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ORIGINAL ARTICLE

Is strength-training frequency a key factor to develop performance adaptations in young elite soccer players?

CARLOS OTERO-ESQUINA[1], MOISÉS DE HOYO LORA[1,2], ÓLIVER GONZALO-SKOK[3], SERGIO DOMÍNGUEZ-COBO[1], & HUGO SÁNCHEZ[1]

[1]*Fitness Section, Sevilla Football Club, Seville, Spain;* [2]*Department of Physical Education and Sport, University of Seville, Seville, Spain &* [3]*Faculty of Health Sciences, University of San Jorge, Zaragoza, Spain*

Abstract
The aim of this study was to analyse the effects of a combined strength-training programme (full-back squat, YoYo^{TM} leg curl, plyometrics and sled towing exercises) on performance in elite young soccer players and to examine the effects when this training programme was performed one or two days per week. Thirty-six male soccer players (U-17 to U-19) were recruited and assigned to experimental groups (EXP1: 1 s w^{-1}; EXP2: 2 s w^{-1}) or a control group (CON). Performance was assessed through a countermovement jump (CMJ) test (relative peak power [CMJ$_{PP}$] and CMJ height [CMJ$_{H}$]), a 20-m linear sprint test with split-times at 10-m, and a change of direction test (V-cut test) 1 week before starting the training programme and also 1 week after performing such training programme. Within-group analysis showed substantial improvements in CMJ variables (ES: 0.39–0.81) and COD (ES: 0.70 and 0.76) in EXP1 and EXP2, while EXP2 also showed substantial enhancements in all linear sprinting tests (ES: 0.43–0.52). Between-group analysis showed substantially greater improvements in CMJ variables (ES: 0.39–0.68) in experimental groups in comparison to CON. Furthermore, EXP2 achieved a substantial better performance in 20-m (ES: 0.48–0.64) than EXP1 and CON. Finally, EXP2 also showed greater enhancements in 10-m (ES: 0.50) and V-cut test (ES: 0.52) than EXP1. In conclusion, the combined strength-training programme improved jumping ability, independently of training frequency, though the achievement of two sessions per week also enhanced sprinting abilities (linear and COD) in young soccer players.

Keywords: *Performance, strength, team sport, training, soccer*

Highlights

- High level of muscular strength of the lower limbs has been suggested to be related to performance in soccer players.
- The aim of this study was to analyse the effects of a combined strength-training programme (one or two s/w) on performance in elite young soccer players.
- The combined strength-training used in the current study improved jumping, sprinting and changing of direcction abilities in young soccer players when players performed 2 s/w.

Introduction

During a soccer match, the most decisive situations are compounded by strength power and speed abilities such as linear sprint, change of direction (COD) and jump (Faude, Koch, & Meyer, 2012). As such, it is suggested that soccer players need a high level of muscular strength of the lower limbs at high velocity (Michailidis et al., 2013) to perform these abilities. In this regard, several training strategies have been successfully included to enhance specific performance in junior soccer players, such as plyometric training (PT) (de Hoyo et al., 2016a; Michailidis et al., 2013), resistance training (RT) (Chelly et al., 2009; de Hoyo et al., 2016a; Styles, Matthews, & Comfort, 2016), sled towing training (STT) (Spinks, Murphy, Spinks, & Lockie, 2007; Zafeiridis et al., 2005) and eccentric-overload training (EOT) (de Hoyo et al., 2015, 2016b; Tous-Fajardo, Gonzalo-Skok, Arjol-Serrano, & Tesch, 2016), among other methods. However, the vast majority of the above-mentioned studies have analysed the influence of an isolated training method.

Correspondence: M. De Hoyo Lora, Department of Physical Education and Sport, University of Seville, Pirotecnia street s/n, 41013 Seville, Spain. Email: dehoyolora@us.es

Plyometric training is a type of training that involves jumping exercises using the stretch-shortening cycle (Markovic & Mikulic, 2010). According to Bedoya, Miltenberger, and Lopez (2015), the specific actions performed during PT are similar to soccer demands. Meanwhile, RT approaches are based on emphasizing the vertical component during the lower body triple extension such as in different squat exercises, due to the fact that these are deemed closer to actions performed at high velocity, such as sprinting and jumping tasks (Kawamori & Haff, 2004).

Usually, authors have used high loads (70–90% 1 repetition maximum [1RM]) to improve high-intensity actions such as jumping or sprinting (Chelly et al., 2009; Smilios et al., 2013; Styles et al., 2016). In this line, greater magnitude improvements have been reported in sprinting ability through heavy loads (80% 1RM) in comparison to maximal power output load in the squat jump exercise, though no between-group differences are presented (Harris, Cronin, Hopkins, & Hansen, 2008). Conversely, others have provided that actual velocity (high speeds) seems to be crucial to yield positive performance adaptations (McBride, Triplett-McBride, Davie, & Newton, 2002). Furthermore, a recent study has shown that a training programme using light loads (40–60% 1RM) at maximal intended velocity may be a preferential stimulus for jumping and sprinting improvements (de Hoyo et al., 2016a). Therefore, it seems that the combination between high-speed actual velocity and maximal intended velocity might also be useful to improve high-intensity actions.

STT 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 (Hrysomallis, 2012). This type of training is commonly used to increase sprinting performance (Spinks et al., 2007). In this regard, the optimal resisted load for sprint training has not been established yet, although it has been suggested that a resistance reducing the athlete's velocity by more than 10% from unloaded sprinting would entail substantial changes in the athlete's sprinting mechanics (Lockie, Murphy, & Spinks, 2003; Spinks et al., 2007). Recently, several studies have provided that the initial phase of acceleration up to 30 m might be improved through using loads ≥20% BM, while to improve high-speed acceleration phases, loads around 5–12.5% of BM should be preferred (Bachero-Mena & González-Badillo, 2014; Morin et al., 2015).

As an alternative to these traditional training methods, flywheel inertial devices have appeared increasingly in scientific research and are being incorporated into regular training programmes (de Hoyo et al., 2015, 2016a, 2016b; Tous-Fajardo et al., 2016). The benefits of these devices include both eliciting a greater overall amount of muscle activity than traditional overload exercises (Askling, Karlsson, & Thorstensson, 2003) and a greater eccentric overload (Romero-Rodriguez, Gual, & Tesch, 2011). Thus, the introduction of EOT methods, which can overload the eccentric phase, might be appropriate to improve jumping, sprinting and COD abilities in soccer players such as different studies have reported (de Hoyo et al., 2015, 2016a, 2016b). In this sense, several studies have shown that the knee flexors are very likely contributors to sprint acceleration performance, where subjects who produced the greatest amount of horizontal force during sprinting are both able to highly activate their hamstring muscles just before ground contact and present high eccentric hamstring peak torque capability (Edouard et al., 2016).

In the real-world soccer-training environment, limited time is available for strength-training sessions during the in-season period. The search for time-efficient strategies that concurrently enhance several locomotive specific actions while preventing injuries seems crucial. Furthermore, it is often difficult to develop a scientific-based strength-training programme, which comprises two or three sessions per week. In this sense, several studies have investigated the effects of frequency of strength training and its effects on specific performance (i.e. sprints, jumps, COD …). Hence, Peterson, Rhea, and Alvar (2005) observed that, depending on the training status of subjects, the best choice in terms of frequency and intensity of training would be three sessions per week for untrained individuals. On the other hand, for recreationally trained nonathletes and athlete populations, maximal strength gains were elicited using two sessions per week (Peterson et al., 2005). However, the results of our research group showed that young soccer players training with a frequency of two sessions per week in the full-squat exercise reached an improvement in both jumping and sprinting abilities (de Hoyo et al., 2016a). Thus, it seems that two strength-training sessions per week is a good choice to improve performance, but is needed to evaluate if just one session per week would be necessary for improve specific performance with the use of more than one exercise. Therefore, it would be interesting to analyse the effects of a combined (use several strength exercises) strength-training programme performed once or twice per week.

Accordingly, a training programme, which includes the simultaneous involvement of these strength methods, may be appropriate for improving specific soccer abilities. Therefore, the aim of this study was to analyse the effects of two different frequencies of training protocols through a combined strength-training programme with traditional full-back squat in smith machine, leg curl in yoyo device, plyometrics and sled towing exercises on jumping, sprinting and COD performance in elite young soccer players. In this sense, we hypothesize that the group who trains with a frequency of 2 days per week will improve their specific performance more than the control and one session per week groups.

Materials and methods

Subjects

Thirty-six young (U-17 to U-19) highly trained (4–5 sessions of combined soccer and strength/power and one match per week over 10 months per year and last 5 years) male soccer players (age = 17.0 ± 1.0 years; height = 176.7 ± 2.2 cm; body mass (BM) = 69.4 ± 4.2 kg; BMI = 18.2 ± 2.4 kg m^{-2}) from a professional Spanish soccer club (La Liga BBVA) voluntarily took part in the present study. All participants were involved in usual soccer training with a similar weekly training volume (4–5 sessions/week of 60–90 min and 1 match per week). All procedures performed were in accordance with the ethical standards of the local committee and with the 1964 Helsinki declaration. Informed consent was obtained from either all-individual participants included in the study or their parents in case of those players under 18.

Design

Using a controlled non-randomised study design, players from three different teams (without any between-group differences at pre-test), in the same professional Spanish soccer club, were divided into two combined strength-training groups who performed 1 s wk^{-1} (EXP1, $n = 12$) or 2 s wk^{-1} (EXP2, $n = 12$) respectively, and a control group (CON, $n = 12$). Tests were performed 1 week before training and 1 week following the training period. One week before the commencement of the study, two familiarization sessions separated by at least 72 h were carried out in all groups. Within these sessions, the participants executed all the exercises and tests and, additionally, performed two tests in the flywheel device and full-squat exercise to select the inertia and load used throughout the intervention (Figure 1).

Strength-training programme

Strength-training programme consisted of four exercises performed in the following order in each session: full-back squat exercise, Yo-Yo leg curl exercise, plyometric exercise and resisted-sprint exercise. Players involved in EXP1 group performed one strength-training session per week, while EXP2 group executed the same training session but twice per week for 7 consecutive weeks.

Full-back squat exercise. This exercise consisted of 2–3 full-squat (inguinal fold under a straight horizontal line with the top of the knee musculature) sets × 4–6 repetitions at 40–55% 1RM (mean propulsive velocity [MPV]: ~1.28–1.07 m/s) (Table I). The concentric phase was performed as fast as possible and the eccentric phase was executed in a controlled manner (i.e. approximately 2 s). Between-sets recovery was 3 min. At the beginning of every session, the MPV was measured to adjust the load to the "real daily" performance within each session. So, if a player did not elicit the MPV considered in that session the training load was adjusted. MPV has been considered as a precise measure of relative load intensity (%1RM) ($R^2 = 0.98$) to prescribe and monitor the resistance-training load (González-Badillo & Sánchez-Medina, 2010; Sánchez-Medina, Pallares, Perez, Morán-Navarro, & González-Badillo, 2017).

YoYo^{TM} leg curl exercise. In this exercise, players performed 2 sets × 4 repetitions in weeks 1 and 2, 3 sets × 4 repetitions in weeks 3 and 4, 3 sets × 5 repetitions in weeks 5 and 6, and 3 sets × 6 repetitions in week 7. Between-sets recovery was 2 min.

Plyometric exercise. This exercise consisted in one set of 3–6 repetitions per session. Each repetition was compounded by the following jumps: one tuck jump with landing on a box (height was progressively increased from 85 to 100 cm) following by a descent box and two-leg drop jumps (40–70 cm) and subsequently four hurdle jumps (60 cm). The total number of ground contacts progressively increased from 12 to 24 during the 7-week period. Between-repetitions recovery was 1 min.

Resisted-sprint exercise. Resisted-sprint exercise consisted of 3–5 repetitions × 20-m loaded sprints. The load corresponded to 20% of BM (Bachero-Mena & González-Badillo, 2014) was used in the current study. Players performed 3 repetitions in week 1 and 2 (60 m total distance), 4 repetitions in week 3, 4 and 5 (80 m total distance), and 5 repetitions in

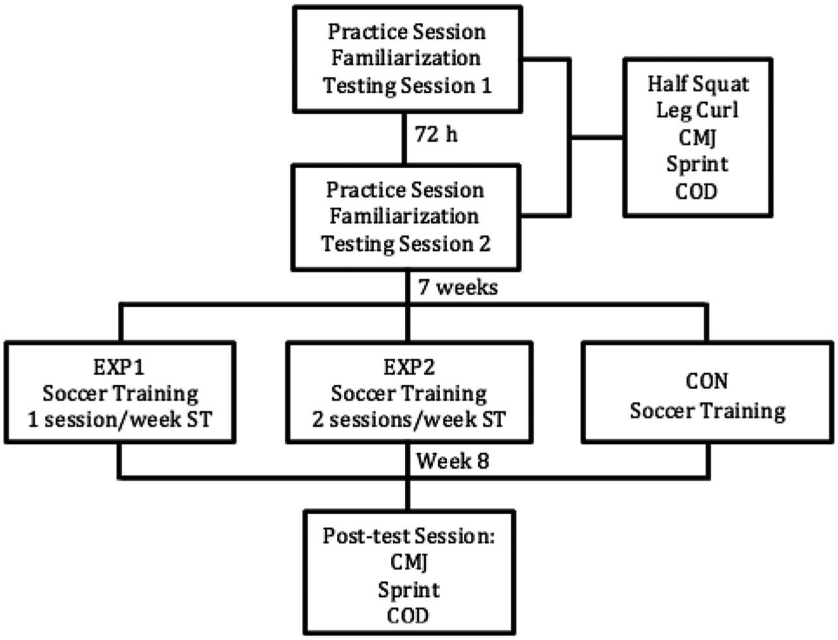

Figure 1. Project-design timeline. ST: strength-training programme; CMJ: counter movement jump; COD: change of direction; EXP1: experimental group 1; EXP2: experimental group 2; CON: control group.

week 6 and 7 (100 m total distance). Between-repetitions recovery was 2 min.

Performance tests

YoYo^{TM} leg curl test. Each player performed a testing protocol using a flywheel isoinertial device to know the inertia used throughout the study. Power output was measured during each concentric action (SmartCoach^{TM} Power Encoder, SmartCoach Europe AB, Stockholm, Sweden). Given their properties (material: PVC; density: 1.4 kg/cm^3, diameter: 380 mm; thickness: 20 mm), the resulting inertia of each flywheel was 0.11 kg m^2. To determine the inertia that was used during the study, an assessment with inertia 1, 2, 3 and 4 (4 repetitions per inertia with 180 s inter-inertia recovery) was performed. The inertia that achieved higher power output was selected.

Full-back squat test. An incremental full-back squat (40°–45°) load test was performed before the training programme (Hartmann, Wirth, and Klusemann

Table I. Descriptive characteristics of the back squat exercise.

		Intensity		Volume		
Week	Session	% 1RM	MPV (m/s)	Sets	Repetitions	Recovery Time (min)
1	1	40	~1.28	3	6	2
	2			3	6	2
2	3	40	~1.28	3	6	2
	4			3	6	2
3	5	45	~1.20	3	4	2
	6			3	4	2
4	7	45	~1.20	3	4	2
	8			3	4	2
5	9	50	~1.20	3	6	2
	10			3	6	2
6	11	50	~1.15	3	4	2
	12			3	4	2
7	13	50	~1.15	3	4	2
	14			3	4	2

Note: %1RM: percentage of 1 repetition maximum; MPV: mean propulsive velocity (m s^{-1}).

(2013). The full-squat was carried out with plantar flexion to finish the movement, but jumping was not allowed. The MPV for each load in the concentric phase was measured (coefficient of variation 2.9–4.0%; intraclass correlation coefficient 0.92–0.94). This measurement was performed with the Smith machine (Multipower Fitness Line; FITLAND, Seville, Spain). An isoinertial dynamometer (T-Force Dynamic Measurement System; Ergotech, Murcia, Spain) was used for mean propulsive velocity (MPV) measurements. The device, at a frequency of 1000 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. ≥ -9.81 m s^{-2}) (González-Badillo & Sánchez-Medina, 2010). The testing method was adapted for that purpose by López-Segovia, Palao, and González-Badillo (2010). 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 s^{-1}. Thereafter, load was adjusted in 5-kg increments until the end of the test. The number of repetitions executed by each athlete with each load was determined according to the speed of their first repetition. Three or two repetitions were performed, with the loads in which the subject moved the bar at a MPV of ≥ 1 m s^{-2} or when MPV was <1 m s^{-1}, respectively. Four minutes of passive recovery were allowed between each load. The incremental load test ended for each subject when the MPV was less than 0.85 m s^{-1} because this velocity is appropriate to estimate individual 1RM (Sanchez-Medina, Perez, & Gonzalez-Badillo, 2010). Only the best repetition at each load was considered for further analysis (Sanchez-Medina et al., 2010).

Countermovement Jump (CMJ) test. The CMJ test was assessed using a dual force platform system (NMP ForceDecks Limited, model FD4000a, London, UK) with a sampling rate of 1000 Hz. Players performed five CMJs with 15 s rest between-trials, and were instructed to jump as high as possible with hands on hips. The variables included within the analysis were: the relative peak power ($\mathrm{CMJ_{PP}}$) and jumping height ($\mathrm{CMJ_H}$) calculated according to the impulse-momentum method (Linthorne, 2001): $V^2_{\mathrm{takeoff}}/(2g)$, where V^2_{takeoff} = velocity at take-off and g = acceleration due to gravity. Various kinetic variables were automatically obtained with force platform software. Thus, left and right platform vertical forces were summed to calculate total vertical force. Acceleration was determined by dividing the net force by system mass, and velocity and displacement calculated from integration and double integration of acceleration, respectively. Impulse is the integral of force with respect to time between two time points. The onset of movement was taken from the point when the vertical force deviated 20 N from body weight and take-off when total vertical force dropped below 20 N. The point of maximal negative displacement between start of movement and take-off was used to separate the movement into eccentric and concentric phases. Peak power was calculated as the instantaneous maximum value of the product of vertical ground reaction force (GRF) and velocity during the concentric phase, and relative peak power determined by dividing this by body mass. The best and the worst scores (according the concentric peak velocity) were removed and the mean of the remaining three CMJ was recorded for subsequent analysis (de Hoyo et al., 2015). The jump test showed excellent reliability for $\mathrm{CMJ_{PP}}$ (ICC = 0.95 [0.93–098.]; CV = 1.7) and $\mathrm{CMJ_H}$ (ICC = 0.99 [0.98–0.99]; CV = 1.8).

10-m acceleration and 20-m sprint tests. Linear sprinting tests were measured using a dual beam electronic timing gates (OptoJump System, MICROGATE, Bolzano, Italy). All subjects' sprint times were assessed for 10 m (V_10), 10–20 m (V_10_20) and 20 m (V_20). The front foot was placed 1 m before the first timing gate. All assessments were performed on an artificial grass surface, and subjects wore specific soccer shoes. The 20-m sprint was performed twice and separated by at least 120 s of passive recovery. The best time was considered for further analysis. The sprint test showed excellent reliability for V_10 (ICC = 0.81 [0.63–0.91]; CV = 2.4), V_10_20 (ICC = 0.96 [0.91–0.98]; CV = 1.3) and V_20 (ICC = 0.93 [0.86–0.96]; CV = 1.5).

Change of direction test (V-cut test). In the V-cut test, players performed a 25-m sprint with 4 COD of 45° each 5 m (Tous-Fajardo et al., 2016). For the trial to be valid, players had to pass the line, drawn on the floor, with one foot completely at every turn. If the trial was considered as failed, a new trial was allowed. The front foot was placed 1 m before the first timing gate. The distance between each pair of cones was 0.7 m. The V-cut test was performed two times, separated by at least 120 s. The best time was selected for the subsequent analysis. The V-cut test showed excellent reliability (ICC: 084 [0.72–0.91]; CV = 2.1).

Data analysis

Data are presented as mean ± standard deviation (SD). All data were first log-transformed to reduce bias arising from non-uniformity error. An ANCOVA was conducted to determine the between-group differences using the pre-test as a covariate to avoid any difference at the pre-test with a specific spreadsheet (xCompare2groups.xls). The effect size (ES, 90% confidence limit) in the selected variables was calculated using the pooled pre-training SD. Threshold values for Cohen ES statistics were >0.2 (small), >0.6 (moderate) and >1.2 (large) (Hopkins, Marshall, Batterham, & Hanin, 2009). 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 standard deviation, based on Cohen's *d* principle]), similar or worse/smaller were calculated. Quantitative chances of 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 (18). If the chance of having beneficial/better or detrimental/poorer performances was both >5%, the true difference was assessed as unclear. Otherwise, we interpreted that change as the observed chance (Hopkins et al., 2009).

Results

Within-group analyses

Relative changes and qualitative outcomes from the within-group analyses are shown in Table II. Substantial improvements in CMJ_H, CMJ_{PP} and V-cut test time were found in both experimental groups compared with the pre-test. EXP_2 also showed substantial enhancements in all linear sprinting variables (V_10, V_10_20, V_20). In addition, COD was substantially enhanced in CON group.

Between-group analyses

Results from the between-group analyses are illustrated in Figure 2. The improvements in CMJ_H (EXP_1; %: 8.4 (90%CL: 0.8; 16.6), 91/8/1% with chances for greater/similar/lower values, respectively; EXP_2; %: 7.4 (90%CL: 3.2; 11.6), 97/3/0%) and CMJ_{PP} (EXP_1; %: 6.5 (90%CL: 0.7; 12.6), 90/9/1%; EXP_2; %: 4.3 (90%CL: −0.3; 9.1), 78/21/1%) during CMJ were substantially greater in both EXP_1 and EXP_2 than CON group. Furthermore, V_10_20 (%: 2.2 (90%CL: 0.6; 3.7), 95/5/0%) and V_20 (%: 1.7 (90%CL: −0.1; 3.4), 86/11/2%) were substantially better in EXP_2 than in CON group. Finally, when compared both experimental groups, substantial greater enhancements in V_10 (%: 1.6 (90%CL: 0.2; 3.0), 88/12/1%), V_20 (%: 1.4 (0.2; 2.6), 87/12/1%) and COD (%: 2.9 (90%CL: 1.9; 5.8), 85/13/2%) were reported in EXP_2 than in EXP_1.

Discussion

The present study aimed to investigate the effects of two different training frequencies (one vs. two sessions per week) protocols through a combined strength-training programme (full-back squat, yo-yo leg curl, plyometric and resisted sprint) on performance in young soccer players. In the current study, a 7-week combined strength-training programme showed greater improvements in jumping ability in comparison to CON, irrespective of the training frequency. However, the executions of two training sessions per week achieved better linear sprinting and COD performance than performing one session per week.

Previous studies have suggested that combined strength-training programmes have beneficial effects on jumping and sprinting performance in soccer players (Faude, Roth, Di Giovine, Zahner, & Donath, 2013; Franco-Márquez et al., 2015; Los Arcos et al., 2014; López-Segovia et al., 2010). According to a recent meta-analysis, one possible explanation to this might be that, by increasing their lower body strength levels, the subjects might produce higher GRFs, impulse and rate of force development after the training interventions, resulting in a greater performance in these tasks (Seitz, Reyes, Tran, Saez de Villarreal, & Haff, 2014). Franco-Márquez et al. (2015) showed that a strength-training programme consisted in low-load full squats, jumps, sprints, step phase triple jumps and COD exercises performed twice per week, on non-consecutive days, for a 6-week period, induced important enhancements in vertical jumping ability (ES: 0.58) and sprinting performance (ES: 0.25–0.35) in young soccer players. These improvements were lower than those found in the current study in both jumping (ES: 0.60–0.81) and sprinting ability (ES: 0.43–0.52). Between-studies differences might be due to the addition of two key exercises (resisted sled towing and YoYo^{TM} Leg Curl) in the training programme. In this regard, Bachero-Mena and González-Badillo (2014) reported substantial improvements in the initial phase of acceleration (0–30 m) using a resisted sprinting training programme with loads around 20% of BM which are similar to those

Table II. Changes in performance after combined strength-training programme for the control and experimental groups (mean ± SD).

				Difference			
	Variable	Pre-test	Post-test	Standardized (90% CL)^a	% (90% CL)	Chances^b	QA
EXP1	CMJ$_H$	34.48 ± 3.82	37.96 ± 2.74	0.81 (0.41; 1.22)	10.5 (5.2; 16,1)	99/1/0%	Almost Certainly
	CMJ$_{PP}$	51.18 ± 4.64	54.86 ± 3.82	0.71 (0.39; 1.04)	7.4 (4.0; 10.9)	99/1/0%	Almost Certainly
	V_10	1.70 ± 0.06	1.70 ± 0.05	−0.09 (−0.42; 0.23)	−0.3 (−1.5; 0.8)	28/65/7%	Unclear
	V_10_20	1.27 ± 0.04	1.26 ± 0.03	0.29 (−0.18; 0.75)	1.0 (−0.7; 2.7)	4/33/63%	Possibly
	V_20	2.99 ± 0.07	2.98 ± 0.08	0.12 (−0.21; 0.45)	0.3 (−0.5; 1.2)	5/61/33%	Unclear
	COD	6.66 ± 0.20	6.51 ± 0.18	0.70 (0.26; 1.15)	2.2 (0.8; 3.6)	0/3/97%	Very Likely
EXP2	CMJ$_H$	36.29 ± 4.21	39.32 ± 4.84	0.60 (0.44; 0.76)	8.3 (6.1; 10.6)	100/0/0%	Almost Centainly
	CMJ$_{PP}$	55.28 ± 6.19	58.01 ± 6.27	0.39 (0.21; 0.57)	5.0 (2.7; 7.3)	96/4/0%	Very Likely
	V_10	1.71 ± 0.05	1.69 ± 0.05	0.43 (0.20; 0.66)	1.4 (0.7; 2.2)	0/5/95%	Very Likely
	V_10_20	1.26 ± 0.04	1.24 ± 0.05	0.52 (0.29; 0.75)	1.8 (1.0; 2.6)	0/2/98%	Very Likely
	V_20	2.98 ± 0.09	2.93 ± 0.11	0.47 (0.22; 0.71)	1.5 (0.7; 2.4)	0/4/96%	Very Likely
	COD	6.80 ± 0.42	6.46 ± 0.25	0.76 (0.42; 1.10)	5.0 (2.8; 7.1)	0/1/99%	Almost Centainly
CON	CMJ$_H$	34.89 ± 3.07	35.17 ± 4.22	0.05 (−0.22; 0.31)	0.5 (−2.2; 3.3)	16/77/6%	Unclear
	CMJ$_{PP}$	54.03 ± 3.86	54.51 ± 6.28	0.07 (−0.41; 0.55)	0.5 (−3.1; 4.2)	32/51/17%	Unclear
	V_10	1.74 ± 0.04	1.74 ± 0.05	0.17 (−0.67; 1.01)	0.5 (−1.7; 2.6)	22/30/48%	Unclear
	V_10_20	1.29 ± 0.03	1.29 ± 0.03	−0.15 (−0.70; 0.40)	−0.3 (−1.5; 0.9)	25/48/27%	Unclear
	V_20	3.04 ± 0.05	3.04 ± 0.06	0.06 (−0.83; 0.95)	0.1 (−1.2; 1.4)	30/30/39%	Unclear
	COD	6.63 ± 0.20	6.46 ± 0.20	0.81 (0.22; 1.39)	2.5 (0.7; 4.3)	0/4/96%	Very Likely

Note: For clarity, all differences are presented as improvements (positive), so that negative and positive differences are in the same direction. Abbreviations: EXP1: experimental group with 1 s wk^{-1}; EXP2: experimental group with 2 s wk^{-1}; CON: control group; CL, confidence limits; QA, qualitative assessment; CMJ$_H$, countermovement jump height calculated according impulse variable; CMJ$_{PP}$, relative peak power achieved during countermovement jump; V_10, sprint test for 10 m; V_10_20, sprint test for 10–20 m; V_20, sprint test for 20%; COD, change of direction test.

^{a}Effect size.

^{b}Percentage chance of having better/similar/poorer values.

added in our study. It is assumed that adding an external load of 20–30% BM through a sled towing during a sprint requires more horizontal force application and increases the demand for horizontal impulse production (Kawamori & Haff, 2004). This induces specific adaptations within the neuromuscular system allowing larger horizontal GRF and impulse production, which would theoretically lead to increased step length, thereby improving sprinting performance under unresisted conditions (Lockie et al., 2003; Spinks et al., 2007). Notwithstanding, a recent work has found that a load of 80% of BM substantially increased maximal horizontal force production and mechanical effectiveness (i.e. more horizontally applied force) (Morin et al., 2016). Therefore, it should be interesting to compare the effects between different sled towing loads to find the most appropriate load to improve sprinting ability.

Regarding the potential benefits of eccentric training focused on hamstring muscles during sprinting, in a recent review, Morin et al. (2015) indicated that the horizontal component of GRF is the key mechanical feature of sprinting acceleration performance. When trying to explain the muscular origin of this, previous researchers have focused on the hamstrings muscles (Schache, Dorn, Williams, Brown, & Pandy, 2014). Authors have been suggested that during late swing phase, when hamstrings are actively lengthened, these ones appears to contribute to the subsequent early stance force application through a reduced deceleration time during impact (Morin et al., 2015). According to this, our research group revealed in a previous study that an eccentric-overload programme focused on hamstring and quadriceps muscles elicited a 20-m sprint time (ES: 0.37), a 10-m flying-sprint time (ES: 0.77) and a CMJ (ES: 0.79) improvement (de Hoyo et al., 2015). In this line, after 10 weeks of hamstring eccentric-overload strength training using flywheel devices (one or two times per week), Askling et al. (2003) observed an improvement in a 30-m sprinting test (ES: 0.80). These results are in line with those found in EXP2. Therefore, it seems crucial to include exercises that overload the eccentric phase in hamstrings muscles to improve sprinting ability.

With regard to COD ability, all groups obtained a substantial effect after the training programme (ES = 0.70–0.81). These results indicate that the specific training on the pitch was sufficient to elicit an improvement in COD ability. However, the group, which performed two sessions per week, achieved a greater response than executing one session per week (EXP1; ES: 0.52), or included no strength-training

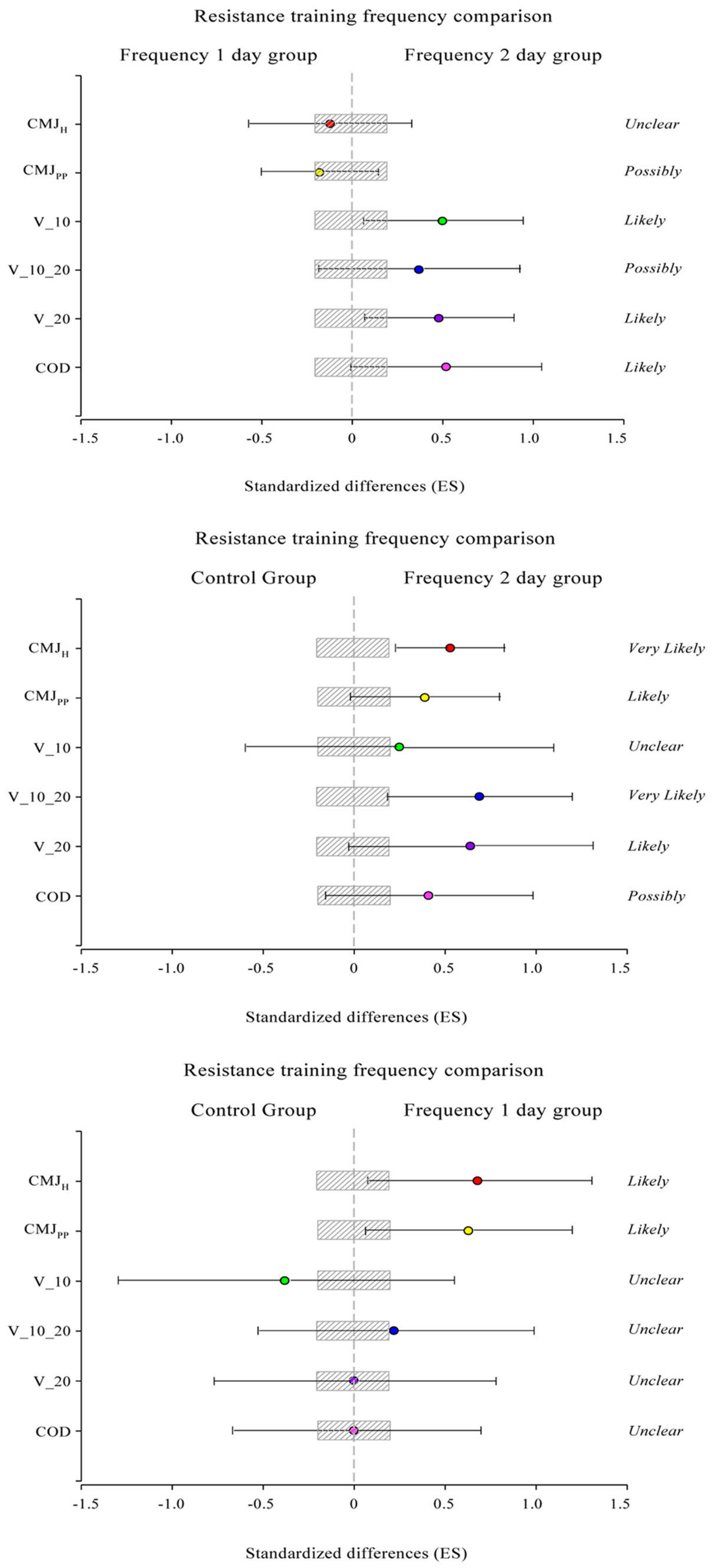

Figure 2. Effectiveness of the experimental training groups with 1 s w^{-1} (EXP1) and 2 s w^{-1} (EXP2) in comparison to control group (CON) to improve relative peak power (CMJPP) and jumping height (CMJH) during a CMJ test, a 10 m (V_10), 10–20 m (V_10_20) and 20 m (V_20) liner-sprinting tests, and a COD tests (bars indicate uncertainty in the true mean changes with 90% confidence intervals). Trivial areas were calculated from the smallest worthwhile change (SWC) (see methods).

session (CON; ES: 0.41) while no substantial differences were found between these two groups (EXP1 vs. CON). Hence, it seems that one session per week is not enough for additional improvements in the ability to COD. In this regard, controversy still exists regarding the effectiveness of lower body strength-training programmes to improve COD ability. Despite that traditional strength interventions might mainly develop one of the strength components (i.e. eccentric, concentric, isometric), a soccer player is required to brake (eccentric strength), plant his foot (isometric strength) and propel (concentric strength) his body in the new direction during these COD actions (Spiteri et al., 2014). In a recent study, different programmes using exclusively full-back squat or plyometric or resisted sprinting exercises in young soccer player only showed improvements in jumping and sprinting abilities, but not in COD ability (de Hoyo et al., 2016a). It might be possible that a training programme, which requires the simultaneous involvement of several strength components, may be appropriate for improving COD ability. Furthermore, COD ability has been related with both eccentric knee flexor strength (stepwise multiple regression revealed that it explained 67% of the variance in CODs) (Jones, Bampouras, & Marrin, 2009) and eccentric lower body strength ($r = -0.79$ to -0.89) (Spiteri et al., 2014). Lastly, several studies, which incorporate flywheel devices (i.e. EOT), have provided positive effects in COD time (Tous-Fajardo et al., 2016) and COD kinetic parameters (de Hoyo et al., 2016b). Thus, the introduction of training methods, which can overload the eccentric phase, might be appropriated to improve the ability to rapidly COD. Besides, research examining GRF and impulses production during COD manoeuvres has identified the importance of braking ability (eccentric strength) to improve the re-acceleration phase after a COD (Spiteri, Cochrane, Hart, Haff, & Nimphius, 2013). However, as there are several studies which have found positive results after performing a strength-training intervention (Keiner, Sander, Wirth, & Schmidtbleicher, 2014; Loturco et al., 2016), further studies are needed to elucidate the influence of both training approaches (i.e. EOT vs. Resistance training) on COD ability. Moreover, we must consider that in COD ability, hip extension is more important than knee flexion (Rabita et al., 2015), and in our study the exercise selected was knee dependent. Thus, it is possible that hamstring strength elicited with leg curl exercise could not improve both joint movements in biarticular muscles.

To the best of our knowledge, this is the first study that has analysed the effects of a combined strength-training frequency in young soccer players. The results of this study can contribute to raise awareness about in-season strength-training programmes design for young soccer players. Our study shows that, in addition to technical and tactical training, well-planned strength training with duration of 7 weeks, 1 or 2 days per week, influences multidimensional development of muscular performance. This study showed that the present combined strength-training programme was useful to increase jumping, sprinting and COD performance in late adolescent soccer players. However, it is necessary a minimum dose of two sessions per week to improve sprinting and COD tasks, while one session per week is enough to improve jumping ability. Furthermore, the specific soccer training was sufficient to improve COD, though the introduction of two sessions per week reported an optimal enhancement. Despite this, a limitation in our study may be considered, because we do not know if the EXP1 could reach the same improvements as EXP2 if they extended their training during 14 weeks to equate the training volume. Also, progressive training load used in our study was appropriated to avoid muscle soreness on the days following the strength-training sessions. Consequently, we had no muscle injury during the training programme and neither technical nor tactical session was modified due to our strength-training programme.

Disclosure statement

No potential conflict of interest was reported by the authors.

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