Acta Kinesiologica 18 (2024) Issue.1
DOI. 10.51371/issn.1840-2976.2024.18.1.5

Original Investigation

The effects of resisted sprint training programs on vertical jump, linear sprint and change of direction speed in male soccer players: A systematic review and meta-analysis

Elena Mainer-Pardos[a*], Sara Mahmoudzadeh Khalili[b], Oscar Villanueva-Guerrero[a], Filipe Manuel Clemente[c,d] , Hadi Nobari[e,f]
[a] Health Sciences Faculty, Universidad San Jorge, Autov A23 km 299, Villanueva de Gállego, 50830 Zaragoza, Spain
[b] Department of Health and Sport Rehabilitation, Faculty of Sport Sciences and Health, Shahid Beheshti University, Tehran, Iran
[c] Instituto de Telecomunicações, Delegação da Covilhã, Lisboa, Portugal
[d] Escola Superior Desporto e Lazer, Instituto Politécnico de Viana do Castelo, Viana do Castelo, Portugal
[e] Department of Exercise Physiology, Faculty of Educational Sciences and Psychology, University of Mohaghegh Ardabili, Ardabil, Iran
[f] Faculty of Sport Sciences, University of Extremadura, Cáceres, Spain

ABSTRACT: This systematic review with meta-analysis aimed to observe the effects of resisted sprint training (RST) on jump ability, linear sprint, and change of direction speed (CODS) performance in male soccer players. PubMed, Web of Science, Google Scholar, and SportDiscus electronic databases were used as information resources from interception until 30 October 2023. A PICOS (participants, intervention, comparators, outcomes, and study design) approach was used to rate studies' eligibility. The results of the overall effects on RST showed a significant and moderate improvement between pre- and post-test on full sprint time [effect size (ES) -0.85 (95% confidence interval (CI) – 1.62, -0.09), Z=2.20 (*P*= .03)]. Resisted sprint training was associated with significant moderate improvement in CODS [ES -0.92 (95% CI – 1.63, -0.20), Z=2.51 (*P*= .01)]. Pooled effects of RST on vertical jump height performance showed small and not significant improvements between pre- and post-test [ES 0.28 (95% CI – 0.17, 0.73), Z=1.23 (*P*= .22)]. Also, regarding the moderator variables, the subgroup analysis suggested high levels of between-group heterogeneity only with session volume in sprint time and CODS performance. Resisted sprint training effectively enhances linear sprint time and CODS performance in male soccer players, whereas this improvement was not significant for vertical jump height.

Keywords: football, performance, sprint-running, agility, bio-motor ability

Introduction

Soccer is a highly demanding sport where most of the maximum high-intensity during a game are ballistic movements constituting eccentric factors such as running, accelerating, change of direction speed (CODS), and jumping [1,2]. Hence, superior physical performance andskills are needed for the continuous development of soccer players [3]. In this regard, power and linear sprint speed are relevant elements in soccer-specific physical performance [4,5], and they must be developed with appropriate strength, power, speed, and agility training programs [6]. As for sprinting, it must be noted that elite soccer players reach the maximum intensity while running over 15 m during competitions [7]. Furthermore, about 1-11% of the distance covered in a soccer game includes sprinting, which represents 0.5-3.0% of the sufficient game time [8], and most sprints are shorter than 20 m [9]. Likewise, most sprints leading to a goal are linear [10]. This reflects the importance of strength and power as key performance determinants. For this reason, vertical jump has been used to assess the power of leg muscles in soccer [11,12], and an association between vertical jump and sports performance has been found [13,14]. However, Lockie et al. suggest that while the vertical jump remains a valuable tool, the inclusion of additional parameters such as the rate of force development (RFD) and mechanical power outputs may provide a more comprehensive understanding of a soccer player's power skills [15]. This broader perspective is increasingly recognized for its potential to more accurately reflect the multifaceted nature of soccer performance. The role of vertical jump in physical activities during soccer practice —like defending situations and heading—highlights the importance of this skill in soccer players [16]. However, since soccer is also a multidirectional sport [17], players are primarily involved in rapid changes of direction (COD). Therefore, agility is also essential to soccer [18,19]. Agility is defined as the ability to change the body direction quickly while sprinting, and it is also known as change of direction speed (CODS) [20]. Change of direction speed represents the ability of athletes to decelerate and accelerate in a new direction during a short time while running [21]. Therefore, linear sprints, jumps, and CODS are fundamental components for soccer players' performance [10,22] that can be developed with various training exercises [23].

In this sense, resisted sprint training (RST) has been revealed as an effective training modality where athletes attempt to sprint against an added overload and repeat the motor pattern of sprinting [24,25]. Resisted sprint training can be performed using different load directions [26], and it is one of the most prevalent and most investigated methodologies in sports training [27]. Resisted sprint training can be executed in two forms: pulling and pushing. Sled pulling is the most common version to improve sprint speed and acceleration performance [25]. The differences are in terms of force application, friction, size, and shape, which can change the mechanics and training outcomes [27]. This kind of training can also be performed with light, moderate, heavy, and very heavy loads based on the resistance used (<10.0%; 10-19.9%; 20.0-20.9%; or >30.0% of body mass, respectively) [25]. Moreover, RST is an efficient training method for developing sprints, especially in the initial acceleration phase (≤10 m). However, the optimal workload for RST has yet to be established. The load should be adjusted according to the objectives of the exercise [24]. In this training modality, the sled is attached to the athletes' chest or waist with a harness and cord [24], and the additional resistance is mainly caused by the friction between the running surface and the sled base [25].

The physical demands of soccer require maximal physical capabilities encompassing speed, explosive power and COD. It is well known that RST training could be instrumental in improving these physical attributes, especially concerning sprint acceleration and maximal velocity [24,25,28]. In the current scientific literature, research has been conducted on athletes with other tools such as parachutes or hills [29-31], but there is a lack of knowledge in the field of soccer.

Indeed, recent studies have indicated the efficacy of RST in improving various physical performance metrics, such as sprint performance, jumping, and strength [32-34]. In a similar context to soccer, RST, particularly with sled towing, has attracted considerable interest in sport science, particularly because of its potential acute and chronic effects on team sport athletes [35]. However, no consensus has yet been reached on its overall effects on sprinting techniques, neuromuscular aspects, force production, and muscle architecture considerations in resisted versus unresisted conditions [25,35]. Nuances associated with equipment (sled or vest) and the magnitude of resistive loading, e.g., above or below 20% of body mass, further complicate these findings, pointing to a compelling need for more specific analysis [28]. Another tool used in resisted sprints is the weighted vest, which has been shown to improve sprint speed but there is a lack of information in the scientific literature about volume and optimal loading [36].

Systematic reviews in this field have been crucial in bringing together the evidence on the effects of RST, but few are explicit for soccer players or focus solely on younger players [24,25,28]. Previous analyses have predominantly focused on the effect of RST on sprint performance, often neglecting fundamental aspects intrinsic to soccer, such as change of direction speed (CODS) and vertical jumping ability [24,25,28]. The added value of this systematic review lies in its comprehensive approach, the identification and addressing of gaps in the scientific literature, and its practical applicability. These elements contribute significantly to the advancement of scientific knowledge in the field of resisted sprint training in male soccer players.

The present systematic review and meta-analysis aims to fill these existing gaps by focusing on male soccer players. It aspires to provide a holistic understanding of the effects of RST on linear sprinting, CODS and vertical jumping ability, which are key performance variables in this sport. Improvements in these areas can have a positive impact on soccer players, coaches and physical trainers, potentially boosting game performance and influencing team success. Thus, this systematic review and meta-analysis aimed to examine the effects of RST on linear sprint, CODS, and vertical jump ability in male soccer players.

Methods

A systematic review and meta-analysis were carried out following with the Cochrane Collaboration's guidelines [37].The Preferred Reporting Items guided this meta-analytical review for Systematic Reviews and Meta-Analyses (PRISMA) statement [38]. The inclusion and exclusion criteria for the investigations were established using the PICOS methodology Table 1). PROSPERO, the prospective international register of systematic reviews was used to register the protocol (CRD42021248975).

Search strategy and quality assessment of studies

The Web of Science, SportDiscus, Google Scholar, and US National Library of Medicine (PubMed) electronic databases were used until 30 October 2023. Only articles written in English and Spanish were taken into account. We utilized the search terms and applied the Boolean logic: ("male" OR "men") AND ("soccer" OR "football") AND ("intervention" OR "training") AND ("Resisted sprint" OR "towing" OR "pulling" OR "sled") AND ("change of direction" OR "agility" OR "jump" OR "sprint"). All relevant article titles were reviewed before looking at article abstracts and then completing published papers to determine which studies should be included.. The meta-analysis included only peer-reviewed articles, and two authors carried out the procedure separately. Finally, possible differences in opinion concerning the study conditions between the two reviewers were settled by agreement with a third author. Figure 2 presents the search procedure.

Following the guidelines of the Cochrane Collaboration, randomized-controlled trials studies were evaluated using Version 2 of the Cochrane Tool for assessing the risk of bias in randomized trials (RoB 2; [39,40] and for nonrandomized-controlled trials, the Risk of Bias in Non-Randomized Studies of Interventions tool (ROBINS-I; [39]) was used. A total level of risk of bias for each study was calculated. The manuscripts were rated independently by two authors, and a discussion was used to settle differences in the writers' ratings.

Study selection criteria

The PICOS method was used to assess the eligibility of the studies [38]. Table 1 shows the relevant inclusion/exclusion criteria used in our meta-analysis.

Data extraction and outcome measures

In selecting studies for inclusion, a review of all relevant article titles was conducted before examing article abstracts and then full-published articles. Two authors conducted the process independently. Potential discrepancies between the two reviewers about study conditions were resolved by consensus with a third author. Full-text articles excluded, with reasons, were recorded. Data were extracted from gathered articles by two authors independently, using a form created in Microsoft Excel (Microsoft Corporation, Redmond, WA, USA). Two reviewers undertook the data extraction from gathered articles.

Three main outcomes were considered for extraction: (i) vertical jump, (ii) linear sprint, and (iii) CODS test.

Vertical jump was commonly evaluated using the countermovement jump (CMJ) test, with and without arm swing. The linear sprint over various distances was recorded, along

Table 1. Inclusion and exclusion criteria.

Category	Inclusion Criteria	Exclusion Criteria
Population	Cohorts of professional or amateur male soccer players of 18 years or older.	Studies having only female or both genders.
Intervention/Exposure	Resisted sled and sprinting training method.	Exercise interventions not involving sled towing and sprinting programs; combined sled training with strength, plyometric or change of direction speed exercises.
Comparator	Active control group or another experimental group.	Absence of active control group or another experimental group.
Outcome	At least one measure of physical fitness (linear sprinting, jumping, and change of direction speed) before and after the training intervention.	Lack of baseline and/or follow-up data.
Study design	Randomized/Nonrandomized controlled trial.	Cross-sectional study.
Other	Only original and full-text studies written in English or Spanish. Measures that were analysed three or more times for different articles were included.	Not written in English or Spanish. Non-original, full research articles (e.g., reviews, letters to editors, trial registrations, proposals for protocols, editorials, book chapters, and conference abstracts). Measures that were analysed two or less times for different articles were included

with partial time values. The CODS time was usually measured at zigzag, V-cut, or L-run tests. In addition, the following details were taken from the studies that were included: (i) participants (n), age (years), body mass (BM) (kg), height (cm), and competitive level; (ii) intervention period (weeks), sessions per week, and total sessions; (iii) regimen of intervention (if available): distance covered per sprint (m), volume per session range (m), a total distance of all sessions (m), and sled load (% BM).

For the acceleration phase subgroup analysis, the time it took to cover a maximum of 10 meters was used in studies. For the subgroup analysis of the entire sprint, studies that included the time required to cover a distance of at least 20 meters were used.

Statistical Analyses

RevMan version 5.3 was used for meta-analytical comparisons [41]. Six studies with nine individual experimental groups were included. To calculate effect size (ES), means and standard deviations were utilized to compare pre- and post- intervention performance in the experimental group and also differences between the experimental group and control group. Hedges' small sample size bias correction was used to adjust effect sizes [42]. To assign a proportional weight to the studies regarding the size of the standard errors, the model of inverse- variance random effects was utilized [43], and this makes analysis easier and takes into account the variety of studies [42]. The standardized mean difference (Hedges' *g*), which represents ESs, is shown along with 95% confidence intervals (CI). The ESs were interpreted using Hopkins et al. guideline's for standardized mean difference [44].

For participant comparison, the control group was fairly divided when there were multiple intervention groups [45].

The I^2 statistic was calculated to determine how different the included studies. This represents the proportion of effects caused by heterogeneity rather than chance. Although these limits are considered provisional, low, moderate, and high levels of heterogeneity agree on I^2 values of 25%, 50%, and 75% [46]. The X^2 (chi-square) is used to assess whether any observed discrepancies in findings may be attributed to pure chance. When compared to its degrees of freedom, a low p-value or a large X^2 statistic shows that intervention effects are heterogeneous beyond what can be explained by chance [43].

Analysis of Moderator Variables

Subgroup analyses were used to examine how moderator factors might have any effect. Based on the known disadvantages of meta-regression when used with short datasets, low sample sizes, and few predictor variables, subgroup analysis was used instead [47].

Potential sources of heterogeneity that would probably affect training effects were chosen in advance using a random-effects model. The program duration moderator variables (weeks), frequency of training (sessions per week), session volume (m), volume of total training (m), and percentage load used during training (%) were selected according to the well-known effect that the frequency, intensity, time, and type (FITT) principle has on how well the participants adapt to exercise [48], as was recently shown in meta-analyses carried out on athletes taking part in resisted sled intervention [49]. A median split was used to separate each variable. Nevertheless, the cut-off was chosen arbitrarily in some cases such as load. Each of these characteristics was used to stratify meta-analyses, with the cutoff for statistical significance being a *p* value of less than .05.

Results

Study selection

Four hundred nine studies were initially identified during the screening process. 238 publications were selected once replicas were eliminated. Based on title and abstract 88 articles were subsequently excluded. Twenty of the remaining 28 records were also excluded after being thoroughly scrutinized using the specified inclusion/exclusion criteria. Eight studies [50-57] were finally included in the systematic review and meta-analysis. (Figure 1).

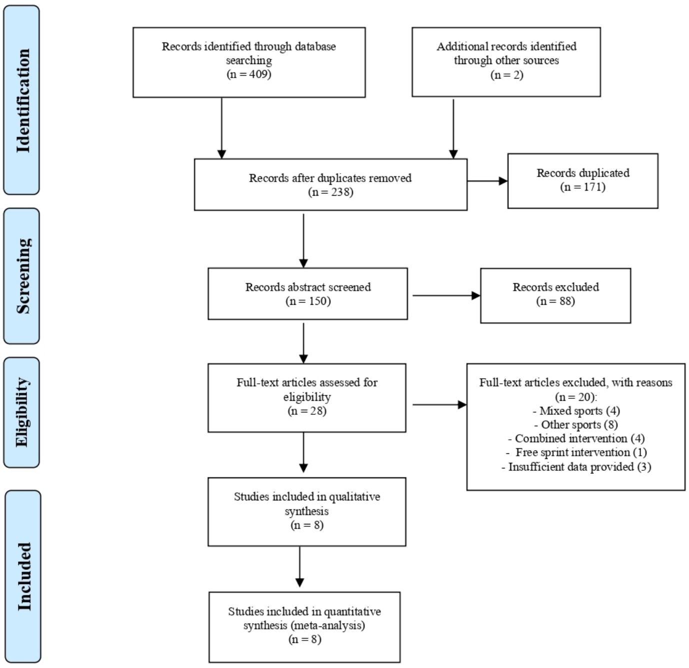


Fig. 1. PRISMA flow chart for inclusion and exclusion of studies

Risk of bias

To determine the risk of bias, the chosen studies were submitted to the RoB 2 and ROBIN-I tools. Regarding the randomized studies, three studies demonstrated a low probability of bias in all areas, four studies raised some concerns about domain 2 and domain 3. As a result, the three studies' overall biases were low, whereas the other studies did have some cause for concern. The nonrandomized study had an overall classification of moderate risk. A table detailing the risk of bias is included as a Supplementary file.

Characteristics of the included studies

Table 2 shows the participant characteristics and resisted sled parameters for programming from the eight studies in this meta-analysis. Two hundred ninety-five male soccer players were included in the studies. The average age of the participants ranges from 18.3 to 26.5 years. The resisted sprint interventions ranged in duration from 6 to 9 weeks, and the weekly training sessions ranged from 1 to 3.

Main effect

Linear Sprint Time on The Acceleration Phase and Full Sprint

This study included seven studies in total. For the acceleration phase of linear sprints, a moderate improvement was observed from pre- to post-test within groups (ES - .53 [95% CI–1.21, .16], [*P*= .13]), along with significant heterogeneity (I^2=73% [*P*= .0006]). This ES suggests a moderate improvement, likely reflecting the efficacy of specific training interventions on short-term acceleration skills. The wide CI and significant heterogeneity (I^2=73%) highlight the variability among included studies.Moreover, when compared to the control group, there was no statistically significant improvement among those in the resisted sprint training group (ES .07, [*P*= .67]). This minimal change, along with very low heterogeneity (I^2=5%), indicates that while there may be some benefits of RSTs, they are not systematically superior to traditional training methods

Figure 2A (baseline vs. follow-up) and Figure 2B (experimental vs. control) show these findings.

Between the pre- and post-test, the overall effects on full sprint time showed that linear sprint times improved significantly and largely (ES - .85, [*P*= .03]). This large effect size suggests that RST could be a factor in the improvement of longer sprint efforts. However, the high and significant heterogeneity (I^2=81% [*P*< .00001]) points to the possible influence of various study designs and participant groups on the results. Despite this significant improvement in full sprint time, no significant differences were observed between the RST and control groups (ES - .24, [*P*= .40]), with a high heterogeneity of I^2= 71%.

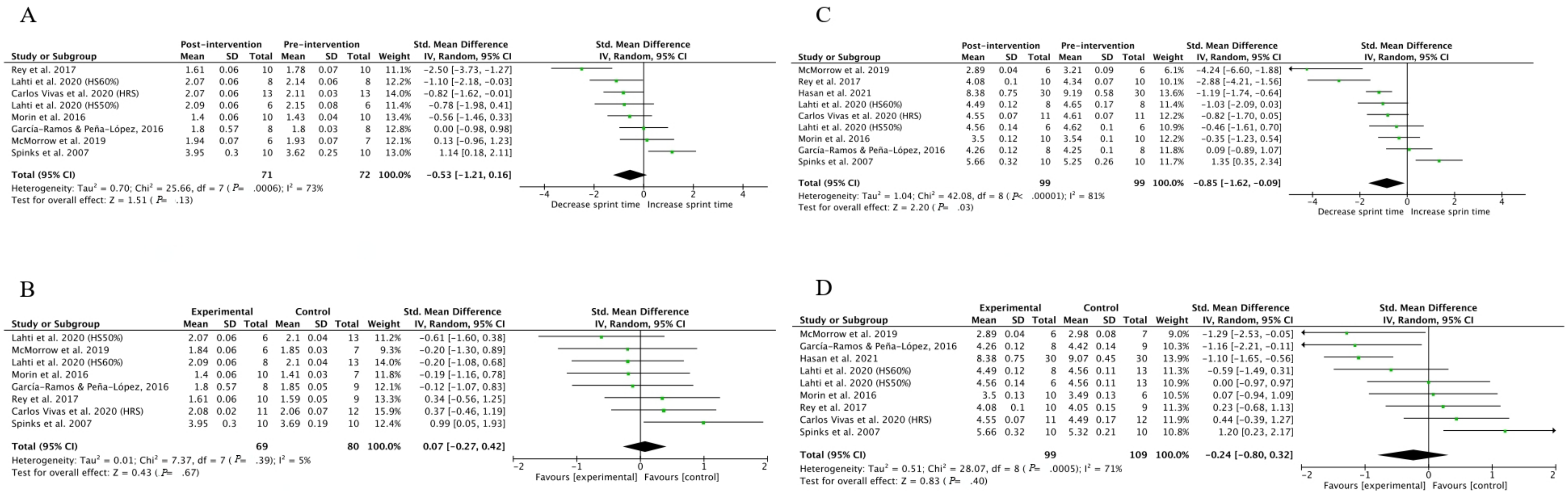
These findings are shown in Figure 2C (baseline vs. follow-up) and Figure 2D (experimental vs. control).

CODS Time

Two original studies were included. The duration of CODS was found to be significantly and largely reduced as a result of the training program's execution (ES -0.92, [*P*= .01]), showing the possible effectiveness of the training intervention. No significance between-study heterogeneity was found [I^2= 0% (*P*=.71)], suggesting a consistent effect across the studies included. In addition, no significant differences were observed between the experimental and control groups (ES 0.10, [*P*=.77]). The absence of heterogeneity (I^2=0%, [*P*=.59]) in this comparison reinforces the conclusion that the observed effects are consistent, although the magnitude of the difference between the experimental and control groups was not statistically significant. These results are shown in Figure 3A (baseline vs. follow-up) and Figure 3B (experimental vs. control).

Vertical Jump Performance

Four original studies were included. The overall effects on vertical jump height showed a non-significant and slight improvement in vertical jump performance between the pre- and post-tests (ES .28, [*P*= .22]),. This suggests a slight improvement in vertical jump performance, which, although not statistically significant, shows a possible trend towards improvement with the interventions applied. The absence of significant heterogeneity (I^2=0%, [*P*= .67]) between studies indicates a uniform effect across studies. Furthermore, no significant differences were found between the experimental and control groups (ES .10, [*P*= .65]), with an average heterogeneity of I^2=0%. The consistency of the observed effects, in combination with the absence of notable improvements, implies that the RST group



A

	Post-intervention			Pre-intervention				Std. Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
Rey et al. 2017	1.61	0.06	10	1.78	0.07	10	11.1%	−2.50 [−3.73, −1.27]
Lahti et al. 2020 (HS60%)	2.07	0.06	8	2.14	0.06	8	12.2%	−1.10 [−2.18, −0.03]
Carlos Vivas et al. 2020 (HRS)	2.07	0.06	13	2.11	0.03	13	14.0%	−0.82 [−1.62, −0.01]
Lahti et al. 2020 (HS50%)	2.09	0.06	6	2.15	0.08	6	11.4%	−0.78 [−1.98, 0.41]
Morin et al. 2016	1.4	0.06	10	1.43	0.04	10	13.4%	−0.56 [−1.46, 0.33]
García-Ramos & Peña-López, 2016	1.8	0.57	8	1.8	0.03	8	12.8%	0.00 [−0.98, 0.98]
McMorrow et al. 2019	1.94	0.07	6	1.93	0.07	7	12.1%	0.13 [−0.96, 1.23]
Spinks et al. 2007	3.95	0.3	10	3.62	0.25	10	13.0%	1.14 [0.18, 2.11]
Total (95% CI)			**71**			**72**	**100.0%**	**−0.53 [−1.21, 0.16]**

Heterogeneity: Tau^2 = 0.70; Chi^2 = 25.66, df = 7 (P= .0006); I^2 = 73%
Test for overall effect: Z = 1.51 (P= .13)

B

	Experimental			Control				Std. Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
Lahti et al. 2020 (HS50%)	2.07	0.06	6	2.1	0.04	13	11.2%	−0.61 [−1.60, 0.38]
McMorrow et al. 2019	1.84	0.06	6	1.85	0.03	7	9.3%	−0.20 [−1.30, 0.89]
Lahti et al. 2020 (HS60%)	2.09	0.06	8	2.1	0.04	13	14.0%	−0.20 [−1.08, 0.68]
Morin et al. 2016	1.4	0.06	10	1.41	0.03	7	11.8%	−0.19 [−1.16, 0.78]
García-Ramos & Peña-López, 2016	1.8	0.57	8	1.85	0.05	9	12.1%	−0.12 [−1.07, 0.83]
Rey et al. 2017	1.61	0.06	10	1.59	0.05	9	13.3%	0.34 [−0.56, 1.25]
Carlos Vivas et al. 2020 (HRS)	2.08	0.02	11	2.06	0.07	12	15.9%	0.37 [−0.46, 1.19]
Spinks et al. 2007	3.95	0.3	10	3.69	0.19	10	12.4%	0.99 [0.05, 1.93]
Total (95% CI)			**69**			**80**	**100.0%**	**0.07 [−0.27, 0.42]**

Heterogeneity: Tau^2 = 0.01; Chi^2 = 7.37, df = 7 (P= .39); I^2 = 5%
Test for overall effect: Z = 0.43 (P= .67)

C

	Post-intervention			Pre-intervention				Std. Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
McMorrow et al. 2019	2.89	0.04	6	3.21	0.09	6	6.1%	−4.24 [−6.60, −1.88]
Rey et al. 2017	4.08	0.1	10	4.34	0.07	10	10.1%	−2.88 [−4.21, −1.56]
Hasan et al. 2021	8.38	0.75	30	9.19	0.58	30	13.6%	−1.19 [−1.74, −0.64]
Lahti et al. 2020 (HS60%)	4.49	0.12	8	4.65	0.17	8	11.4%	−1.03 [−2.09, 0.03]
Carlos Vivas et al. 2020 (HRS)	4.55	0.07	11	4.61	0.07	11	12.2%	−0.82 [−1.70, 0.05]
Lahti et al. 2020 (HS50%)	4.56	0.14	6	4.62	0.1	6	10.9%	−0.46 [−1.61, 0.70]
Morin et al. 2016	3.5	0.12	10	3.54	0.1	10	12.2%	−0.35 [−1.23, 0.54]
García-Ramos & Peña-López, 2016	4.26	0.12	8	4.25	0.1	8	11.8%	0.09 [−0.89, 1.07]
Spinks et al. 2007	5.66	0.32	10	5.25	0.26	10	11.7%	1.35 [0.35, 2.34]
Total (95% CI)			**99**			**99**	**100.0%**	**−0.85 [−1.62, −0.09]**

Heterogeneity: Tau^2 = 1.04; Chi^2 = 42.08, df = 8 (P< .00001); I^2 = 81%
Test for overall effect: Z = 2.20 (P= .03)

D

	Experimental			Control				Std. Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
McMorrow et al. 2019	2.89	0.04	6	2.98	0.08	7	9.0%	−1.29 [−2.53, −0.05]
García-Ramos & Peña-López, 2016	4.26	0.12	8	4.42	0.14	9	10.3%	−1.16 [−2.21, −0.11]
Hasan et al. 2021	8.38	0.75	30	9.07	0.45	30	13.9%	−1.10 [−1.65, −0.56]
Lahti et al. 2020 (HS60%)	4.49	0.12	8	4.56	0.11	13	11.3%	−0.59 [−1.49, 0.31]
Lahti et al. 2020 (HS50%)	4.56	0.14	6	4.56	0.11	13	10.9%	0.00 [−0.97, 0.97]
Morin et al. 2016	3.5	0.13	10	3.49	0.13	6	10.5%	0.07 [−0.94, 1.09]
Rey et al. 2017	4.08	0.1	10	4.05	0.15	9	11.3%	0.23 [−0.68, 1.13]
Carlos Vivas et al. 2020 (HRS)	4.55	0.07	11	4.49	0.17	12	11.9%	0.44 [−0.39, 1.27]
Spinks et al. 2007	5.66	0.32	10	5.32	0.21	10	10.8%	1.20 [0.23, 2.17]
Total (95% CI)			**99**			**109**	**100.0%**	**−0.24 [−0.80, 0.32]**

Heterogeneity: Tau^2 = 0.51; Chi^2 = 28.07, df = 8 (P= .0005); I^2 = 71%
Test for overall effect: Z = 0.83 (P= .40)

Figure 2. A) Forest plot of between-mode effect sizes in the time of linear sprint on the acceleration phase of sprint (s). B) Forest plot of within-mode effect sizes in the time of linear sprint on the acceleration phase of sprint (s). C) Forest plot of between-mode effect sizes in the time of linear sprint on the full sprint (s). D) Forest plot of within-mode effect sizes in the time of linear sprint on the full sprint (s). Each plot includes 95% confidence intervals (CIs), IV inverse variance method, SD standard deviation, Std standardized.

Table 2. Characteristics of participants and the resisted sled training interventions of the studies included in the meta-analysis.

Study	Study Group	Study characteristics of RST	N	Age (ys)	BM (kg)	Heigh (cm)	Level	Wks	F	TS	Volume PRR (m)	Volume PSR (m)	TT (m)	Load (% BM)	Outcome Analyzed	Response
Vivas et al. (HRS)	VRS: 11 HRS: 13 CRS: 12 URS: 12	W1/4/8: S1: 20m x 1s x 2rep + 30m x 1s x 2rep; S2: 10m x 1s x 4rep + 15m x 1s + 3rep W2/3/5/6/: S1: 15m x 1s x 3rep + 20m x 1s x 2rep + 30m x 1s x 2rep; S2: 5m x 1s x 5rep + 10m x 1s x 4rep + 15m x 1s x 3rep The main difference between RST groups is the equipment used to apply resistance.	60	18.32 ± 2.20	71.3 ± 7.50	178 ± .04	Trained	8	2	16	5-20	114	1830	10-20	30-m linear sprint Zigzag CODS test CMJ	↓ 10m ↓ 30m ↓ Zigzag CODS test ↑ CMJ
García-Ramos & Peña-López	RS: 8 PLYO: 9 GC: 9	W1-4: 30m x 1s x 6reps W5-8: 30m x 1s x 8reps	26	21.3 ± 2.53	78.8 ± 12.1	177.2 ± 6.19	Trained	8	2	16	30	180-240	1680	15-20	10-m linear sprint 30-m linear sprint CMJ	=10m =30m ↑ CMJ
Hasan et al.	RST: 30 PLYO: 30 URS: 30	W1: 20m x 3s x 3rep W2: 20m x 4s x 3rep W3: 40m x 3s x 3rep W4: 40m x 4s x 3rep W5: 50m x 3s x 3rep W6: 40m x 4s x 3rep	90	20.5 ± .12	64.8 ± 1.7	171.6± .04	Recreationally active	6	3	18	20-50	84	1340	10	50-m linear sprint	↓ 50m

Lathi et al. (HS50%)	HS50%: 6 HS60%: 8 URS: 13	W1: S1: - S2: 20m x 4rep W2-4: S3: 20m x 2 rep; S4: 20m x 4 rep W5-6: S5: 20m x 5 rep; S6: - W7: S7: 20m x 2 rep; S8: - W8: S9: 20m x 3 rep; S10: - W9: S11: 20m x 3 rep; S12: 20m x 5rep	32	24.1 ± 5.1	76.7 ± 7.7	180 ± 10	Highly trained	9	1-2	15	20	40-100	700	94-120	30-m linear sprint	↓ 10m ↓ 30m
Lahti et al. (HS60%)		W1: S1: - S2: 15m x 4rep W2-4: S3: 15m x 2 rep; S4: 15m x 4 rep W5-6: S5: 15m x 5 rep; S6: - W7: S7: 15m x 2 rep; S8: - W8: S9: 15m x 3 rep; S10: - W9: S11: 15m x 3 rep; S12: 15m x 5rep									15	30-75	495			↓ 10m ↓ 30m
McMorrow et al.	RS: 6 URS: 7	W1: 20m x 1s x 5rep W2: 20m x 1s x 6rep W3: 20m x 1s x 7rep W4: 20m x 1s x 8rep W5: 20m x 1s x 9rep W6: 20m x 1s x 5rep	18	24.7 ± 3.4	80.6 ± 8.8	180 ± .06	Highly trained	6	1-2	10	20	100-180	800	30	20-m linear sprint CODS test	↓ 10m ↓ 20m ↓ CODS test

Morin et al.	VHS: 10 URS: 6	W1-2: 20m x 2s x 5 rep (5 resisted sprints) W3-4: 20m x 2s x 5 rep (6 resisted sprits) W5-6: 20m x 2s x 5 rep (7 resisted sprits) W7-8: 20m x 2s x 5 rep (8 resisted sprits)	20	26.5 ± 4.1	72.6 ± 5.9	176 ± .08	Trained	8	2	16	20	200	3200	80	20-m linear sprint	↓ 5m ↓ 20m
Rey et al.	RS: 10 URS: 9	W1: 20m x 1s x 6rep W2: 20m x 2s x 5rep W3: 20m x 2s x 5rep W4: 20m x 4s x 3rep W5: 20m x 4s x 3rep W6: 20m x 7s x 2rep	19	23.6 ± 2.4	74.5 ± 6.65	179.1 ± 4.85	Trained	6	2	12	20	120-280	2560	18.9	30-m linear sprint CMJ	↓ 10m ↓ 30m = CMJ

Spinks et al.	RS:10 NRS:10 CG:10	W1: 0-5m x 2s x 4rep; 0-10m x 1s x 4reps; 0-15m x 1s x 5reps; 0-20 x 1s x 3reps W2: 0-5m x 2s x 6rep; 0-10m x 2s x 3reps; 0-15m x 1s x 3reps; 0-20 x 1s x 3reps W3: 0-5m x 3s x 5rep; 0-10m x 2s x 4reps; 0-15m x 1s x 3reps; 0-20 x 1s x 3reps W4: 0-5m x 3s x 5rep; 0-10m x 2s x 4reps; 0-15m x 1s x 3reps; 0-20 x 1s x 3reps W5: 0-5m x 2s x 6rep; 0-10m x 2s x 3reps; 0-15m x 1s x 3reps; 0-20 x 1s x 3reps W6: 0-5m x 3s x 5rep; 0-10m x 2s x 4reps; 0-15m x 1s x 3reps; 0-20 x 1s x 3reps W7: 0-5m x 3s x 5rep; 0-10m x 2s x 4reps; 0-15m x 1s x 3reps; 0-20 x 1s x 3reps W8: 0-5m x 2s x 5rep; 0-10m x 2s x 4reps; 0-15m x 2s x 3reps; 0-20 x 2s x 3reps	30	21.8 ± 4.2	83.3 ± 8.7	181.9 ± 6.2	Trained	8	2	16	5-20	215-340	2045	Equation	5-m linear sprint 15-m linear sprint CMJ	↑ 15m ↑ 15m ↑ CMJ

F: frequency (per wk); TS: total sessions; PRR: per repetition range; PRS: per session range; TT: total training; CODS: change of direction speed; CMJ: countermovement jump; BM: body mass; VRS: vertical resisted sprint group; HRS: horizontal resisted sprint group; CRS: combined resisted sprint group; URS: unresisted sprint group; SQ: back squat group; RS: resisted sprint group; PLYO: plyometric and speed/agility group; HS: heavy sled group; VHS: very heavy sled group; S: sets; Rep: repetitions; W: week; S: session

Table 3. Effect of moderator variables with 95% confidence intervals (CI) in resisted sprint training.

Variable		Subgroup	Groups	Effect Size with 95% CI	Effect Descriptor	Within-Group I^2 (%)	Within-Group P^a	Between Group I^2 (%)	Between Group P^b
Linear sprint test (s) Acceleration phase Full sprint	D	≤ 6 weeks	3	- .71 (-1.63; .21)	Moderate	70	.13	37.5	.21
		> 6 weeks	6	.01 (- .62; .32)	Trivia	62	.98		
	F	≤ 2 sessions/weeks	8	- .09 (- .64; 0.45)	Trivial	70	.74	84.7	.01
		> 2 sessions/weeks	1	-1.10 (-1.65; -0.56)	Moderate	NE	<.0001		
	SV	≤ 125 m/session	3	- .03 (- .63; .57)	Trivial	26	.92		
		> 125 m/session	6	- .34 (-1.14; .46)	Small	79	.41	0	.55
	TTV	≤ 1250 m/training	3	- .55 (-1.22; .12)	Small	23	.11		
		> 1250 m/training	5	- .07 (- .85; .71)	Trivial	80	.85	0	.37
	L	<20% BM	2	- .61 (-1.63; .41)	Moderate	80	.24		
		≥ 20% BM	5	- .25 (- .74; .25)	Small	19	.33	0	.53
Change of direction speed test (s)	D	≤ 6 weeks	1	.13 (- .96; 1.23)	Trivial	NE	.81		
		> 6 weeks	1	-1.02 (-1.92; - .12)	Moderate	NE	.03	60.8	.11
	F	≤ 2 sessions/weeks	2	- .92 (-1.63; - .20)	Moderate	0	.01		
		> 2 sessions/weeks	0					NE	NE
	SV	≤ 125 m/session	1	-1.02 (-1.92; - .12)	Moderate	NE	.03		
		> 125 m/session	1	- .74 (-1.93; .45)	Moderate	NE	.22	0	.71
	TTV	≤ 1250 m/training	1	- .74 (-1.93; .45)	Moderate	NE	.22		
		> 1250 m/training	1	-1.02 (-1.92; - .12)	Moderate	NE	.03	0	.71
	L	<20% BM	1	- .74 (-1.93; .45)	Moderate	NE	.22		
		≥ 20% BM	1	-1.02 (-1.92; - .12)	Moderate	NE	.03	0	.71
Vertical jump (cm)	D	≤ 6 weeks	1	-2.50 (-3.73; 1.27)	Large	NE	<.0001		
		> 6 weeks	4	.25 (- .26; .77)	Small	0	.34	93.9	<.0001
	F	≤ 2 sessions/weeks	4	.19 (- .25; .64)	Trivial	0	.40		
		> 2 sessions/weeks	0					NE	NE
	SV	≤ 125 m/session	1	.04 (-.79; .88)	Trivial	NE	0		
		> 125 m/session	3	.25 (- .27; .77)	Small	0	.35	0	.68
	TTV	≤ 1250 m/training	0						
		> 1250 m/training	4	.19 (- .25; .64)	Trivial	0	.40	NE	NE
	L	<20% BM	4	.26 (- .38; .89)	Small	0	.43		
		≥ 20% BM	1	.02 (- .86; .90)	Trivial	NE	.96	0	.67

D: duration; F: frequency; SV: session volume; TTV: total training volume; L: Load; NE: not estimable.

may not have adequately differentiated from the control group to effect a significant alteration in vertical jump performance. These findings are shown in Figure 4A (baseline vs. follow-up) and Figure 4B (experimental vs. control).

Effect Of Moderator Variables

Linear Sprint Time on The Acceleration Phase and Full Sprint

The results of the subgroup analysis for the linear sprint performance on the acceleration phase and full sprint did not indicate significant levels of between-group heterogeneity with any variable except for session volume (Table 3).

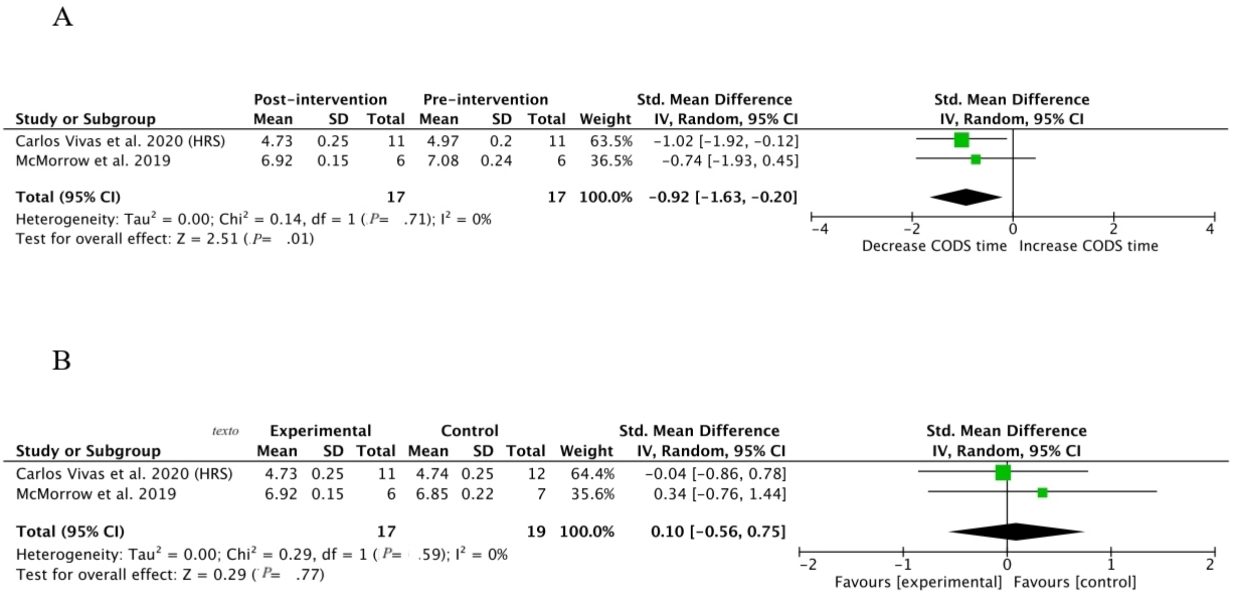


Figure 3. A) Forest plot of between-mode effect sizes in the time of change of direction (s). B) Forest plot of within-mode effect sizes with 95% confidence intervals (CIs) in the time of change of direction (s). Each plot includes 95% confidence intervals (CIs), IV inverse variance method, SD standard deviation, Std standardized.

Performance differences in the linear sprint were small to moderate among subgroups for each training method. However, one subgroup variable had a significant impact on sprint performance. The resisted sprint intervention with a frequency of training was more than two sessions (ES -1.10, [*P*=<.0001]) was substantially more effective than its contrary moderator variable. Subgroups with higher session volume, total training volume, and lower percentage load used during training had higher levels of heterogeneity.

CODS Time

Based on the subgroup analysis, moderate levels of between-group heterogeneity of weekly volume and session volume were found in CODS performance (Table 3).

Performance differences in CODS were found to be trivial to moderate among subgroups for each training method. However, a few subgroup variables had a significant impact on CODS performance. The resisted sprint intervention with a training duration of more than six weeks, session volume lasting less

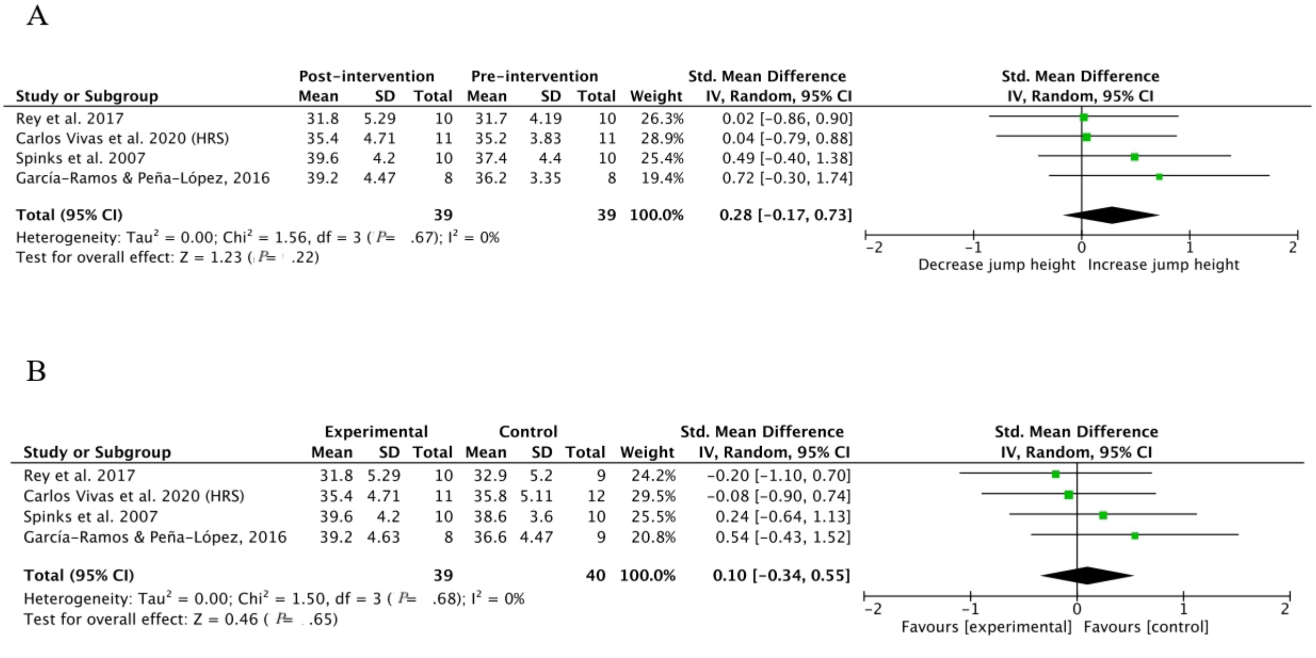


Figure 4. A) Forest plot of between-mode effect sizes in the time in vertical jump performance (cm). B) Forest plot of within-mode effect sizes with 95% confidence intervals (CIs) in vertical jump performance (cm). Each plot includes 95% confidence intervals (CIs), IV inverse variance method, SD standard deviation, Std standardized.

than 125 meters, a total training volume of more than 1250 meters, and percentage load used during training less than 20% (ES -1.02, *P*= .03) were substantially more effective than the moderator variables, that were contrary.

Vertical Jump Performance

The results of the subgroup analysis for vertical jump did not indicate significant levels of between-group heterogeneity with any variable except program duration (Table 3).

For each training method, performance differences in vertical jump were trivial to large among subgroups. The resisted sprint intervention with a training duration of less than six weeks (ES -2.50, *P*≤.0001) was substantially more effective than its contrary moderator variable.

Discussion

This study aimed to investigate the effects of resisted sprint training (RST) on male soccer players' jump ability, linear sprint, and change of direction speed (CODS) performance. A total of eight studies were included in the analysis. The results showed that RST had a significant and moderate effect on improving sprint performance, concretely in the maximum velocity phases. However, no significant improvements in vertical jump performance were found. As for CODS, RST produced significant and moderate improvements. Regarding the between-group comparisons (experimental vs. control group), no significant differences were observed for any of the three variables analyzed (sprint, vertical CODS, and jump). The heterogeneity between the studies was generally high, indicating a need for further investigation. Overall, this meta-analysis suggests that RST may be an effective training method for improving linear sprint and CODS performance in male soccer players. However, more research is needed to determine its effectiveness in improving vertical jump performance.

Linear sprint time

First, it is important to highlight the importance of the acceleration phase in soccer since the average duration of sprints in professional matches ranges between 2 and 4 seconds [58]. As for the linear sprint time, in line with our research, several studies have revealed improvements in running performance after developing resistance training for one season [59-61]. Additionally, a systematic review conducted by Alcaraz et al. highlights the effectiveness of RST in decreasing sprint time, particularly in the early acceleration phase [24]. Different intervention studies showed that heavy RST is an effective way to optimize sprint performance in professional soccer players [51,53] especially during the early acceleration phase [62]. Furthermore, several studies have observed that resisted training leads to greater improvements in sprint velocity compared to regular sprint training [33,63], and RST is useful, particularly throughout the acceleration phase of linear sprints [33]. Zafeiridis et al. reported that, to explain the mechanism of this improvement, it should be noted that RST creates an overload that elicits a greater neuromuscular activation and, thus, increases the use of fast-twitch fibers [63] and also, this exercise modality could increase the force output of hip and knee extensors [63]. However, it should be noted that sleds used in RST can produce changes in sprint kinematics during the acceleration and maximum speed phases [31,63,64]. Specifically, sleds used during the acceleration phase can decrease an athlete's velocity, stride length, and frequency, while increasing contact time and trunk inclination. Meanwhile, sleds used during the maximum speed phase can reduce an athlete's stride length and running velocity and increase trunk inclination. Therefore, the recommended approach is to use a sled load that does not significantly alter the athlete's technique. The quantification of the training load imposed on the athlete during RST is still undetermined by the scientific community. This aspect conditions the internal load imposed on the athlete and, therefore, the adaptations that occur in one direction or another. Thus, there is a need for research in this area [30].

Finally, it should be noted that two of the studies included in the meta-analysis were conducted with U-19 soccer players. Due to their age, these study participants might have greater trainability potential, which may have favored a larger effect size in the improvements found [65,66].

CODS performance

Based on the results of the two studies included in the meta-analysis, it was observed that RST is an effective methodology for attaining improvements in COD performance. In this regard, Gil et al. also demonstrated that RST improved sprinting, CODS, and vertical jumps (i.e., squat jump and CounterMovement Jump (CMJ)) [67]. These enhancements could be because the COD capacity is related to acceleration ability and vertical and horizontal propulsive forces. Thus, athletes producing higher vertical and horizontal propulsive forces may perform better in COD [68]. These results were predictable since RST could influence horizontal forces [69] and acceleration ability [24]. However, it must be highlighted that in neither of the two studies there were between-group improvements. In the research conducted by Carlos-Vivas et al., the authors consider that the absence of differences between the sled training and control groups could be because the load does not act in the vertical plane with this training modality, and therefore, there is no constant demand on athlete´s musculature, unlike when the resisted sprinting is practiced with a weighted vest [52]. In the study conducted by McMorrow et al., the authors consider that the absence of between-group differences could be because the intervention was carried out within the competitive season, and also due to the lack of a tapering period to gradually reduce the training volume after applying the intervention to consolidate the adaptations attained [53]. The six-week period may not have been sufficient to observe significant changes due to the need for time for physiological adaptations to manifest themselves and the level of performance of the professional players in the middle of the season. In addition, both groups performed an intervention, with no control group, so the study design used contrast groups instead of actual control groups [53]. Furthermore, it must also be taken into account that the duration of this study was only six weeks, and was carried out with professional soccer players. Therefore, their level of trainability or reserve of adaptation is lower. Another possible reason for the absence of significant differences between the experimental and control groups could be that the control groups also underwent sprint interventions (albeit unresisted). This implies that contrast groups were used instead of real control groups in the study design [67]. Likewise, it must be considered that RST is a modality that does not present a high degree of specificity regarding CODS [67,70]. Moreover, at present, it is not entirely clear what is the adequate load magnitude to attain neuromuscular improvements while performing sled training [71]. Therefore, it cannot be ruled out that using an optimal load based on the athlete´s characteristics and the season period may provide additional improvements.

Vertical jump performance

Vertical jump height has been assumed to be an indicator of muscle power output [72], and it is an essential functional parameter for athletes, specifically in team sports [73]. The present study used the CMJ to assess the vertical jump height as it is widely recognized for its reliability and validity in measuring this parameter [74]. Despite the expectations surrounding the relationship between RST and vertical jump performance, our findings revealed a slight improvement in vertical jump performance between the pre- and post-tests; however, this improvement was not statistically significant. Additionally, no significant differences were found between the experimental and control groups. Thus, of the four studies included in the present meta-analysis, in three of them, no significant differences were found between resisted and unresisted sprint groups [52,55,56]. Likewise, in the study conducted by García Ramos and Peña López , no significant differences were observed between the resisted sprint and control groups [50]. The authors of these studies consider that the absence of significant differences in vertical jumping is because resisted sprint training improves specific coordination and agility more than explosive strength due to a greater application of horizontal power and the lack of specific vertical overload [75]. Furthermore, the absence of specific vertical overload in RST might explain the modest effects observed on vertical power. These considerations align with the hypothesis proposed by Lockie et al., suggesting that RST primarily emphasizes horizontal power production, while vertical jumps require vertical power production [69]. These findings contradict previous research [76,77], which indicated that optimizing the load in RST, determined by the reduction of velocity according to the linear load-velocity relationship, along with medium to high loads, resulted in enhanced vertical jump performance among basketball players and moderately trained individuals. However, some studies have shown conflicting results, reporting increased jump height after applying RST protocols but without significant differences between RST and control groups [56,70].

Finally, while the overall effects of RST on vertical jump height were not significant in this meta-analysis, the findings suggest that further investigation is needed to determine the optimal protocols and training variables for improving vertical jump performance. Future studies should consider incorporating combined training interventions that target both horizontal and vertical power production, as well as explore a variety of jump variations to better understand their impact on soccer performance.

The present study had some limitations. Firstly, only male soccer players were considered in this study, and the studies focusing solely on women or comparing the two genders were ignored. Secondly, a reduced number of studies have been analyzed in the present research, two of which are of moderate quality. Another controversial point is that not all articles were used in the different analyses. The analysis between RST and sprint included all eight articles, whereas the evaluation of RST over CODS incorporated only two articles, and the analysis of RST over CMJ was based on four articles. Consequently, the most robust analysis in terms of the volume of articles examined is the one related to sprinting. Finally, no specific load was mentioned for this study, while some studies have listed the load of RST [51,71].

To address the limitations of this study and provide direction for future research, a few aspects should be investigated. Future studies should examine the effects of RST on women to determine if gender differences exist in RST's effectiveness. Comparing the effects of RST between genders can provide valuable information for personalizing and optimizing this training modality, recognizing the physiological and biomechanical differences that exist between men and women. As RST has been shown to be effective when combined with other training modalities, such as plyometrics[78], future studies should investigate the impact of additional training methods on sprint time, CODS, and jump height. This will provide a better understanding of optimal training protocols for improving athletic performance and may identify potential adverse effects of combining training methods. It is important that future research delve deeper into specific components such as rate of force development (RFD), acceleration, reaction time, and mechanical power output, along with the assessed physical qualities of vertical jump, sprinting, and COD. This more comprehensive analysis could refine training protocols. Finally, it is recommended that future studies should consider the specific load (weight) applied during RST. The load can positively or negatively affect the kinetic or kinematic properties of sprinting, so measuring it can help researchers understand the impact of RST on athletes and provide more precise recommendations for optimal training programs.

Practical applications

- Incorporating RST using sleds can effectively improve linear sprint performance, particularly in the maximum velocity phase, in male soccer players.
- Strength and conditioning professionals can use RST interventions based on the findings of this meta-analysis to enhance sprinting ability in soccer players, considering the overload created by sleds that leads to increased neuromuscular activation and utilization of fast-twitch muscle fibers.
- Resisted sprint training has the potential to produce significant and moderate improvements in CODS performance, as COD capacity is closely related to acceleration ability and horizontal propulsive forces that can be influenced by RST.
- The specificity of RST to CODS needs further investigation, highlighting the need for research to determine the appropriate load magnitude for neuromuscular improvements during sled training.
- The effectiveness of RST on vertical jump performance in male soccer players is inconclusive based on the current study, emphasizing the need for further research to determine its impact.
- Individual athlete characteristics and participants' age and trainability potential should be considered when designing RST interventions, as different player populations may require specific training approaches.

Conclusions

In conclusion, the findings of this meta-analysis suggest that RST has a significant and moderate effect on improving linear sprint performance, particularly in the maximum velocity phase, in male soccer players. Several studies included in the analysis have reported improvements in sprint performance after implementing RST interventions. Using sleds in RST can create an overload that leads to greater neuromuscular activation and increased utilization of fast-twitch muscle fibers, resulting in enhanced sprinting ability. However, it is important to note that sleds should be used with caution to avoid significant alterations in sprint kinematics. Further research is needed to determine the optimal training load and its impact on soccer players' internal load and adaptations.

Regarding CODS performance, RST was found to produce significant and moderate improvements. The COD capacity is closely related to acceleration ability and vertical and horizontal propulsive forces, which can be influenced by RST by improving the power of the muscles responsible for horizontal and vertical propulsion. However, the between-group comparisons did not show significant differences, suggesting that other factors such as training volume, training timing within the competitive season, and the use of contrast groups could have influenced the results. Additionally, the specificity of RST to CODS needs further investigation, and determining an appropriate load magnitude for neuromuscular improvements during sled training is still unclear. Future studies should consider individual athlete characteristics and season periods when designing RST interventions for optimal improvements in CODS.

Overall, this meta-analysis supports the effectiveness of RST as a training method for improving linear sprint and CODS performance in male soccer players. However, further research is needed to determine the impact of RST on vertical jump performance, as no significant improvements were found in this study. The age and trainability potential, the capacity of an individual to improve performance with training, of the participants may have influenced the results, highlighting the need for specific training interventions for different player populations. To optimize the outcomes of RST, future studies should address the methodological limitations identified in this analysis and explore the ideal training load, timing, and individualized approaches for soccer players.

Ethical Committee approval

PROSPERO, the prospective international register of systematic reviews was used to register the protocol (CRD42021248975).

ORCID

Elena Mainer-Pardos: http://orcid.org/0000-0003-2947-9564
Sara Mahmoudzadeh Khalili: http://orcid.org/0000-0001-7019-4275
Oscar Villanueva-Guerrero: http://orcid.org/0000-0001-7952-5798
Filipe Manuel Clemente: http://orcid.org/0000-0001-9813-2842
Hadi Nobari: http://orcid.org/0000-0001-7951-8977

Informed Consent Statement

Topic

Sport Performance.

Conflicts of interest

The authors have no conflicts of interest to declare.

Funding

No funding was received for this investigation.

Declaration if used ChatGPT

Author-s contribution

Conceptualization, E.P.-M. and H.N.; methodology, E.P.-M., H.N. and F.M.C; writing—original draft preparation, S.M.K. and P.P.G.; writing—review and editing, E.P.-M., F.M.C, O.V.-G. and H.N.; supervision, S.M.K., O.V.-G. and P.P.G.; All authors have read and agreed to the published version of the manuscript.

References

1. Varley MC, Aughey RJ. Acceleration profiles in elite Australian soccer *Int J Sports Medicine.* 2013;34(01):34-39. doi: 10.1055/s-0032-1316315.
2. Nobari H, Kargarfard M, Minasian V, Cholewa JM, Pérez-Gómez J. The effects of 14-week betaine supplementation on endocrine markers, body composition and anthropometrics in professional youth soccer players: a double blind, randomized, placebo-controlled trial. *J. Int. Soc. Sports Nutr.* 2021;18(1):20. doi: 10.1186/s12970-021-00417-5
3. Taşkın C, Karakoç Ö, Acaroglu E, Budak C. The investigation of the relationship among selected motoric features of children soccer players. *Journal of Sports and Performance Researches.* 2015;6(2):101-107.
4. Bradley PS, Sheldon W, Wooster B, Olsen P, Boanas P, Krustrup P. High-intensity running in English FA Premier League soccer matches. *J. Sports Sci.* 2009;27(2):159-168. doi: 10.1080/02640410802512775.
5. Nobari H, Alves AR, Clemente FM, et al. Associations between variations in accumulated workload and physiological variables in young male soccer players over the course of a season. *Front Physiol.* 2021;12:233. doi: 10.3389/fphys.2021.638180.
6. Lehnert M, Stastny P, Tufano JJ, Stolfa P. Changes in isokinetic muscle strength in adolescent soccer players after 10 weeks of pre-season training. *The Open Sports Sciences Journal.* 2017;10(1). doi:10.2174/1875399X01710010027.
7. Stølen T, Chamari K, Castagna C, Wisløff U. Physiology of soccer. *Sports medicine.* 2005;35(6):501-536. doi: 10.2165/00007256-200535060-00004.
8. Bangsbo J, Nørregaard L, Thorsoe F. Activity profile of competition soccer. *Canadian journal of sport sciences.* 1991;16(2):110-116.
9. Haugen TA, Tønnessen E, Hisdal J, Seiler S. The role and development of sprinting speed in soccer. *International journal of sports physiology and performance.* 2014;9(3):432-441. doi: 10.1123/ijspp.2013-0121.
10. Faude O, Koch T, Meyer T. Straight sprinting is the most frequent action in goal situations in professional football. *J Sports Sci.* 2012;30(7):625-631. doi: 10.1080/02640414.2012.665940.
11. Chlif M, Jullien H, Temfemo A, Mezouk A, Manouvrier C, Choquet D. Suivi physique et physiologique de footballeurs semi-professionnels: vers un entraînement individualisé par poste. *Science & sports.* 2010;25(3):132-138.
12. Lago-Peñas C, Casais L, Dellal A, Rey E, Domínguez E. Anthropometric and physiological characteristics of young soccer players according to their playing positions: relevance for competition success. *J. Strength Cond. Res.* 2011;25(12):3358-3367. doi: 10.1519/JSC.0b013e318216305d.
13. Wisløff U, Castagna C, Helgerud J, Jones R, Hoff J. Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *Br. J. Sports Med.* 2004;38(3):285-288. doi: 10.1136/bjsm.2002.002071.
14. Pardos-Mainer E, Bishop C, Gonzalo-Skok O, Nobari H, Pérez-Gómez J, Lozano D. Associations between inter-limb asymmetries in jump and change of direction speed tests and physical performance in adolescent female soccer players. *Int. J. Environ. Res. Public Health.* 2021;18(7):3474. doi: 10.3390/ijerph18073474.
15. Lockie RG, Stage AA, Stokes JJ, et al. Relationships and

Predictive Capabilities of Jump Assessments to Soccer-Specific Field Test Performance in Division I Collegiate Players. *Sports (Basel).* 2016;4(4).

16. Fradkin AJ, Zazryn TR, Smoliga JM. Effects of warming-up on physical performance: a systematic review with meta-analysis. *J. Strength Cond. Res.* 2010;24(1):140-148. doi: 10.1519/JSC.0b013e3181c643a0.
17. Taylor JB, Wright AA, Dischiavi SL, Townsend MA, Marmon AR. Activity demands during multi-directional team sports: a systematic review. *Sports Med.* 2017;47(12):2533-2551. doi: 10.1007/s40279-017-0772-5.
18. Little T, Williams A. Specificity of acceleration, maximum speed and agility in professional soccer players. Routledge London, UK:; 2003.
19. Nobari H, Tubagi Polito LF, Clemente FM, et al. Relationships between training workload parameters with variations in anaerobic power and change of direction status in elite youth soccer players. *Int. J. Environ. Res. Public Health.* 2020;17(21):7934. doi: 10.3390/ijerph17217934.
20. Paul DJ, Gabbett TJ, Nassis GP. Agility in team sports: Testing, training and factors affecting performance. *Sports Med.* 2016;46(3):421-442. doi:10.1007/s40279-015-0428-2.
21. Chaabene H. Change of direction tasks: Does the eccentric muscle contraction really matter. *Sci Pages Sports Med.* 2017;1(1):1-2. doi: 10.36959/987/222.
22. Nobari H, Silva AF, Clemente FM, et al. Analysis of Fitness Status Variations of Under-16 Soccer Players Over a Season and Their Relationships With Maturational Status and Training Load. *Front Physiol.* 2021;11(1840). doi: 10.3389/fphys.2020.597697.
23. Gutiérrez-Hernández SJ, Pérez-Gómez J, Nobari H, Carlos-Vivas J. Eccentric training as strategy to improve change of direction and sprint performance in team-sports: A systematic review. *e-Motion Revista de Educación Motricidad e Investigación*. 2020; 14:43-65. doi. 10.33776/remo.v0i14.4849.
24. Alcaraz PE, Carlos-Vivas J, Oponjuru BO, Martinez-Rodriguez A. The effectiveness of resisted sled training (RST) for sprint performance: a systematic review and meta-analysis. *Sports Med.* 2018;48(9):2143-2165 doi: 10.1007/s40279-018-0947-8.
25. Petrakos G, Morin J-B, Egan B. Resisted sled sprint training to improve sprint performance: a systematic review. *Sports Med.* 2016;46(3):381-400. doi: 10.1007/s40279-015-0422-8.
26. Cronin J, Hansen K, Kawamori N, Mcnair P. Effects of weighted vests and sled towing on sprint kinematics. *Sports Biomech.* 2008;7(2):160-172. doi: 10.1080/14763140701841381.
27. Cahill M. The effectiveness of resisted sprinting to improve short distance sprint performance in young athletes, Auckland University of Technology; 2019.
28. Fernandez-Galvan LM, Casado A, Garcia-Ramos A, Haff GG. Effects of Vest and Sled Resisted Sprint Training on Sprint Performance in Young Soccer Players: A Systematic Review and Meta-analysis. *J Strength Cond Res.* 2022;36(7):2023-2034. doi: 10.1519/JSC.0000000000004255.
29. Paradisis GP, Cooke CB. The effects of sprint running training on sloping surfaces. *J Strength Cond Res.* 2006;20(4):767-777.
30. Alcaraz P. El entrenamiento del sprint con métodos resistidos *Cultura, Ciencia y Deporte.* 2010;5:19-26.
31. Alcaraz P, Palao JM, Elvira JL, Linthorne NP. Effects of three types of resisted sprint training devices on the kinematics of sprinting at maximum velocity. *J Strength Cond Res.* 2008;22(3):890-897.
32. Alcaraz P, Elvira J, Palao J. Kinematic, strength, and stiffness adaptations after a short-term sled towing training in athletes. *Scand. J. Med. Sci. Sports.* 2014;24(2):279-290. doi: 10.1111/j.1600-0838.2012.01488.x.
33. Harrison AJ, Bourke G. The effect of resisted sprint training on speed and strength performance in male rugby players. *J. Strength Cond. Res.* 2009;23(1):275-283. doi. 10.1519/JSC.0b013e318196b81f.
34. Makaruk B, Sozański H, Makaruk H, Sacewicz T. The effects of resisted sprint training on speed performance in women. *Human Movement.* 2013;14(2):116-122. doi: 10.2478/humo-2013-0013.
35. Zabaloy S, Freitas TT, Pareja-Blanco F, Alcaraz PE, Loturco I. Narrative Review on the Use of Sled Training to Improve Sprint Performance in Team Sport Athletes. *Strength Cond J.* 2023;45(1):13-28. doi: 10.1519/SSC.0000000000000730.
36. Macadam P, Cronin JB, Feser EH. Acute and longitudinal effects of weighted vest training on sprint-running performance: a systematic review. *Sports Biomech.* 2022;21(3):239-254.
37. Higgins JP, Thomas J, Chandler J, et al. *Cochrane Handbook for Systematic Reviews of Interventions.* New York (USA)2019.
38. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *BMJ.* 2009;339:b2700. doi: 10.1136/bmj.b2700.
39. Sterne JA, Hernán MA, Reeves BC, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. *BMJ.* 2016;355:i4919. doi: 10.1136/bmj.i4919.
40. Sterne JAC, Savovic J, Page MJ, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ.* 2019;366:l4898. doi: 10.1136/bmj.l4898.
41. Centre TNC. *Review Manager. Cochrane Collaboration.* London (UK)2014.
42. Hedges L, Olkin I. *Methods for Meta-Analysis. Academic Press.* New York, NY, USA1985.
43. Deeks J, Higgins J, Altman D. *Analysing data and undertaking meta-analyses.* Cochrane Book Series; 2008.
44. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc.* 2009;41(1):3-13. doi: 10.1249/MSS.0b013e31818cb278.
45. Pardos-Mainer E, Lozano D, Torrontegui-Duarte M, Carton-Llorente A, Roso-Moliner A. Effects of Strength vs. Plyometric Training Programs on Vertical Jumping, Linear Sprint and Change of Direction Speed Performance in Female Soccer Players: A Systematic Review and Meta-Analysis. *Int J Environ Res Public Health.* 2021;18(2). doi: 10.3390/ijerph18020401.
46. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *BMJ.* 2003;327(7414):557-560. doi: 10.1136/bmj.327.7414.557.
47. Schmidt F. Statistical and measurement pitfalls in the use of meta-regression in meta-analysis. *Career Dev Int.* 2017;22:469-476. doi: 10.1108/CDI-08-2017-0136.
48. Pescatello LS, MacDonald HV, Lamberti L, Johnson BT. Exercise for Hypertension: A Prescription Update Integrating Existing Recommendations with Emerging

Research. *Curr Hypertens Rep.* 2015;17(11):87. doi: 10.1007/s11906-015-0600-y.

49. Alcaraz PE, Carlos-Vivas J, Oponjuru BO, Martinez-Rodriguez A. Correction to: The Effectiveness of Resisted Sled Training (RST) for Sprint Performance: A Systematic Review and Meta-analysis. *Sports Med.* 2018;48(9):2167-2168. doi: 10.1007/s40279-018-0947-8.
50. García-Ramos F, Peña-López J. Efectos de 8 Semanas de Entrenamiento Pliométrico y Entrenamiento Resistido Mediante Trineo en el Rendimiento de Salto Vertical y Esprint en Futbolistas Amateurs. *Kronos.* 2016;15(1).
51. Lahti J, Huuhka T, Romero V, Bezodis I, Morin J-B, Häkkinen K. Changes in sprint performance and sagittal plane kinematics after heavy resisted sprint training in professional soccer players. *PeerJ.* 2020;8:e10507, doi: 10.7717/peerj.10507
52. Carlos-Vivas J, Perez-Gomez J, Eriksrud O, Freitas TT, Marin-Cascales E, Alcaraz PE. Vertical Versus Horizontal Resisted Sprint Training Applied to Young Soccer Players: Effects on Physical Performance. *Int J Sports Physiol Perform.* 2020;15(5):748-758. doi: 10.1123/ijspp.2019-0355.
53. McMorrow BJ, Ditroilo M, Egan B. Effect of Heavy Resisted Sled Sprint Training During the Competitive Season on Sprint and Change-of-Direction Performance in Professional Soccer Players. *Int J Sports Physiol Perform.* 2019;14(8):1066-1073. doi: 10.1123/ijspp.2018-0592.
54. Morin JB, Petrakos G, Jimenez-Reyes P, Brown SR, Samozino P, Cross MR. Very-Heavy Sled Training for Improving Horizontal-Force Output in Soccer Players. *Int J Sports Physiol Perform.* 2017;12(6):840-844. doi: 10.1123/ijspp.2016-0444.
55. Rey E, Padron-Cabo A, Fernandez-Penedo D. Effects of Sprint Training With and Without Weighted Vest on Speed and Repeated Sprint Ability in Male Soccer Players. *J Strength Cond Res.* 2017;31(10):2659-2666. doi: 10.1519/JSC.0000000000001726.
56. Spinks CD, Murphy AJ, Spinks WL, 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.* 2007;21(1):77-85. doi: 10.1519/00124278-200702000-00015.
57. Hasan S, Kandasamy G, Alyahya D, et al. Effect of Resisted Sprint and Plyometric Training on Lower Limb Functional Performance in Collegiate Male Football Players: A Randomised Control Trial. *Int J Environ Res Public Health.* 2021;18(13):6702. doi: 10.3390/ijerph18136702.
58. Uthoff A, Oliver J, Cronin J, Harrison C, Winwood P. Sprint-specific training in youth: Backward running vs. forward running training on speed and power measures in adolescent male athletes. *J Strength Cond Res.* 2020;34(4):1113-1122. doi: 10.1519/JSC.0000000000002914.
59. Hoffman JR, Ratamess NA, Klatt M, et al. Comparison between different off-season resistance training programs in Division III American college football players. *J Strength Cond Res.* 2009;23(1):11-19. doi: 10.1519/jsc.0b013e3181876a78.
60. Wilder N, Gilders R, Hagerman F, Deivert RG. The effects of a 10-week, periodized, off-season resistance-training program and creatine supplementation among collegiate football players. *J Strength Cond Res.* 2002;16(3):343-352.
61. Stodden DF, Galitski HM. Longitudinal effects of a collegiate strength and conditioning program in American football. *J Strength Cond Res.* 2010;24(9):2300-2308. doi: 10.1519/JSC.0b013e3181dc4255.
62. Cahill MJ, Oliver JL, Cronin JB, et al. Influence of Resisted Sled-Pull Training on the Sprint Force-Velocity Profile of Male High-School Athletes. *J Strength Cond Res.* 2020;34(10):2751-2759. doi: 10.1519/JSC.0000000000003770
63. Zafeiridis A, Saraslanidis P, Manou V, Ioakimidis P. The effects of resisted sled-pulling sprint training on acceleration and maximum speed performance. *J Sports Med Phys Fitness.* 2005;45(3):284.
64. Cronin J, Hansen K. Resisted Sprint Training for the Acceleration Phase of Sprinting. *ECU Publications.* 2006;28.
65. Suarez-Arrones L, Saez de Villarreal E, Nunez FJ, et al. In-season eccentric-overload training in elite soccer players: Effects on body composition, strength and sprint performance. *PLoS One.* 2018;13(10):e0205332.
66. De Hoyo M, Gonzalo-Skok O, Sanudo B, et al. 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.* 2016;30(2):368-377. doi: 10.1519/JSC.0000000000001094.
67. Gil S, Barroso R, Crivoi do Carmo E, et al. Effects of resisted sprint training on sprinting ability and change of direction speed in professional soccer players. *J Sports Sci.* 2018;36(17):1923-1929. doi: 10.1080/02640414.2018.1426346.
68. Brughelli M, Cronin J, Levin G, Chaouachi A. Understanding change of direction ability in sport. *Sports Med.* 2008;38(12):1045-1063. doi: 10.2165/00007256-200838120-00007.
69. Lockie RG, Murphy AJ, Schultz AB, Knight TJ, de Jonge XAJ. The effects of different speed training protocols on sprint acceleration kinematics and muscle strength and power in field sport athletes. *J Strength Cond Res.* 2012;26(6):1539-1550. doi. 10.1519/JSC.0b013e318234e8a0.
70. Prieske O, Krüger T, Aehle M, Bauer E, Granacher U. Effects of resisted sprint training and traditional power training on sprint, jump, and balance performance in healthy young adults: a randomized controlled trial. *Front physiol.* 2018;9:156. doi: 10.3389/fphys.2018.00156.
71. Morin J-B, Petrakos G, Jiménez-Reyes P, Brown SR, Samozino P, Cross MR. Very-heavy sled training for improving horizontal-force output in soccer players. *Int J Sports Physiol Perform.* 2017;12(6):840-844. doi: 10.1123/ijspp.2016-0444.
72. Markovic G, Jaric S. Is vertical jump height a body size-independent measure of muscle power? *J Sports Sci.* 2007;25(12):1355-1363. doi. 10.1080/02640410601021713.
73. Ziv G, Lidor R. Vertical jump in female and male basketball players—A review of observational and experimental studies. *J Sci Med Sport.* 2010;13(3):332-339. doi. 10.1016/j.jsams.2009.02.009.
74. Markovic G, Dizdar D, Jukic I, Cardinale M. Reliability and factorial validity of squat and countermovement jump tests. *J Strength Cond Res.* 2004;18(3):551-555. doi: 10.1519/1533-4287.
75. Loturco I, Kobal R, Kitamura K, et al. Mixed Training Methods: Effects of Combining Resisted Sprints or Plyometrics with Optimum Power Loads on Sprint and Agility Performance in Professional Soccer Players. *Front Physiol.* 2017;8:1034.
76. Álvarez JAE, García JPF, Conceição F, Solera-Herrera A,

Reyes PJ. Effect of resisted sled training with the optimal loading for power output on jumping and acceleration performance in basketball players. 2020.

77. Bachero-Mena B, 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.* 2014;28(10):2954-2960. doi: 10.1519/JSC.0000000000000492.
78. Pareja-Blanco F, Asián-Clemente JA, Sáez de Villarreal E. Combined Squat and Light-Load Resisted Sprint Training for Improving Athletic Performance. *J Strength Cond Res.* 2019; 35(9):2457-2463. doi: 10.1519/JSC.0000000000003171.

Corresponding information:
Received: 17.12.2023.
Accepted: 25.02.2024.
Correspondence to: *Elena Mainer-Pardos PhD.
University: Faculty of Health Sciences, University of San Jorge, Autovía A-23 Zaragoza- Huesca Km. 299, 50830 Zaragoza, Spain
E-mail: epardos@usj.es