González-Badillo, JJ. Effect of movement velocity during resistance training on neuromuscular performance. *Int J Sports Med* 35: 916–924, 2014.
32. Ramírez-Campillo, R, Alvarez, C, Henríquez-Olguín, C, Baez, EB, Martínez, C, Andrade, DC, and Izquierdo, M. Effects of plyometric training on endurance and explosive strength performance in competitive middle- and long-distance runners. *J Strength Cond Res* 28: 97–104, 2014.
33. Saez de Villarreal, E, Requena, B, and Cronin, JB. The effects of plyometric training on sprint performance: A meta-analysis. *J Strength Cond Res* 26: 575–584, 2012.
34. Sanchez-Medina, L, Perez, CE, and Badillo, JJ. Importance of the propulsive phase in strength assessment. *Int J Sports Med* 31: 123–129, 2010.
35. Sheppard, JM and Young, WB. Agility literature review: Classifications, training and testing. *J Sports Sci* 24: 919–932, 2006.
36. Söhnlein, Q, Müller, E, and Stöggl, TL. The effect of 16-week plyometric training on explosive actions in early to mid-puberty elite soccer players. *J Strength Cond Res* 28: 2105–2114, 2014.
37. Spinks, CD, Murphy, AJ, Spinks, WL, and Lockie, RG. The effects of resisted sprint training on acceleration performance and kinematics in soccer, rugby union, and Australian football players. *J Strength Cond Res* 21: 77–85, 2007.
38. Suarez-Arrones, L, Tous-Fajardo, J, Núñez, J, Gonzalo-Skok, O, Gálvez, J, and Mendez-Villanueva, A. Concurrent repeated-sprint and resistance training with superimposed vibrations in rugby players. *Int J Sports Physiol Perform* 9: 667–673, 2014.
39. Tønnessen, E, Shalfawi, SAI, 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.
40. Váczi, M, Tollár, J, Meszler, B, Juhász, I, and Karsai, I. Short-term high intensity plyometric training program improves strength, power and agility in male soccer players. *J Hum Kinet* 36: 17–26, 2013.
41. Zafeiridis, A, Saraslanidis, P, Manou, V, Ioakimidis, P, Dipla, K, and Kellis, S. The effects of resisted sled-pulling sprint training on acceleration and maximum speed performance. *J Sports Med Phys Fitness* 45: 284–290, 2005.