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Strength Training in Professional Soccer: Effects on Short-sprint and Jump Performance

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ABSTRACT

Several studies have confirmed the efficacy of strength training to maximize soccer player performance during competition. The aim of this meta-analysis was to determine the effects of different strength training protocols on short-sprint and vertical jump performance of professional soccer players from the first division of their countries. The following inclusion criteria were employed for the analysis: (a) randomized studies; (b) high validity and reliability instruments; (c) studies published in a high-quality peer-reviewed journal; (d) studies involving professional soccer players from the first division; (e) studies with descriptions of strength training programs; and (f) studies where countermovement jump and 10-m sprint time were measured pre and post training. Overall, the different strength-oriented training schemes produced similar performance improvements, which seem not to depend on the training strategy. Strength training appears to have a lower effect when applied during in-season than when applied in pre-season periods in first division soccer players. In this meta-analysis it is not possible to confirm that strength training in isolation is capable of improving the short-sprint and jump performance of elite soccer players. The congested fixture schedule and, thus, the limited time to perform complementary (non-specific) training sessions, may contribute to these reduced effects.

Introduction

Soccer is a tactical game; therefore, player behavior on the field is often constrained by tactical tasks [1–3]. To perform these tasks successfully, players need to be competent in several fitness attributes [3, 4]. It is well established that some of these qualities, which play significant roles in soccer performance, are maximal strength and power [4–9], being considered key physical components for professional soccer players [10]. Usually, maximal strength is described in terms of one-repetition maximum (1RM), assessed in traditional resistance exercises (e.g., squat). Power is defined as the product of force and movement velocity; that is, the ability to perform as much work as possible in the shortest time possible [6]. Although technical-tactical training along with different soccer drills (e.g., small-sided games) seem to act as useful methods for improving endurance-related capacities and game skills, the development of strength and power in elite soccer players requires focused interventions in order to provide sufficient and effective stimuli to elicit significant adaptations [11, 12].

The strength demands of soccer are complex and multifaceted. Overall, players must be able to effectively accelerate, decelerate, change direction, and jump [8, 11, 13–15]. On average, an elite player performs about 150–250 high-intensity activities during a soccer game [16]. Different training approaches have been suggested to enhance neuromuscular [8–11, 17–25] and recovery adaptations in soccer players [26]. It has now become apparent that strength and power training requires maximal efforts and optimal intensities to yield best effects [21]. Nevertheless, this scenario is not common in professional soccer training routines [17]. At the professional level, coaches are often concerned about the "side effects" from intensive training periods (e.g., muscle injuries, perceived muscle pain, and chronic fatigue), added to which, their training and recovery practices are extremely affected by congested match schedules [18, 21, 27]. As a consequence, almost all interventions which investigated the potential effects of strength-power training on soccer players were conducted with semi-professional or amateur soccer teams [21]. At the professional level, considerably less information is available about the training approaches used to improve or maintain optimal strength levels. Thus, it remains to be established whether more traditional strength training programs really provide significant benefits to professional soccer players.

The ultimate goal of professional soccer players is to maximize performance during competition [28], where the ability to produce high levels of muscle power is considered of fundamental importance [29]. To date, coaches and researchers have provided some practical recommendations to properly assess power output in soccer players [6, 30]. In fact, it is not possible to determine a single gold-standard measurement since the neuromuscular demands of soccer are multifactorial. The force-vector theory, for example, states that the direction of the force vector applied during resistance exercises (e.g., half-squat or hip-thrust) may play a key role in the development of strength-and power-related abilities [31]. Likewise, during strength-power training sessions, athletes usually execute different types of ballistic exercises, in an attempt to improve their vertical and horizontal-based performance (e.g., vertical jumps and maximum acceleration efforts) [10, 11, 23, 24]. In this regard, by examining changes in counter-movement jump (i.e., [CMJ]; related to vertical force application) and short-sprint abilities (i.e., 10 m time, [T10 m]; related to horizontal force application), we can indirectly evaluate the influence of strength training on the physical performance of professional soccer players [30]. These simple and applied physical tests are considered valid and reliable measures of power and speed [17, 24, 32], and have been shown to be strongly correlated with a number of strength-and power-related variables [29, 33].

We consider that a systematic review of studies conducted with professional soccer players playing in the first division leagues is necessary, especially for guiding practitioners working with this population [21]. This could help coaches to draw more consistent conclusions regarding the actual effects of strength training on the physical qualities of soccer players and, more importantly, to select the best training strategies for their players. Therefore, the aim of this meta-analysis was to determine the effects of different strength training programs on short-sprint and vertical jump performance of professional soccer players who play in the first division leagues of their countries.

Materials and Methods

Procedures

In this investigation a meta-analysis of 13 studies with a total of 29 effect sizes was performed to determine the effects of different strength training programs on jumping and sprinting abilities of professional soccer players who play in the first division of their countries. This study meets the IJSM ethical standards [34]. The following inclusion criteria were employed for the analysis: a) randomized controlled studies, 2) instruments with high validity and reliability, 3) published in a high-quality peer-review journal, 4) professional soccer players playing in the first division of their countries, 5) studies where the strength training was fully described, and 6) studies where CMJ and T10m were measured pre- and post-training.

To evaluate the chronic effects of different strength training protocols on jumping and sprinting performance of professional soccer players, a meta-analysis was conducted. Literature searches were electronically conducted to identify investigations which examined the effects of different strength training protocols applied to professional soccer players on CMJ and T10m. The research assessed the ADONIS, ERIC, SPORTDiscus, EBSCOhost, Google Scholar, Medline, and PubMed electronic databases between December 2020 and January 2021 and was updated in February 2021. Moreover, manual searches were performed in relevant sport science journals. The references of identified articles were examined to identify additional studies eligible for the review. The search included studies published in English and studies in any language for which the abstract was available in English. Key words used included "strength training", "resistance training", "power training", "professional", "top-professional", "elite", "soccer", and "football". No age or sex restrictions were imposed at the search stage.

For the study selection, three steps were followed: 1) the article titles were read, 2) the abstracts were read, and 3) the entire articles were read. In this review, only full primary research papers (i.e. not conference abstracts, letter to the editors, and thesis, or reviews) were eligible for inclusion.

Studies were included if they met the following criteria based on the recommendations by Campbell and Stanley [35]: 1) randomized controlled studies, 2) instruments with high validity and reliability, 3) published in a high quality peer-review journal, 4) professional soccer players playing in the first division of their countries, 5) studies where the strength training was fully described, and 6) studies where CMJ (▶ **Table 1**) and T10m (▶ **Table 2**) were measured pre- and post-training. Following this search process, 13 articles were included in the analysis (▶ **Fig. 1**).

Each article was read and coded by two investigators for the following variables: 1) descriptive information (i.e., age, body-mass, and height), league or competition in which the players participate (i.e., Greek Super league, Champions League, Norwegian Premier League, Brazilian First Division, Morocco First Division, Swedish First Division, China First Division, Ireland First Division); period of the season (i.e., pre-season, in-season, pre-season + in-season); 2)

▶ **Table 1** Summary of characteristics of all studies meeting the inclusion criteria. CMJ.

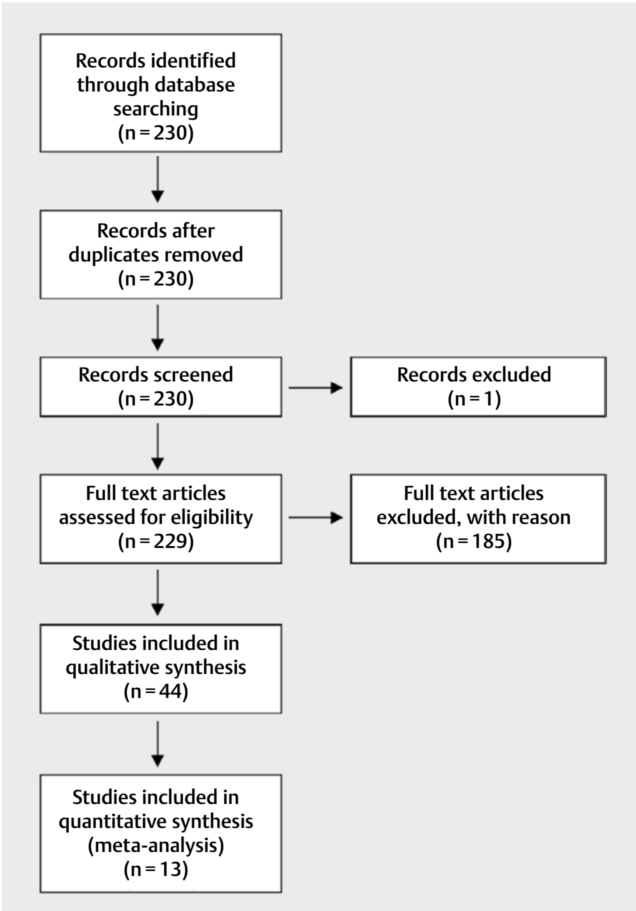
Authors	Year	L	PoS	Gr	n	Age	Bm	H	Wk	FWS	TS	DF	Nexe	Nset	Nrs	TNr	IR	Iex	VC	% CMJ	ES
Koundourakis et al.	2014	Gre	P-I	E	23	25.5	79	182	24	1.5	36	V	3	4	10	4320	4	70-80 RM	No	7.23	0.87
Koundourakis et al.	2014	Gre	P-I	E	22	24.7	80	181	24	1	24	OKC	4	4	5-6	1920	4	90 RM	No	7.48	1.08
Koundourakis et al.	2014	Gre	In	E	23	25.5	79	182	18	1.5	27	V	3	4	10	2160	4	70-80 RM	No	4.03	0.41
Koundourakis et al.	2014	Gre	In	E	22	24.7	80	181	18	1	18	OKC	4	4	5-6	1440	4	90 RM	No	-0.21	-0.02
Helgerud et al.	2011	Cha	Pre	E	21	25	78	184	8	2	16	V	1	4	4	256	3	90 RM	Yes	5.24	0.64
Rønnestad et al.	2008	Nor	Pre	E	6	23	74	180	7	2	14	V	2	3-5	4-6	272	–	85-90 RM	Yes	4.95	2.00
Rønnestad et al.	2008	Nor	Pre	E	8	22	80	186	7	2	14	V-H	5	2-5	4-10	928	–	0-90 RM	Yes	1.94	0.35
Rønnestad et al.	2008	Nor	Pre	C	7	24	81	186	7	–	–	–	–	–	–	–	–	–	–	-0.83	-0.33
Rønnestad et al.	2011	Nor	Pre	E	12	24	80	185	10	2	20	V	1	3	4-10	387	–	80-90 RM	Yes	4.58	1.13
Rønnestad et al.	2011	Nor	In	E	7	22	76	184	12	1	12	V	1	3	4-10	144	–	80-90 RM	Yes	-1.46	-0.15
Rønnestad et al.	2011	Nor	In	E	7	26	83	186	12	0.5	6	V	1	3	4-10	72	–	80-90 RM	Yes	-1.46	-0.14
Loturco et al.	2013	Bra	Pre	E	16	19.2	73	173	6	2	6	V	1	4	4-8	296	2	30-80 RM	Yes	6.70	0.62
Loturco et al.	2013	Bra	Pre	E	16	19.1	72	172	6	2	6	V	1	4	4-8	296	2	30-80 RM	Yes	6.90	0.62
McGawley et al.	2013	Swe	Pre	E	9	23	76	180	5	3	15	V-H	6	2-3	5-10	60	1-1.5	75-90 RM	Yes	7.00	0.83
McGawley et al.	2013	Swe	Pre	E	9	23	76	180	5	3	15	V-H	6	2-3	5-10	60	1-1.5	75-90 RM	Yes	1.90	0.19
Gil et al.	2018	Bra	Pre	E	9	22.8	78	179	6	1	6	V-H	3	2-6	4-6	348	1-3	60 BM	No	15.37	1.80
Gil et al.	2018	Bra	Pre	E	9	22	76	180	6	1	6	V-H	3	2-6	4	348	1-3	60 BM	No	15.44	1.80
Loturco et al.	2017	Bra	Pre	E	7	21.7	74	177	5	2.5	12	V-H	2	4-8	1	1152	–	20-60 BM	No	-2.87	-0.39
Loturco et al.	2017	Bra	Pre	E	11	22.2	76	179	5	2.5	12	V-H	2	4-6	4	1704	–	0-60 BM	No	2.05	0.20
Pareja-Blanco et al.	2017	Mor	In	E	10	23.8	76	174	6	3	18	V	1	2-3	–	–	4	50-70 RM	No	5.34	0.45
Pareja-Blanco et al.	2017	Mor	In	E	10	23.8	76	174	6	3	18	V	1	2-3	–	–	4	50-70 RM	No	-2.62	-0.24
Loturco et al.	2015	Bra	Pre	E	12	23.4	76	178	4	2.5	10	V	1	6	4	372	2	–	Yes	0.37	0.06
Loturco et al.	2015	Bra	Pre	E	11	24.1	76	179	4	2.5	10	V	1	6	4	372	2	–	Yes	-1.24	-0.15
Loturco et al.	2016	Bra	Pre	E	12	23.1	75	176	6	3	18	V	1	6	4	470	1-1.5	30-90 RM	No	11.40	1.41
Loturco et al.	2016	Bra	Pre	E	11	23.9	75	177	6	3	18	V	1	6	6	648	1-1.5	–	Yes	11.50	1.53

L: League or competition in which he participates (Gre: Greek Super league; Cha: Champions League; Nor: Norwegian Premier League; Bra: Brasil First Division Championship; Mor: Morocco First Division Championship; Swe: Swedish First Division 1); PoS: Period of the season (Pre: Pre-season; In: In-season; P-I: Pre-season + In-season) Gr: Group (E: Experimental group; C: Control Group); Bm: Body mass; H: Height; Wk: Weeks program duration; FWS: frequency of weekly sessions; TS: Total sessions;DF: Direction of force applied during the exercise (V:Vertical; V-H: Vertical + Horizontal; OKC: Open Kinetic Chain exercise); Nexe: number of exercise per day; Nset: number of sets per exercise; Nrs: number of repetition per set; TNr: Total number of repetition during the training period; RI:rest intervals; Iex: Intensity of the exercise (RM: One repetition maximum, BM: Body mass) ; VC: Variability of the charge during the training period (Yes/No); CMJ (%); ES: Effects size

▶ **Table 2** Summary of characteristics of all studies meeting the inclusion criteria. T 10m.

Authors	Year	L	PoS	Gr	n	Age	Bm	H	Wk	FWS	TS	DF	Nexe	Nset	Nrs	TNr	IR	Iex	VC	% T 10m	ES
Koundourakis et al.	2014	Gre	P-I	E	23	25.5	79	182	24	1.5	36	V	3	4	10	4320	4	70-80 RM	No	-2.2	-0.66
Koundourakis et al.	2014	Gre	P-I	E	22	24.7	80	181	24	1	24	OKC	4	4	5-6	1920	4	90 RM	No	-2.8	-0.07
Koundourakis et al.	2014	Gre	In	E	23	25.5	79	182	18	1.5	27	V	3	4	10	2160	4	70-80 RM	No	-1,1	-0.33
Koundourakis et al.	2014	Gre	In	E	22	24.7	80	181	18	1	18	OKC	4	4	5-6	1440	4	90 RM	No	0	0
Helgerud et al.	2011	Cha	Pre	E	21	25	78	184	8	2	16	V	1	4	4	256	3	90 RM	Yes	-3.2	-1
Rønnestad et al.	2008	Nor	Pre	E	6	23	74	180	7	2	14	V	2	3-5	4-6	272	1	85-90 RM	Yes	-1.1	-1
Rønnestad et al.	2008	Nor	Pre	E	8	22	80	186	7	2	14	V-H	5	2-5	4-10	928	1	0-90 RM	Yes	-1.7	-1
Rønnestad et al.	2008	Nor	Pre	C	7	24	81	186	7	–	–	–	–	–	–	–	–	–	–	0	0
Loturco et al.	2013	Bra	Pre	E	16	19.2	73	173	6	2	6	V	1	4	4-8	296	2	30-80 RM	–	-1.6	-0.25
Loturco et al.	2013	Bra	Pre	E	16	19.1	72	172	6	2	6	V	1	4	4-8	296	2	30-80 RM	Yes	-4.3	-0.5
McGawley et al.	2013	Swe	Pre	E	9	23	76	180	5	3	15	V-H	6	2-3	5-10	60	1-1.5	75-90 RM	–	-1.4	-0.4
McGawley et al.	2013	Swe	Pre	E	9	23	76	180	5	3	15	V-H	6	2-3	5-10	60	1-1.5	75-90 RM	Yes	-2.2	-0.5
Gil et al.	2018	Bra	Pre	E	9	22.8	78	179	6	1	6	V-H	3	2-6	4-6	348	1-3	60 BM	No	-5.3	-1.3
Gil et al.	2018	Bra	Pre	E	9	22	76	180	6	1	6	V-H	3	2-6	4	348	1-3	60 BM	No	-5.4	-1.3
Loturco et al.	2015	Bra	Pre	E	12	23.4	76	178	4	2.5	10	V	1	6	4	372	2	–	Yes	-0.5	-0.17
Loturco et al.	2015	Bra	Pre	E	11	24.1	76	179	4	2.5	10	V	1	6	4	372	2	–	Yes	-1.1	-0.31
Loturco et al.	2016	Bra	Pre	E	12	23.1	75	176	6	3	18	V	1	6	4	470	1-1.5	30-90 RM	No	-3.3	-0.8
Loturco et al.	2016	Bra	Pre	E	11	23.9	75	177	6	3	18	V	1	6	6	648	1-1.5	–	Yes	-7.1	-2.1
Loturco et al.	2017	Bra	Pre	E	7	21.7	74	177	5	2.5	12	V-H	2	4-8	1	1152	–	20-60 BM	No	-5.7	-2.5
Loturco et al.	2017	Bra	Pre	E	11	22.2	76	179	5	2.5	12	V-H	2	4-6	4	1704	–	0-60 BM	No	-5.17	-1.8
Wong et al.	2010	Chi	P	E	20	24.6	71.4	176	8	2	18	V	4	6	3	72	3	85 RM	Yes	-5.8	-5.5
Wong et al.	2010	Chi	P	C	19	21	63.7	173	8	0	0	0	0	0	0	0	0	0	No	0	0
Mc Morrow et al.	2019	Ire	I	E	7	24.7	80.6	180	6	2	10	V-H	1-6	2-9	6	4	1-5	85-95 RM	Yes	-4	-1.06
Mc Morrow et al.	2019	Ire	I	E	6	24.7	80.6	180	6	2	10	V-H	1-6	2-9	6	4	1-5	85-95 RM	Yes	-5	-1.31

L: League or competition in which he participates (Gre: Greek Super league; Cha: Champions League; Nor: Norwegian Premier League; Bra: Brasil First Division Championship; Swe: Swedish First Division 1; Chi: China First División; Ire: Ireland First Division); PoS: Period of the season (Pre: Pre-season; In: In-season; P-I: Pre-season + In-season) Gr: Group (E: Experimental group; C: Control Group); Bm: Body mass; H: Height; Wk: Weeks program duration; FWS: frequency of weekly sessions; TS: Total sessions; DF: Direction of force applied during the exercise (V:Vertical; V-H: Vertical + Horizontal; OKC: Open Kinetic Chain exercise) ; Nexe: number of exercise per day; Nset: number of sets per exercise; Nrs: number of repetition per set; TNr: Total number of repetition during the training period; RI:rest intervals; Iex: Intensity of the exercise (RM: One repetition maximum, BM: Body mass); VC: Variability of the charge during the training period (Yes/No); T 10m (%); ES: Effects size



▶ **Fig 1** Flow of study selection.

training exercises: direction of force applied (vertical, vertical + horizontal, or open kinetic chain movements), variability of loads throughout the training period (yes or no); 3) training variables and content: program duration in weeks, frequency of weekly sessions, total training sessions, number of exercises per day, number of sets per exercise, number of repetitions per set, total number of repetitions during the training period, rest intervals, and exercise intensity. Mean agreement was calculated using the intraclass correlation coefficient (ICC). The coding agreement between investigators was determined by dividing the variables coded by the total number of variables. The mean agreement between coding for this study was 0.90. A mean agreement of 0.90 is accepted as an appropriate level of reliability for such procedures [36]. Any coding differences between investigators were scrutinized and resolved before the analysis.

Gain effect size (ES) was calculated using the Hedges' g and Olkin's formula (1):

$$g = (M_{post} - M_{pre}) / SD_{pooled},$$

where Mpost is the mean for the post-test, Mpre is the mean for the pre-test, and SDpooled is the pooled SD of the measurements (2):

$$SD_{pooled} = \frac{(M_{post} - M_{pre})}{\sqrt{((n_1 - 1) \cdot SD_1^2 + (n_2 - 1) \cdot SD_2^2) / (n_1 + n_2 - 2)}}$$

The ES is a standardized value that permits the determination of the magnitude of the differences between the groups or experimental conditions. It has been suggested that the ES should be corrected for the magnitude of the sample size of each study[35]. Therefore, corrections were performed using the formula (3):

$$1 - 3 / (4m - 9),$$

where m = n -1, as proposed by Hedges and Olkin [36].

Statistical analyses

To determine the effects of the categorical independent variables (league or competition in which players participated, period of the season, and programmed exercises [direction of force applied during the exercise, variability of the load during the training period (yes or no)], on CMJ and T10m effect sizes (ES), an analysis of variance (ANOVA) was employed. In the case of quantitative independent variables (e.g., age, body-mass, height, program duration in weeks, frequency of weekly sessions, total sessions, number of exercises per day, number of sets per exercise, number of repetitions per set, total number of repetitions during the training period, rest intervals, and exercise intensity) a Pearson's (r) correlation test was used to examine the relationships between CMJ ES and T10m ES, and the descriptive information of players and training variables. The level of significance was set at $p \le 0.05$. In addition, data were also assessed for clinical significance using an approach based on the magnitude of the changes. Threshold values for assessing magnitudes of ES were < 0.35, 0.35–0.80, 0.80–1.50, and > 2.0 for trivial, small, moderate, and large, respectively [37].

Results

The analysis demonstrated that there were no statistical differences between average ES of the experimental (0.10 ± 1.24; n = 44) and control groups (0.11 ± 0.19; n = 3), for the two assessed variables (i.e., CMJ and T10m) (p = 0.986).

CMJ

There were no significant differences (p = 0.2) between average ES in the experimental (ES = 0.62; n = 24) and control groups (ES = −0.33; n = 1) when examining the CMJ performance. Similarly, regarding subjects' characteristics, the results indicated that there were no significant correlations for age, body-mass, or height and the CMJ ES magnitude (▶**Table 3**). ANOVA results revealed a possible effect for some of the assessed variables (i.e., period of the season, p = 0.063; ▶**Table 4**). No significant relationships were detected between the training program variables with CMJ ES (▶**Table 5**).

▶ **Table 3** CMJ (cm). Analysis for independent variables of subject characteristics.

Independent Variables	**% of change ± *SD***	***F***	**Level**	**ES**	***SD***	***n***	***r***	***p***
Subject Characteristics								
Age (y)						24	−0.059	0.758
Body mass (kg)						24	−0.087	0.685
Height (cm)						24	−0.038	0.861
League		*F*(5,18) = 0.245	*p* = 0.937					
Greece	4.63 ± 3.59			0.58	0.49	4		
Champions League	5.24			0.64	–	1		
Norway	1.71 ± 3.11			0.63	0.92	5		
Brazil	6.56 ± 0.77			0.75	0.82	10		
Sweden	4.45 ± 3.60			0.51	0.45	2		
Morocco	1.36 ± 5.62			0.10	0.48	2		
Period of the season		*F*(2,21) = 3.157	*p* = 0.063					
Pre-Season	5.7 ± 5.4			0.79	0.74	16		
In-Season	0.6 ± 3.2			0.05	0.30	6		
Pre-Season + In-Season	7.3 ± 0.17			0.97	0.14	2		

ES = Effect size; n = sample; Level = alpha level; r = Pearson Correlation coefficient; p = alpha level * p < 0.05, * * p < 0.01

▶ **Table 4** CMJ (cm). Analysis of variance results on the differences of ES between various elements of eccentric training independent variables of program elements.

Independent Variables	**% of change ± *SD***	***F***	**Level**	**ES**	***SD***	***n***	***r***	***p***
Program Exercises								
Direction of force applied during the exercise		*F*(2,21) = 0.044	*p* = 0.957					
Vertical	4.09 ± 4.51			0.60	0.68	15		
Vertical + Horizontal	5.83 ± 7.1			0.68	0.84	7		
Open Kinetic Chain Exercise	3.63 ± 5.4			0.53	0.77	2		
Variability of the charge during the training period		*F*(1,22) = 0.843	*p* = 0.368					
Yes	3.06 ± 4.10			0.50	0.67	14		
No	6.66 ± 6.16			0.77	0.75	10		

ES = Effect size; n = sample; Level = alpha level; r = Pearson Correlation coefficient; p = alpha level. * p < 0.05, * * p < 0.01.

T10m

There were no significant differences (p = 0.2) between average ES in the experimental (ES = −0.97; n = 20) and control groups (ES = 0.0; n = 2) when examining the T10m. Regarding the subjects' characteristics, the results indicated that there were no significant correlations for age, body-mass, or height and the T10m ES magnitude (▶ **Table 6**). However, ANOVA results revealed significant effects for certain variables analyzed (i.e., League, p < 0.000; ▶ **Table 7**). The league analysis demonstrated that the average ES in the China First Division (ES = −5.5; n = 1) was significantly higher (p < 0.05) than the ES observed in other leagues (ES ranging from −0.26 to −1.18). No significant relationships were noted between training program variables and T10m ES (▶ **Table 8**).

Discussion

The objective of this review was to determine the chronic effects of different strength training protocols on short-sprint and vertical jump performance in professional soccer players playing in the first division of their countries. The main findings from this review were: a) the distinct strength training programs analysed here produced similar performance improvements, regardless of their specific characteristics (i.e., training exercises, volume, and intensity), and they were not significantly different from the improvements exhibited by the control groups; b) the different strength training protocols appear to have a lower effect when applied during in-season phases than when applied during pre-season and/or inter-season periods.

The most commonly used exercises in the different strength programs for the "vertical direction" were the back squat [8–11, 17–22] and the jump squat (JS) [8, 17, 18, 20, 23, 24]; and for the "horizontal direction" the resisted sprints (i.e., sled towing) [23–25] and unloaded horizontal jumps [10, 24]. Curiously, there were no significant differences in performance improvements between protocols that used exercises with different directions (i.e., vertical or horizontal) of force application during the training sessions (▶ **Tables 4** and **7**). The first study that addressed this topic in professional soccer players (Norwegian Premier League) was conducted by Ronnestad et al. [10], who examined the chronic effects of training under vertical or vertical-horizontal training schemes. These authors compared, throughout a pre-season period, a 6-week training protocol composed of two sessions per week, based on 3–5 sets of 4–6 repetitions of vertically-oriented exercises (e.g., half squats) at 85–90 % 1RM with a similar protocol combined with 2–4 sets of 5–10 repetitions of vertically-horizontally-oriented exercises (i.e., alternate leg bound, double leg hurdle jump, and single leg forward hop), and with a control group. There were no significant effects of time for CMJ (from 1.94 to 4.95 %) and T10m (from -1.1 to -0.7 %) and no significant differences between groups for any other performance variables. Subsequently, the authors pooled the two groups into the same experimental group, who showed a significantly higher increase than the control group in the T10m. Similarly, Koundourakis et al. [9] (Greek Super league soccer players), compared vertically-oriented vs. open kinetic chain exercises during the pre-season, the first half of the season (24 weeks), and the second half of the season (throughout 18 weeks): the first protocol was based on 1-2 sessions per week of 4 sets of 10 repetitions of circuit strength training using vertical exercises (e.g., lunge, squats, steps up on bench with external weight) at 70-80 % 1RM; and the second protocol was based on 1 session per week of 4 sets of 10 repetitions of open kinetic chain movements (e.g., leg extension, hamstring curl) at 90 % 1RM. Both groups showed increases in CMJ (from 7.2 to 7.5 %) and decreases in T10m (from -2.2 to 2.8 %) from the beginning of the pre-season to the end of the first half of the season. During the second half of the season, only the vertically-oriented protocol produced increases in CMJ (4.3 %) and T10m (from -2.2 to 2.8 %), but there were no significant differences for the open kinetic chain group. Nevertheless, the strength training schemes which used vertically-horizontally-oriented exercises obtained a non-significantly higher CMJ mean of 5.83 % [10, 11, 23, 24] and a lower T10m mean of -3.57 % [10, 11, 23–25], compared to the training scheme using solely vertically-oriented exercises (CMJ mean = 4.09 %) [8–10, 17–19, 21, 22] and T10m mean = -2.85 % [8–10, 17, 18, 20, 21]), and to the program using only open kinetic chain exercises (CMJ mean = 3.63 % and T10m mean = -1.4 %)[9] (see ▶ **Tables 4** and ▶ **7**). In fact, the different combinations of exercises used to design these protocols (i.e., vertically- or horizontally-oriented exercises) and the variations in loading strategies (e.g., resisted sprints and horizontal-vertical jumps) could provide more comprehensive and effective mechanical stimuli to improve neuromuscular performance in profes-

▶ **Table 5** CMJ (cm). Pearson correlation coefficients (r) between various program elements and training gains.

Training Program Variables	*n*	*r*	*p*
Frequency session/week	24	−0.094	0.663
Program duration (wk)	24	−0.009	0.968
Total of session	24	0.061	0.775
Number of exercises per day	24	0.075	0.729
Min number of sets per day	24	−0.058	0.789
Max number of sets per day	24	0.172	0.422
Min number of rep. per set	22	0.137	0.543
Max number of rep. per set	22	−0.248	0.265
Total of repetitions	22	−0.048	0.833
Min intensity of the exercise	21	−0.022	0.925
Max intensity of the exercise	21	−0.224	0.329
Rest	19	−0.228	0.347

n = sample; r = Pearson Correlation coefficient; p = alpha level
$^{*}p<0.05$, $^{**}p<0.01$

▶ **Table 6** T10m (s). Analysis for independent variables of subject characteristics.

Independent Variables	% of change ± *SD*	*F*	Level	ES	*SD*	*n*	*r*	*p*
Subject Characteristics								
Age (y)						22	−0.075	0.741
Body mass (kg)						22	0.410	0.058
Height (cm)						22	−0.229	0.305
League		*F*(6,21) = 8.847	*p* = 0.000**					
Greece	−1.54 ± 1.24			−0.26	0.30	4		
Champions League	−3.21			−1	–	1		
Norway	−1.41 ± 0.38			−1	0	2		
Brazil	−3.95 ± 2.22			−1.1	0.82	10		
Sweden	−1.8 ± 0.56			−0.45	0.07	2		
China	−5.8			−5.5	–	1		
Ireland	−4.52 ± 0.67			−1.18	0.17	2		
Period of the season		*F*(1,19) = 0.398	*p* = 0.677					
Pre-Season	−3.18 ± 1.9			−1.25	1.38	14		
In-Season	−2.54 ± 2.36			−0.67	0.61	4		
Pre-Season + In-Season	−3.86 ± 2.2			−0.91	0.85	4		

ES = Effect size; n = sample; Level = alpha level; r = Pearson Correlation coefficient; p = alpha level $^{*}p<0.05$, $^{**}p<0.01$

▶ **Table 7** T10m (s). Analysis of variance results on the differences of ES between various elements of eccentric training independent variables of program elements.

Independent Variables	% of change ± *SD*	*F*	Level	ES	*SD*	*n*	*r*	*p*
Program Exercises								
Direction of force applied during the exercise		*F*(2,19) = 0.867	*p* = 0.436					
Vertical	−2.85 ± 2.13			1.14	1.54	11		
Vertical + Horizontal	−3.99 ± 1.74			−1.24	0.63	9		
Open Kinetic Chain Exercise	−1.4 ± 1.98			−0.03	0.04	2		
Variability of the charge during the training period		*F*(1,20) = 1.463	*p* = 0.242					
Yes	−3.12 ± 2.12			−1.23	1.44	12		
No	−3.26 ± 2.01			−0.90	0.81	10		

ES = Effect size; n = sample; Level = alpha level; r = Pearson Correlation coefficient; p = alpha level * p < 0.05, * * p < 0.01

▶ **Table 8** T10m (s). Pearson correlation coefficients (r) between various program elements and training gains.

Training Program Variables	*n*	*r*	*p*
Frequency session/week	22	−0.116	0.608
Program duration (wk)	22	0.239	0.285
Total of session	22	0.25	0.911
Number of exercises per day	22	0.056	0.805
Min number of sets per day	22	0.015	0.947
Max number of sets per day	22	−0.238	0.287
Min number of rep. per set	22	−0.080	0.725
Max number of rep. per set	22	0.354	0.106
Total of repetitions	22	0.172	0.445
Min intensity of the exercise	22	0.057	0.817
Max intensity of the exercise	22	0.217	0.372
Rest	22	−0.026	0.913

n = sample; r = Pearson Correlation coefficient; p = alpha level
* *p* < 0.05, * * *p* < 0.01.

sional soccer players. This argument certainly requires deeper analysis.

Loturco et al. [24] (Brazilian First Division Championship) compared a training protocol of twelve training sessions in 5 weeks, based on 6 sets of 6 repetitions of JS performed at the optimum power load (i.e., the load that maximizes power output), combined with 6-8 sets of 6 repetitions of horizontal jumps and CMJ, with the same JS protocol mixed with 6–8 sets of resisted sprints (i.e., 20-30m) with 5–20 % body mass overload. The training that combined JS and horizontal-vertical jumps increased the CMJ (2 %), with substantial differences from the training that combined JS and resisted sprints (-2.9 %). The training that combined JS and resisted sprints showed no significant differences from the training that combined JS and horizontal-vertical jumps in T10m. These results are in accordance with the force-vector theory, where one group used more vertically-oriented exercises than the other, which could play a crucial role in increasing CMJ performance [31]. Equally, previous investigations have shown that horizontal plyometrics and resisted sprints improve short-distance acceleration performance (i.e.,T10m) [38]. In fact, recently, McMorrow et al. [25] (Ireland First Division) showed similar results combining the front squat exercise with 20m resisted sprint (T10m -4–5 %); therefore, it is not a surprise that the T10m performance could be similar in both groups. Nevertheless, Gil et al. [23] (Brazil First Division Championship) implementing a training scheme similar to that proposed by Loturco et al.[24] found higher CMJ (15 %) and T10m (-5 %) performance. Briefly, the training protocol was based on 6 weeks, one session per week, including: (1) 4–6 sets of 6 repetitions of JS with 60 % of body mass, (2) 2–4 sets of 7-m linear sprint, and (3) 2-4 sets of change of direction drills. During the 7-m linear sprint, one of the groups executed resisted sprints (VertiMax, Model V8, Genetic Potential, Tampa, Florida) with an overload capable of reducing sprint velocity by 10 % (compared to the unresisted condition). There were no significant differences between groups in any assessed variable. In agreement with Loturco et al. [17], both groups performed the ballistic JS, which appeared to be more indicated for developing the kinematic aspects of both jump- and speed-related capacities (at least for professional soccer players). The main difference was that Loturco et al. [24] used as overload the “optimum power load”, while Gil et al. [23] used 60 % of the body-mass of each player as a fixed overload. Accordingly, Loturco et al. [18] (Brazil First Division Championship) revealed that training continuously at the “optimum power zone” and training under different %1RM (i.e., “traditional” strength-power periodization) produced significant increases in CMJ (11.5; 11.4 %) and T10m (-7.1 %; -3.3 %); respectively, without differences between groups. However, delta change scores demonstrated a superior effect of optimum power loads to improve T10m. The strength training protocol proposed by Loturco et al. [18] comprised 4 weeks, 3 sessions per week, 6 sets of 10-4 repetitions of half squat from 60 % to 90 % 1RM or optimum power load; and two weeks, 6 times per week, 6 sets of 6 repetitions of JS at 30 % 1RM or optimum power load. The results obtained in that study [18] are nearer to those obtained by Gil et al. [23] and those obtained by Loturco et al. [24]. Both studies used the JS with overload at approximately 30 % 1RM, and their results were higher than other studies that used half squat or JS with loads higher than 30 %1RM [8–10, 17, 19, 21, 22]. For example, Loturco et al. [17] (Brazilian First Division Championship) did not find differences between half squat and JS training protocols under optimum loading conditions, and the authors reported changes in CMJ from -1.24 to 0.37 % and in T10m from -0.5 to-1.1 %, in 10 training sessions during a 4-week pre-season period, based on 6 sets of 4-8 repetitions of each exercise. Equally, Loturco et al. [8] (Brazil First Division Championship) obtained better results when combining JS and half squat in the same strength training protocol, in a study that compared the effects of “increasing” or “decreasing” exercise velocity within a 6-week training period. Both groups demonstrated increases in CMJ (6.70; 6.90 %) and decreases in T10m (-1.6; -4.3 %), without differences between groups. Specifically, the protocol used was composed of 3 weeks, 2 days per week, and based on 4 sets of 6-8 repetitions of back squat with 50–80 % 1RM overload, followed by 3 weeks comprising 4 sets of 4–6 repetitions of JS increasing or reducing the exercise velocity with loads ranging from 30 % to 60 %1RM. Pareja-Blanco et al. [22] (Morocco First Division Championship) using a half squat with overloads between 50 and 70 % 1RM, during 6 weeks, three sessions per week, based on 2–3 sets of 4 repetitions, obtained similar results in CMJ performance (5.34 %). Helgerud et al. [21] (Champions League soccer players), when increasing the training intensity to 90 % 1RM overload, showed increments in CMJ (5.2 %) and decrements in T10m (-3.2 %) after 8 weeks, two sessions per week, using 4 sets of 4 repetitions of half squats. Therefore, it seems that lighter intensities may provide improvements towards the high-velocity end of the force-velocity spectrum, and it is possible to speculate that in strength training protocols, during vertically-oriented exercises, overloads ~30 % 1RM could optimize jumping and sprinting performance in professional soccer players. However, we need to consider that the majority of the protocols that used an overload of around 30 % 1RM were preceded by a strength training foundation based on overload above 30 % 1RM [8]. Although there is evidence that this strength training foundation is not able to “increase” the transference of maximum strength capacity to the ability to produce force at higher velocities in elite soccer players [18], more studies are clearly required to corroborate this notion.

Our analysis revealed a possible effect for the period of the season in which the strength training was performed (see ▶ **Table 4**). Ronnestad et al. [19] (Norwegian Premier League), were the first authors to investigate the effects of strength training in different season periods. These authors proposed a training protocol during a pre-season of 10 weeks, two sessions per week, with 3 sets of 4–10 repetitions of vertically-oriented exercises (i.e., half squats), with 80-90 % RM overload. During the next 12 weeks (in-season phase), the authors compared the effects of applying this training protocol once a week versus every two weeks. The results showed increments in CMJ (4.58 %) during the pre-season period. During the in-season period, the values of CMJ height were reduced (-1.46 %) in both groups. These results agreed with those obtained by Koundourakis et al. [9] for the group who performed 1 session per week of 4 sets of 10 repetitions of open kinetic chain exercises (e.g., leg extension, hamstring curl), with 90 % RM overload (CMJ: -0.21 %). However, the group who performed a circuit strength training program composed of 1–2 sessions per week of 4 sets of 10 repetitions of vertically-oriented exercises (e.g., lunge, squats, steps up on bench with external weight), from 70 to 80 % 1RM, improved the CMJ performance by 4 %. This phenomenon could be better elucidated when examining the high physical and physiological demands and the very congested fixture schedules usually imposed by elite soccer leagues. Indeed, during the in-season period, there are increased demands of aerobic-based activities (e.g., technical-tactical training and official matches), which may hamper the proper development of strength-power capacities [39, 40]. In this regard, the strength training seems to work more as an effective strategy to maintain the strength-power levels achieved during the preparatory phases (being unable to elicit substantial gains in sprint and jump performance) [19]. For example, it is possible that heavy strength training, as proposed by Ronnestad et al. [19], once a week, is sufficient to maintain the initial strength gains obtained by professional soccer players during preparatory phases, but only when the resistance training sessions are applied at least once a week. Still in this context, it could be possible that the mixed strength-speed training protocol proposed by Koundourakis et al. [9], applied 1–2 times a week, was a more effective stimulus for these players, increasing CMJ and T10m performance, while avoiding excessive training load and insufficient recovery.

Interventions with professional soccer players present two evident problems: the lack of control over some aspects of the intervention and the nonexistence of control groups that receive the same attention from the coaching staff during the intervention [21]. It is surprising that the majority of the proposed strength training protocols improved athletic performance but did not present significant differences from the players who did not perform a specific strength-training protocol. As mentioned above, this could be partially explained by the concurrent effects of endurance and strength-power adaptations, which typically occur during congested soccer seasons and pre-seasons [17, 19–21, 24]. However, there are studies showing that regular technical-tactical training sessions and high intensity interval running can be simultaneously performed with strength training in order to enhance the strength and endurance capacities of professional soccer players [11, 20, 21]. Accordingly, McGawley et al. [11] (Swedish First Division) analyzed the effects of performing a physical training program 3 times per week during a 5-week preseason on some soccer-specific variables and compared the impacts of completing high intensity training (HIT) and strength-power training sessions in different orders within the same session. The authors observed a positive effect of the concurrent training approach on key measures of soccer performance (increased CMJ from 1.9 to 7 % and T10m from -1.4 to 2.2 %), but the order of completing HIT and strength-power training seemed not to affect performance adaptations. Equally, Wong et al. [20] proposed training protocols where high intensity interval running was concurrently performed with heavy strength training based on 8 weeks, two sessions per week, comprising 4 sets of 6 repetitions of vertically-oriented exercises (i.e., half squats and jump squats) at 85 %1RM, with a 3-min recovery. The professional soccer players presented decreases in T10m time (~6 %) and increases in aerobic capacity with significant differences compared to the control group. Therefore, additional studies are still needed to better elucidate the influence of concurrent training practices on the physical performance of professional soccer players.

In general, researchers suggest that the lack of differences between experimental and control groups commonly found after strength training interventions in soccer players may be due to inadequate (low) volumes and frequencies of resistance training sessions throughout the professional soccer seasons, especially when compared to the total training content [8, 10, 17, 24]. In fact, it is widely known that the specific soccer training (i.e., technical-tactical sessions) places competing demands on complementary training sessions [11], which may compromise the proper development of speed- and power-related performance. Therefore, at least for the moment, it appears that the only practical solution is to search for more time-efficient strength and power training strategies, which are viable and effective in real soccer scenarios.

Conclusions

After examining the data available in the literature, it is possible to infer that strength training – in the way it has been applied - may have a limited impact on the short-sprint and jump performance of elite soccer players. The congested fixture schedules and the high-volume of soccer-specific training usually performed by these players during some specific training phases likely contribute to these “reduced effects”. Coaches and sport scientists are advised to prioritize time-efficient training strategies as well as to use any available time (e.g., warm-up sessions) in an attempt to maximize the strength development of elite soccer players, since an increased number of matches, journeys, and training sessions are commonplace in modern soccer.

Conflict of Interest

The authors declare that they have no conflict of interest.

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