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*Published in:*  
Applied Sciences

*DOI:*  
[10.3390/app11125587](https://doi.org/10.3390/app11125587)

Published: 17/06/2021

*Document Version*  
Publisher's PDF, also known as Version of record

[Link to publication on the UWS Academic Portal](#)

*Citation for published version (APA):*

Aloui, G., Hermassi, S., Hayes, L. D., Bouhaf, E. G., Chelly, M. S., & Schwesig, R. (2021). Effects of loaded combined plyometrics and short sprints with change-of-direction training on athletic performance of soccer players. *Applied Sciences*, 11(12). <https://doi.org/10.3390/app11125587>

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## Article

# Loaded Plyometrics and Short Sprints with Change-of-Direction Training Enhance Jumping, Sprinting, Agility, and Balance Performance of Male Soccer Players

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**Citation:** Aloui, G.; Hermassi, S.; Hayes, L.D.; Bouhafs, E.G.; Chelly, M.S.; Schwesig, R. Loaded Plyometrics and Short Sprints with Change-of-Direction Training Enhance Jumping, Sprinting, Agility, and Balance Performance of Male Soccer Players. *Appl. Sci.* **2021**, *11*, 5587. <https://doi.org/10.3390/app11125587>

Academic Editor: Robert Koprowski

Received: 12 May 2021

Accepted: 15 June 2021

Published: 17 June 2021

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**Featured Application:** The investigation examined the effectiveness of an 8-week loaded plyometric with short sprints and change-of-direction training program on athletic performance in elite adolescent soccer players. We report that replacing some aspects of typical training with loaded plyometric with short sprints and change-of-direction training improved jump performance, sprinting, agility, and balance performance in soccer players.

**Abstract:** This project investigated effects of 8 weeks of biweekly loaded combined plyometric and short sprint with change-of-direction training an in-season regimen of young soccer players. An experimental ( $n = 17$ , age:  $16.5 \pm 0.5$  years, body mass:  $64.5 \pm 5.2$  kg, height:  $1.73 \pm 0.07$  m,) and control group ( $n = 17$ , age:  $16.7 \pm 0.5$  years, body mass:  $65.6 \pm 4.8$  kg, height:  $1.74 \pm 0.07$  m) were tested pre- and post-intervention for squat-jump (SJ), countermovement-jump (CMJ), and five-jump test (5JT), 10 m and 30 m sprint performance, change-of-direction ability, and dynamic balance performance. The experimental group (EG) outperformed the control group (CG) over 8 weeks in jumping ( $p < 0.001$ ;  $d = 0.98$ – $1.17$ ), 10 m sprinting ( $p < 0.001$ ;  $d = 0.94$ ), change-of-direction ability ( $p < 0.001$ ;  $d = 1.24$ ), and dynamic balance performance ( $p < 0.001$ ;  $d = 0.53$ – $0.74$ ). We conclude that adding biweekly loaded plyometric with short sprints and change-of-direction training to habitual training improves athleticism of young soccer players. Therefore, loaded plyometric with short sprints and change-of-direction training should be implemented as a part of research-informed soccer training.

**Keywords:** change-of-direction training; plyometric training; team sports; stretch-shortening cycle

## 1. Introduction

Soccer is typified by intermittent exercise bouts with contributions from aerobic and anaerobic metabolism [1–4]. Therefore, soccer training should mimic this load characteristic in terms of the physiological and biomechanical stimuli in order to induce subsequent adaptation [5]. During match play soccer players cover 10–13 km in distance and complete ~1350 activities (one every 4–6 s), such as multiple changes of direction, jumps, and sprints, involving acceleration, decelerations, and re-accelerations, which are interspersed

with brief periods of recovery [6–8]. In youth soccer, endurance, speed, and muscle strength are essential physical skills, meaning young soccer players are often selected when they demonstrate superiority over peers in one or several of these physical qualities [9]. Consequently, exercise programs should include stimuli to generate positive adaptations regarding the agility (ability to accelerate, change of direction) [10–13].

Davids et al. [14] noted that change-of-direction ability represents a key performance indicator that should be incorporated into soccer conditioning programs. Few previous investigations have explored whether the addition of loaded plyometric with short sprints and change-of-direction training into the soccer season is efficacious for improving jumping, sprinting, and agility. Hammami et al. [10] found a combination of 10-week loaded and unloaded combined plyometrics and short sprint training enhanced change-of-direction ability in elite junior male soccer players (U17). These researchers also noted significant improvement in sprint performance (5, 10, 20, 30, and 40 m), vertical and horizontal jumping, and change of direction ability. Furthermore, Makhoulf et al. [11] and Michailidis et al. [12] observed improved change of direction ability, dynamic balance, vertical and horizontal jumps, and sprinting after plyometric and short sprints with changes of direction training in prepubertal male soccer players.

Mechanisms underpinning these adaptations are relatively well understood, but implementation of these training modes in youth soccer have not been examined thoroughly. Plyometric training exploits the use stretch-shortening cycle (SSC), characterized by an eccentric muscle contraction followed instantaneously by a concentric contraction [15]. The SSC can be summarized as improving the capacity of the neural system and muscle-tendon unit to produce maximum force in a short time [16]. In this context, improved ability to exert force in a short time (i.e., power) positively associates with field test performance in sprinting, agility, and jumping, which are all enhanced after plyometric training [16–18]. Recently, a systematic review of the literature reported plyometric training improved muscle power in 13 of 16 studies analyzed, with improvements ranging from 2% to 31% [19]. Due to the overwhelming support of plyometric training to enhance muscle power, Besier et al. [20] recommended including plyometrics in soccer players' habitual training program. In terms of mechanisms, eccentric actions (such as the countermovement of a vertical jump), with an immediate concentric contraction (such as the take-off phase) results in a stretch reflex, potentiating power output during the concentric contraction [21]. Muscle spindles are not sensitive to the loading of muscle but are sensitive to the rate and magnitude of stretch [22,23]. For this reason, one method to augment plyometric training adaptation is to use additional loads in addition to body mass of individuals [13,24–27]. Furthermore, short sprints with change-of-direction exercises have been also used as a training method of increasing explosive performance of athletes [28,29]. In addition, a common trend in the training programs indicates that a combination of training methods is most effective to improve athletic performance than standalone approaches [30]. To our knowledge, the only study that investigated the effects of combined loaded plyometric and short sprints training on athletic performance of male young soccer players is that of Hammami et al. [10]. They reported significant improvement in sprint performance, jumping, change of direction ability, and balance performance.

Despite the efficacious nature of plyometric, sprint training, and agility training to enhance jumping, sprinting, and agility, scarce research has concerned effects of loaded plyometric with short sprints and change-of-direction training on jumping, sprinting, agility, and balance in elite youth soccer players (U17). The aim of this investigation was therefore to explore effects of loaded plyometric with short sprints and change-of-direction training in elite male junior soccer players (U17). We hypothesized a priori that replacing part of the regular in-season training by 8 weeks of biweekly loaded plyometric with short sprints and change-of-direction training would improve both horizontal and vertical jump performance, sprint performance, agility, and balance when compared with a control group, who continued with their usual training during the season. Specifically, we examined vertical and horizontal jump performance (i.e., squat jump [SJ], countermovement jump

with arm swing [CMJA], and the 5 jump test [5JT]), sprint performance (i.e., 10 m and 30 m sprint), change-of-direction ability ( $S90^\circ$ ), repeated change of direction ability (RCOD), and dynamic balance performance (Y balance test).

## 2. Materials and Methods

### 2.1. Participants

Thirty-four players from a single male soccer team from the highest National division participated. Participants had a playing experience of  $6.6 \pm 0.9$  years and prior to the study were examined by the team doctor. Participants were randomly allocated between an experimental group ( $n = 17$ , age:  $16.5 \pm 0.5$  years, body mass:  $64.5 \pm 5.2$  kg, stature:  $1.73 \pm 0.07$  m, body fat:  $11.7 \pm 1.2\%$ , lower limb muscle volume:  $7.7 \pm 1.0$  L, thigh muscle volume:  $5.2 \pm 0.2$  L, and cross-sectional area:  $165 \pm 16.5$  cm<sup>2</sup>) and a control group ( $n = 17$ , age:  $16.7 \pm 0.5$  years, body mass:  $65.6 \pm 4.8$  kg, height:  $1.74 \pm 0.07$  m, body fat:  $11.5 \pm 1.6\%$ , lower limb muscle volume:  $7.6 \pm 1.1$  L, thigh muscle volume:  $5.3 \pm 0.31$  L, and cross-sectional area:  $168 \pm 13.4$  cm<sup>2</sup>). No significant initial inter-group differences of age and anthropometric characteristics were observed at baseline (age:  $p = 0.280$ ; height:  $p = 0.718$ ; body mass:  $p = 0.527$ ; body fat:  $p = 0.678$ ; lower limb muscle volume:  $p = 0.781$ ; thigh muscle volume:  $p = 0.624$ ).

Prior to the study, participants were well-conditioned as they had completed an 8-week training period of 5–6 training sessions per week. These eight weeks were comprised of resistance training program initially targeting hypertrophy and muscle force. In the final three of these eight weeks, muscular power was targeted by reducing the load and increasing the contraction velocity. Every weekend, participants partook in a noncompetitive training match. Participants participated in five weekly training sessions throughout the championship season.

### 2.2. Experimental Design

Participants did not train in their own time and therefore only trained with the soccer team during the study. Both the experimental and control group trained five times per week (~1.5 h per session), with a competitive fixture at the weekend. Conditioning sessions were undertaken twice per week. The first of these sessions was a high intensity interval training (HIIT) session and small-sided games [31]. The second session comprised resistance training exercises such as half squats, overhead lunges, and countermovement and squat jumps. The other training sessions focused on tactical and technical skills (Table 1).

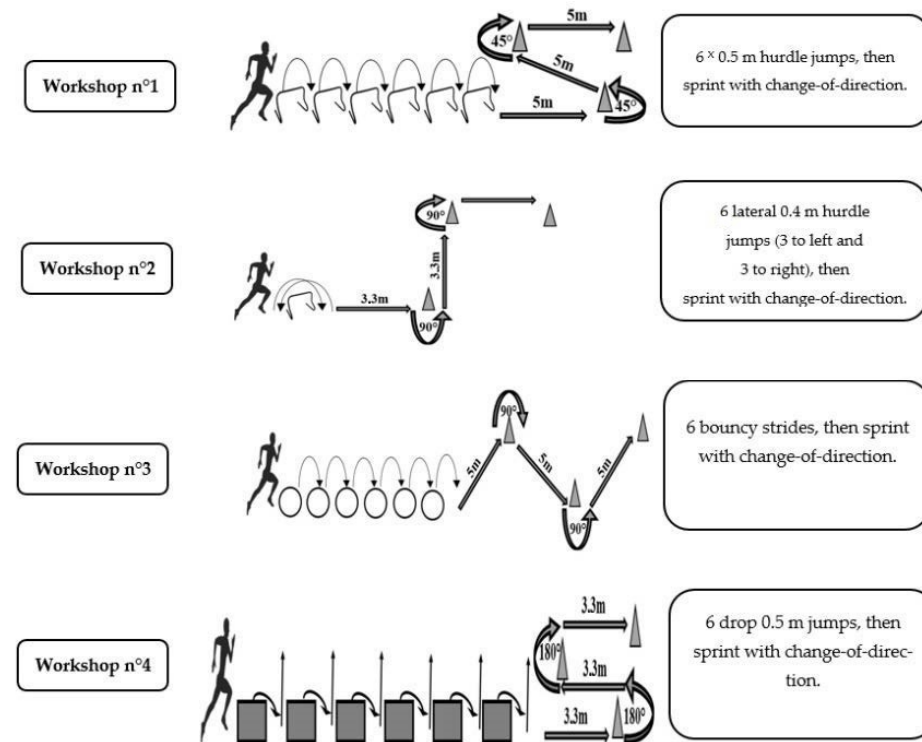
**Table 1.** Details of the weekly training routine of participants performed by both control and experimental groups over the 8-week intervention.

Days	Objectives
Mondays	Rest
Tuesdays	Aerobic training/Defensive tactics training
Wednesdays	Maximum power aerobic/Defensive tactics training
Thursdays	Power anaerobic training/Defensive and offensive tactics training.
Fridays	Technical training/Offensive tactics training.
Saturdays	Technical training/Offensive tactics training.
Sunday	Official games.

The University Institutional Review Committee for the ethical human experimentation approved the study (reference number: KS00000–KS2021 and date of approval 10 December 2020). Participants (and their guardians, in the case of minors) provided written informed consent. Two familiarization sessions were held 2 weeks before testing, and testing commenced 2 months after the start of the competitive season.

The loaded plyometrics and short sprints with change-of-direction training program consisted of 4 principal workshops, twice per week (Figure 1). The plyometric training included vertical (i.e., hurdle jumps) and horizontal (i.e., bouncy strides and drop jumps)

jumps performed at maximal effort (i.e., maximal height and forward distance with a minimal contact time for vertical and horizontal jumping, respectively) [13]. For workshop n°3 (6 bouncy strides) the subject must perform a simple take off. The distance between the hurdles (workshop n°1) and between boxes (workshop n°4) was approximately 70 cm [32,33]. For workshop n°1, hoops were spaced approximately 1.8 m apart with the player placing the supporting leg in, after or before the hoop (just keep the same jumping axis).



**Figure 1.** Exercise used in loaded combined plyometric and short sprint with change-of-direction training jump.

Each workshop commenced with plyometric exercises (hurdle jumps, lateral hurdle jumps, bouncy strides, and drop jumps) and ended with short change-of-direction sprints. Details are given in Table 2.

**Table 2.** Plyometric components introduced into the program of the experimental group.

Week	Workshop 1	Workshop 2	Workshop 3	Workshop 4	Total (Contact)
1	3 Repetitions	3 Repetitions	3 Repetitions	3 Repetitions	72
2	3 Repetitions	3 Repetitions	3 Repetitions	3 Repetitions	72
3	4 Repetitions	4 Repetitions	4 Repetitions	4 Repetitions	96
4	4 Repetitions	4 Repetitions	4 Repetitions	4 Repetitions	96
5	5 Repetitions	5 Repetitions	5 Repetitions	5 Repetitions	120
6	5 Repetitions	5 Repetitions	5 Repetitions	5 Repetitions	120
7	6 Repetitions	6 Repetitions	6 Repetitions	6 Repetitions	144
8	6 Repetitions	6 Repetitions	6 Repetitions	6 Repetitions	144

All repetitions and workshops were separated by 90-s recovery intervals.

The experimental group executed all workshops with a weighted vest (8% body mass) [13,27]. The training protocol was informed by recommendations from Bedoya et al. [34] and recommendations for change of direction ability promotion [35].

### 2.3. Testing Schedule

Tests were conducted  $\geq 3$  days following the last competitive fixture and 5–9 days after the final training session. Testing took place on a tartan surface and a standardized

warm-up preceded each test. Tests were completed over three separate testing days in the following order: anthropometric assessment, SJ and CMJ, S90° (all day 1), Y balance test, 30 m sprint (both day 2), 5JT and the RCOD (both day 3). The SJ, CMJA [24,36], S90° [37], Y balance test [38,39], 10 and 30 m sprint performance [40], 5JT [10], and the RCOD [2,41] were all previously described in detail so are not outlined here for brevity and to avoid self-plagiarism [24,39]. The anthropometric characteristics (body mass and body fat percentage) using by were evaluated barefoot in the morning hours (7–8 a.m.) after an overnight fast, with the electrical impedance method (BC–602, Tanita Co., Tokyo, Japan).

#### 2.4. Statistical Analysis

All statistical analysis were performed using SPSS version 25.0 for Windows (IBM, Armonk, NY, USA).

Normal distribution was confirmed for all variables using the Shapiro–Wilk test and Levene’s test confirmed homogeneity of variance for all variables, justifying parametric data analysis.

Unpaired t-tests tested for between-group differences at baseline. Paired sample t-tests were used to test for within-group differences from pre- to post-intervention. Training-related effects were assessed by 2-way (group × time) mixed factorial analysis of variance (ANOVA). Subsequently, if a main effect of group or time, or an interaction effect (group × time) was observed, Tukey’s post hoc procedure located pairwise differences. Alpha level is reported as exact *p* values as suggested by the American Statistical Association [42].

Cohen’s *d* if provided as a measure of effect size for paired comparisons whereby the difference in means between two samples was divided by the pooled standard deviation (SD). Thresholds of 0.2, 0.50, and 0.85 for Cohen’s *d* [43] were considered small, moderate, and large, respectively.

Reliability was assessed using intra-class correlation coefficients (ICC) [44] with 95% confidence intervals (CI) and coefficients of variation (CV) over consecutive pairs of intra-participant trials [45]. All measures of jumping, sprinting, change of direction ability, and balance performance had an ICC > 0.80 and a CV < 5%.

Data are reported as mean ± SD, other than reliability data which is given as ICC (95% CI) or CV (95% CI).

### 3. Results

Reliability data are summarized in Table 3.

**Table 3.** Interclass correlation coefficient (ICC, 95% confidence intervals (CI)) and coefficient of variation (CV) for all fitness tests.

	ICC (95%CI)	CV (95% CI)
<i>Vertical jump</i>		
SJ (cm)	0.98 (0.94–0.99)	2.4 (2.0–2.7)
CMJA (cm)	0.97 (0.93–0.99)	2.6 (2.3–2.9)
<i>Horizontal jump</i>		
5JT (cm)	0.88 (0.84–0.93)	4.2 (3.8–4.6)
<i>Sprint times</i>		
10 m (s)	0.96 (0.93–0.98)	1.8 (1.4–2.3)
30 m (s)	0.95 (0.92–0.98)	1.9 (1.6–2.3)
<i>Change of direction test</i>		
S90° (s)	0.93 (0.90–0.97)	1.6 (1.3–1.9)
<i>Y-balance test</i>		
Right support leg		
Anterior direction (cm)	0.98 (0.93–0.99)	4.5 (4.0–4.9)
Posteromedial direction (cm)	0.98 (0.93–0.99)	4.3 (3.8–4.7)
Posterolateral direction (cm)	0.96 (0.94–0.99)	4.7 (4.3–5.2)



**Table 3.** *Cont.*

	ICC (95%CI)	CV (95% CI)
Left support leg		
Anterior direction (cm)	0.98 (0.94–0.99)	4.6 (4.2–5.0)
Posteromedial direction (cm)	0.97 (0.94–0.99)	4.3 (3.9–4.7)
Posterolateral direction (cm)	0.95 (0.91–0.97)	4.8 (4.5–5.3)

There were no baseline differences between groups.

*Effect of Training on Performance*

There was a significant group × time interaction for SJ, CMJA, 5JT, 10 and 30 m sprint, and SJ90° (Table 4). There was a significant group × time interaction for RCOD best, RCOD mean, and RCOD total (Table 5). Similarly, there was a group × interaction effect for the anterior, posteromedial, and posterolateral direction r for right support leg during the Y balance test and on the anterior, posteromedial, and posterolateral direction for left support leg.

**Table 4.** Vertical and horizontal jump test, sprint times, and change of direction performance performances in experimental and control groups before and after 8-week intervention.

	Experimental (n = 17)			Paired t-Test		Control (n = 17)			Paired t-Test		ANOVA (Group × Time)	
	Pre	Post	% Δ	p	d	Pre	Post	% Δ	p	d	p	ES
<i>Vertical jump</i>												
SJ (cm)	27.2 ± 2.2	33.6 ± 2.1	23.6 ± 3.7	<0.001	2.95	27.59 ± 2.38	28.79 ± 2.39	4.38 ± 0.92	<0.001	0.50	<0.001	1.17 (large)
CMJA (cm)	33.4 ± 3.6	40.7 ± 3.8	22.2 ± 2.4	<0.001	1.99	33.49 ± 2.33	34.96 ± 2.43	4.39 ± 0.96	<0.001	0.62	<0.001	0.98 (large)
<i>Horizontal jump</i>												
5JT (m)	10.9 ± 0.43	12.5 ± 0.49	14.3 ± 1.2	<0.001	3.38	11.1 ± 0.50	11.6 ± 0.51	4.3 ± 1.2	<0.001	1.02	<0.001	1.16 (large)
<i>Sprint</i>												
10 m (s)	1.9 ± 0.07	1.74 ± 0.06	−8.6 ± 0.78	<0.001	2.51	1.9 ± 0.06	1.83 ± 0.07	−2.4 ± 0.62	<0.001	0.70	<0.001	0.94 (large)
30 m (s)	4.64 ± 0.17	4.31 ± 0.16	−7.0 ± 0.49	<0.001	1.93	4.56 ± 0.24	4.45 ± 0.24	−2.6 ± 0.51	<0.001	0.05	0.041	0.52 (medium)
<i>Change of direction performance</i>												
S90° (s)	7.67 ± 0.21	6.98 ± 0.16	−9.0 ± 0.84	<0.001	3.75	7.60 ± 0.25	7.41 ± 0.21	−2.5 ± 0.64	<0.001	0.82	<0.001	1.24 (large)

Note: A 2-way analysis of variance (group × time) assessed the statistical significance of training-related effects.

**Table 5.** Repeated change of direction and Y balance test performances in experimental and control groups before and after 8-week intervention.

	Experimental (n = 17)			Paired t-Test		Control (n = 17)			Paired t-Test		ANOVA (Group × Time)	
	Pre	Post	% Δ	p	d	Pre	Post	% Δ	p	d	p	ES
<i>Repeated Change of Direction Ability parameters</i>												
Fast Time (s)	6.90 ± 0.28	6.30 ± 0.25	−7.6 ± 0.59	<0.001	1.94	6.80 ± 0.30	6.68 ± 0.30	−1.8 ± 0.43	<0.001	0.41	0.005	0.73 (medium)
Mean Time (s)	7.00 ± 0.25	6.50 ± 0.24	−7.8 ± 0.68	<0.001	2.26	7.00 ± 0.27	6.83 ± 0.26	−1.8 ± 0.56	<0.001	0.45	0.001	0.84 (large)
Fatigue Index (%)	2.4 ± 1.40	2.20 ± 0.91	−1.8 ± 26.9	0.284	0.17	2.80 ± 0.70	2.20 ± 0.90	−1.7 ± 22.9	0.841	0.03	0.650	0.11 (small)
<i>Y-balance test—Right support leg</i>												
Anterior direction (cm)	86.2 ± 5.60	94.3 ± 5.20	8.6 ± 2.00	<0.001	1.50	87.1 ± 5.60	89.0 ± 5.60	2.18 ± 1.3	<0.001	0.35	0.024	0.58 (medium)
Posteromedial direction (cm)	109 ± 5.50	120 ± 4.60	8.7 ± 2.40	<0.001	2.04	110 ± 5.90	113 ± 6.20	2.1 ± 1.3	<0.001	0.39	0.004	0.74 (medium)
Posterolateral direction (cm)	55.8 ± 6.80	63.4 ± 7.30	12.0 ± 2.20	<0.001	1.08	56.6 ± 3.70	58.2 ± 4.40	2.7 ± 2.2	<0.001	0.40	0.037	0.53 (medium)
<i>Y-balance test—Left support leg</i>												
Anterior direction (cm)	88.2 ± 6.50	98.1 ± 7.60	10.0 ± 2.10	<0.001	1.39	88.8 ± 5.70	91.1 ± 5.60	2.5 ± 1.1	<0.001	0.40	0.019	0.61 (medium)
Posteromedial direction (cm)	108 ± 10.3	122 ± 9.30	11.2 ± 3.50	<0.001	1.38	109 ± 8.10	112 ± 8.00	2.2 ± 1.6	<0.001	0.34	0.015	0.63 (medium)
Posterolateral direction (cm)	55.4 ± 5.30	62.9 ± 5.20	12.0 ± 2.60	<0.001	1.43	58.1 ± 4.60	59.8 ± 4.70	2.8 ± 2.1	<0.001	0.37	0.019	0.61 (medium)

Note: A 2-way analysis of variance (group × time) assessed the statistical significance of training-related effects.

## 4. Discussion

This study examined the effect of substituting some regular in-season training with 8 weeks of biweekly loaded plyometric with short sprints and change-of-direction training in elite adolescent soccer players. In this context, we accept our hypothesis that replacing some regular in-season training by 8 weeks of biweekly loaded plyometric with short sprints and change-of-direction training would improve both horizontal and vertical jump performance, sprint performance, agility, and balance.

### 4.1. Effect of Training on Jump Performance

Both vertical acceleration (jumping power) and horizontal acceleration (sprinting) are important in ball possession, repossession, corner kicks, defense play, and attack on goal [46]. Arnason et al. [47] reported that high level competitive players jump higher than lower performance level players. Here we report training effects on vertical and horizontal jump performance. To the authors' knowledge, this study is the first that investigated effects of loaded plyometric with short sprints and change-of-direction training on jump performance in young soccer players. Our data are in agreement with several previous investigations which have described improved jump performance following unloaded combined plyometric and short sprint with change-of-direction training [12,35,39] and loaded and unloaded combined plyometric and short sprint training [10].

Recently, Hammami et al. [10] studied effects of 10-week loaded and unloaded combined plyometric and short sprint training in junior soccer players (U17 elite males). They observed significant improvement in jump performance (SJ,  $p < 0.001$ ; CMJ,  $p < 0.01$ ; CMJA,  $p < 0.01$ ; and 5JT test,  $p < 0.01$ ) after both types of training programs. In addition, Michailidis et al. [12] studied the effects of a 6-week plyometric training and change-of-direction exercises in prepubertal male soccer players. These researchers noted significant improvement in vertical and horizontal jumps performance (squat jump and long jump,  $p < 0.05$ ) but no gain in CMJ and 5JT. Indeed, Hammami et al. [36] studied the influence of 8 weeks of combined plyometric and short sprint with change-of-direction training jump performance in young male handball players (U15) and reported improved jump performance (39%,  $d = 0.26$ ; small; 29%,  $d = 0.26$ ; small; 26%,  $d = 0.25$ ; small; and 13%,  $d = 0.09$ ; small for SJ, CMJ, CMJA, and 5JT, respectively).

Mechanisms which underpin the improved jump performance following plyometric training are commonly explained by neural factors such as more synergistic muscle activation and less antagonistic muscle activation (i.e., intermuscular coordination) and greater motor unit recruitment (i.e., intramuscular coordination) [48]. Furthermore, Kobal et al. [26] reported that the use of additional load during executed jumps allowed players to apply greater force against the ground in the direction of intended movement (vertical or horizontal axes) on a longer period of time. This mechanical adjustment generates higher impulses (possibly additional overload) during jumps [49], thus producing a greater adaptation of jumping ability in the loaded group [26].

### 4.2. Effect of Training on Sprint Performance

To the authors' knowledge, this study is the first that investigated effects of loaded plyometric with short sprints and change-of-direction training on sprint performance in young soccer players. In our study, we could show relevant improvements in both type of sprints. The interaction effects ( $d$ ) differed from 0.52 (30 m) to 0.94 (10 m). The improvements in the EG ( $d$  range: 1.93–2.51) were markedly higher than in the CG ( $d$  range: 0.05–0.70). Improved sprint performance observed herein are in agreement with those of Hammami et al. [10] who examined effects of a 10-week loaded and unloaded combined plyometric and short sprint training in elite junior male soccer players (U17). These researchers reported improvements in sprint performance over 5 ( $p < 0.001$ ), 10 ( $p < 0.001$ ), 20 ( $p < 0.01$ ), 30 ( $p < 0.001$ ), and 40 m ( $p < 0.05$ ) sprint times, after both training programs. Similarly, Michailidis et al. [12] reported improvement in sprint performance over distance of 10 m ( $p < 0.05$ ), but no gain over a distance of 30 m after a 6-week plyometric



training and change-of-direction exercises in prepubertal male soccer players. Hammami et al. [50] reported increases in 5, 10, 20, and 30 m sprint times (9%,  $d = 0.14$ ; 7%,  $d = 0.21$ ; 7%,  $d = 0.10$ ; and 9%,  $d = 0.90$ , respectively), following combined plyometric and short sprint with change-of-direction training in male U15 handball players. Contrary to our results, few studies [51–53] found no gain in sprinting performance following plyometric training in young male soccer players and physical education students. Previous studies have shown that the sprint training charge may increase eccentric strength of extensor muscles during the braking phase of the contact with the ground and increase the rigidity of the springs and leg muscles, potentially increasing the ability of muscle to store elastic energy and improve power output [54,55]. In addition, the contradictory results may be explicated by divergence in training programs and sample populations.

#### 4.3. Effect of Training on Change of Direction Ability

To the best of our knowledge, the present investigation is the first to have studied the effects of loaded combined plyometric and short sprints with change-of-direction on change of direction ability, in young soccer players. Our findings of improved ability to change direction are in accordance with Hammami et al. [10] who reported significant improvement in change of direction ability after a 10-week loaded and unloaded plyometric and short sprint training in elite junior male soccer players. We detected the largest performance improvements (interaction effect:  $d = 1.24$ ) for all investigated parameters in the ability to change direction. The increase in performance in the EG ( $d = 3.75$ ) was more than four times as high as in the CG ( $d = 0.82$ ).

Moreover, Michailidis et al. [12] observed improved ability to change direction following combination of plyometric training and change-of-direction exercises, in prepubertal male soccer players. Indeed, Makhlouf et al. [11] observed improved change of direction ability (Illinois agility test (ICODT) without a ball and 4-m  $\times$  9-m shuttle run test (Agility 4 m  $\times$  9 m), following combined plyometric and short sprint with change-of-direction training, in prepubertal male soccer players. Conversely, Beato et al. [35] examined effects of plyometric and change-of-direction training in elite youth soccer players (U18) for six weeks and observed no gain after training. Loaded sprint training can modify stride length, stride frequency, contact time, and horizontal force production adequately to improve acceleration [56,57], improving the management of change in performance [58]. In addition, dissimilarities in acute program variables (duration, intensity, and frequency) and methodology (period and duration of studies and age, gender, and competitive level of players) could contribute to discrepancies between study results.

#### 4.4. Effect of Training on Repeated Change of Direction Ability

This is the first investigation of the effects of loaded combined plyometric and short sprints with change-of-direction training on the ability of youth soccer players to repeated change of direction. The relevant improvements of performance in our study in this ability ranged in the EG from  $d = 1.94$  (fast time) to  $d = 2.26$  (mean time) and in the CG from  $d = 0.41$  (fast time) to  $d = 0.45$  (mean time). In contrast to the medium (fast time;  $d = 0.73$ ) and large (mean time;  $d = 0.84$ ) interaction effects, the changes regarding fatigue index were small in both groups ( $d = 0.03$  and  $0.17$ ) and not significantly different between groups ( $p = 0.650$ ). Our results of improved repeated change of direction ability (fast and mean time) corroborate those of Hammami et al. [10] who observed improved repeated change of direction ability parameters except the fatigue index after 10 weeks of loaded and unloaded combined plyometric and short sprint training in elite junior male soccer players (U17). In addition, Hammami et al. [50] examined the influence of combined plyometric and short sprint with change-of-direction training on RCOD in U15 male handball players and reported no improvement. One potential explanation for lack of change in RCOD fatigue index may be its poor reproducibility [59] or differences in the duration of the training protocol, period of the season, and players' level.

#### 4.5. Effect of Training on Balance Performance

To our knowledge, our study is the only one that has examined the effects of loaded combined plyometric and short sprints with change-of-direction training program on balance performance in young soccer players. We observed significant and relevant intervention effects for dynamic balance performance. All calculated interaction effects moved on a similar (medium) level ( $d$  range: 0.58–0.74). The effect size  $d$  in the EG ranged from 1.38 (left support leg, posteromedial direction) to 2.04 (right support leg, posteromedial direction). On the other hand, the changes in the CG were only small ( $d$  range: 0.34–0.40). Ricotti et al. [60] reported soccer players from a higher competition level (i.e., division) perform better at balance tests than those from a lower competition level. Balance may be important in soccer as Hrysonmallis et al. [61] observed poor balance associates with increased ligament injury risk. Our data corroborate results of Makhlof et al. [8] who examined effects of 8 weeks of plyometric change-of-direction training in prepubertal male soccer players and noted improved dynamic balance (Y-balance test). In contrast, our results disagreed with the results of Hammami et al. [10] who considered the effects of a 10-week loaded and unloaded combined plyometric and short sprint training program, in elite junior male soccer players (U17). These authors reported no gain in dynamic balance performance (Y-balance test) after both types training programs. In addition, Hammami et al. [50] reported no intervention effects for the Y-balance test following combined plyometric and short sprint with change-of-direction training in male U15 handball players. Because balance improvements may reduce lower extremity injury risk in soccer players [62], our results emphasize the worth of this type of training as a strategy to reduce risk of injury. Nevertheless, it seems that the significant increases in balance performance found for both legs, in our study, are mainly due to the improvement of motor coordination: the improvement of the neuromuscular control of the muscle groups of the lower limbs [63].

#### 4.6. Practical Implications

This study showed biweekly in-season loaded plyometrics and short sprints with change-of-direction training enhances jump performance, sprinting, change-of-direction ability, the ability to repeatedly change direction, and balance performance, in elite adolescent soccer players. Therefore, strength and conditioning coaches should incorporate loaded plyometrics and short sprints with change-of-direction training into in-season soccer training to enhance fitness.

### 5. Conclusions

In conclusion, adding loaded plyometrics and short sprints with change-of-direction training to standard training improves jump performance, sprinting, change-of-direction ability, and balance performance. As such, these data support inclusion of this form of training into in-season soccer training. Future studies may wish to extend these results to other genders, age groups, and competitive level of players. It is also necessary to compare the performance gains in tests with the improvement during competition. Finally, future studies could examine effects of loaded combined plyometric and short sprint with change-of-direction training on other physical qualities.

**Author Contributions:** Conceptualization, G.A. and G.A.; methodology, G.A.; software, G.A.; validation, S.H., M.S.C. and G.A.; formal analysis, E.G.B.; investigation, G.A.; resources, M.S.C.; data curation, G.A.; writing—original draft preparation, G.A.; writing—review and editing, L.D.H. and S.H.; visualization, R.S.; supervision, M.S.C.; project administration, G.A.; funding acquisition, R.S. All authors have read and agreed to the published version of the manuscript.

**Funding:** The authors thank the Ministry of Higher Education and Scientific Research, Tunis, Tunisia for financial support.

**Institutional Review Board Statement:** The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of Research Unit

(UR17JS01) Sport Performance, Health & Society, Higher Institute of Sport and Physical Education, Ksar-Saïd, University.

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The raw data supporting the conclusions of this article will be made available by the authors without undue reservation.

**Acknowledgments:** The authors thank the “Ministry of Higher Education and Scientific Research, Tunis, Tunisia” for financial support.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

- Girard, O.; Mendez-Villanueva, A.; Bishop, D. Repeated-sprint ability—Part I: Factors contributing to fatigue. *Sports Med.* **2011**, *41*, 673–694. [[CrossRef](#)]
- Del Wong, P.; Chan, G.S.; Smith, A.W. Repeated-sprint and change-of-direction abilities in physically active individuals and soccer players: Training and testing implications. *J. Strength Con. Res.* **2012**, *26*, 2324–2330. [[CrossRef](#)]
- Hader, K.; Mendez-Villanueva, A.; Ahmaidi, S.; Williams, B.K.; Buchheit, M. Changes of direction during high-intensity intermittent runs: Neuromuscular and metabolic responses. *BMC Sports Sci. Med. Rehabil.* **2014**, *6*, 2. [[CrossRef](#)]
- Rampinini, E.; Coutts, A.J.; Castagna, C.; Sassi, R.; Impellizzeri, F.M. Variation in top level soccer match performance. *Int. J. Sports Med.* **2007**, *28*, 1018–1024. [[CrossRef](#)]
- Born, D.P.; Zinner, C.; Düking, P.; Sperlich, B. Multi-directional sprint training improves change-of-direction speed and reactive agility in young highly trained soccer players. *J. Sports Sci. Med.* **2016**, *15*, 314–319. [[CrossRef](#)] [[PubMed](#)]
- Di Salvo, V.; Gregson, W.; Atkinson, G.; Tordoff, P.; Drust, B. Analysis of high intensity activity in Premier League soccer. *Int. J. Sports Med.* **2009**, *30*, 205–212. [[CrossRef](#)] [[PubMed](#)]
- Mohr, M.; Krusturup, P.; Bangsbo, J. Match performance of high-standard soccer players with special reference to development of fatigue. *J. Sports Sci.* **2003**, *21*, 519–528. [[CrossRef](#)] [[PubMed](#)]
- Mohr, M.; Krusturup, P.; Bangsbo, J. Fatigue in soccer: A brief review. *J. Sports Sci.* **2005**, *23*, 593–599. [[CrossRef](#)] [[PubMed](#)]
- Reilly, T.; Williams, A.M. (Eds.) Identifying talented players. In *Science and Soccer*; Routledg: London, UK, 2003; pp. 307–326.
- Hammami, M.; Gaamouri, N.; Suzuki, K. Effects of unloaded vs. ankle-loaded plyometric training on the physical fitness of U-17 male soccer players. *Int. J. Environ. Res. Public Health* **2020**, *17*, 7877. [[CrossRef](#)]
- Makhlouf, I.; Chaouachi, A.; Chaouachi, M.; Ben Othman, A.; Granacher, U.; Behm, D.G. Combination of agility and plyometric training provides similar training benefits as combined balance and plyometric training in young soccer players. *Front. Physiol.* **2018**, *9*, 1611. [[CrossRef](#)]
- Michailidis, Y.; Tabouris, A.; Metaxas, T. Effects of plyometric and directional training on physical fitness parameters in youth soccer players. *Int. J. Sports Physiol. Perform.* **2019**, *14*, 392–398. [[CrossRef](#)]
- Negra, Y.; Chaabene, H.; Sammoud, S.; Prieske, O.; Moran, J.; Ramirez-Campillo, R.; Nejmaoui, A.; Granacher, U. The increased effectiveness of loaded versus unloaded plyometric-jump training in improving muscle power, speed, change-of-direction, and kicking-distance performance in prepubertal male soccer players. *Int. J. Sports Physiol. Perform.* **2020**, *15*, 189–195. [[CrossRef](#)]
- Nicol, C.; Avela, J.; Komi, P.V. The stretch-shortening cycle: A model to study naturally occurring neuromuscular fatigue. *Sports Med.* **2006**, *36*, 977–999. [[CrossRef](#)] [[PubMed](#)]
- Taube, W.; Leukel, C.; Gollhofer, A. How neurons make us jump: The neural control of stretch-shortening cycle movements. *Exerc. Sport Sci. Rev.* **2012**, *40*, 106–115. [[CrossRef](#)] [[PubMed](#)]
- Wang, Y.-C.; Zhang, N. Effects of plyometric training on soccer players. *Exp. Ther. Med.* **2016**, *12*, 550–554. [[CrossRef](#)] [[PubMed](#)]
- Slimani, M.; Chamari, K.; Miarka, B.; Del Vecchio, F.B.; Chéour, F. Effects of plyometric training on physical fitness in team sport athletes: A systematic review. *J. Hum. Kinet.* **2016**, *53*, 231–247. [[CrossRef](#)]
- Yanci, J.; Los Arcos, A.; Camara, J.; Castillo, D.; García, A.; Castagna, C. Effects of horizontal plyometric training volume on soccer players’ performance. *Res. Sports Med.* **2016**, *24*, 308–319. [[CrossRef](#)]
- Coratella, G.; Beato, M.; Schena, F. The specificity of the Loughborough Intermittent Shuttle Test for recreational soccer players is independent of their intermittent running ability. *Res. Sports Med.* **2016**, *24*, 363–374. [[CrossRef](#)]
- Besier, T.F.; Lloyd, D.G.; Ackland, T.R.; Cochrane, J.L. Anticipatory effects on knee joint loading during running and cutting maneuvers. *Med. Sci. Sports Exerc.* **2001**, *33*, 1176–1181. [[CrossRef](#)]
- Avela, J.; Santos, P.M.; Komi, P.V. Effects of differently induced stretch loads on neuromuscular control in drop jump exercise. *Eur. J. Appl. Physiol. Occup. Physiol.* **1996**, *72*, 553–562. [[CrossRef](#)]
- Aloui, G.; Hermassi, S.; Hammami, M.; Cherni, Y.; Gaamouri, N.; Shephard, R.J.; van den Tillaar, R.; Chelly, M.S. Effects of elastic band based plyometric exercise on explosive muscular performance and change of direction abilities of male team handball players. *Front. Physiol.* **2020**, *11*, 604983. [[CrossRef](#)] [[PubMed](#)]
- Gollhofer, A.; Kyröläinen, H. Neuromuscular control of the human leg extensor muscles in jump exercises under various stretch-load conditions. *Int. J. Sports Med.* **1991**, *12*, 34–40. [[CrossRef](#)]

24. Coratella, G.; Beato, M.; Milanese, C.; Longo, S.; Limonta, E.; Rampichini, S.; Ce, E.; Bisconti, A.V.; Schena, F.; Esposito, F. Specific adaptations in performance and muscle architecture after weighted jump-squat vs. body mass squat jump training in recreational soccer players. *J. Strength Cond. Res.* **2018**, *32*, 921–929. [[CrossRef](#)] [[PubMed](#)]
25. Davids, K.; Lees, A.; Burwitz, L. Understanding and measuring coordination and control in kicking skills in soccer: Implications for talent identification and skill acquisition. *J. Sport Sci.* **2000**, *18*, 703–714. [[CrossRef](#)]
26. Kobal, R.; Pereira, L.A.; Zanetti, V.; Ramirez-Campillo, R.; Loturco, I. Effects of unloaded vs. loaded plyometrics on speed and power performance of elite young soccer players. *Front. Physiol.* **2017**, *8*, 742. [[CrossRef](#)]
27. Rosas, F.; Ramirez-Campillo, R.; Diaz, D.; Abad-Colil, F.; Martinez-Salazar, C.; Caniunqueo, A.; Canas-Jamet, R.; Loturco, I.; Nakamura, F.Y.; McKenzie, C.; et al. Jump training in youth soccer players: Effects of haltere type handheld loading. *Int. J. Sports Med.* **2016**, *37*, 1060–1065. [[CrossRef](#)] [[PubMed](#)]
28. Young, W.; Rogers, N. Effects of small-sided game and change-of-direction training on reactive agility and change-of-direction speed. *J. Sports Sci.* **2014**, *32*, 307–314. [[CrossRef](#)]
29. Sáez de Villarreal, E.; Molina, J.G.; de Castro-Maqueda, G.; Gutiérrez-Manzanedo, J.V. Effects of plyometric, strength and change of direction training on high-school basketball player's physical fitness. *J. Hum. Kinet.* **2021**, *78*, 175–186. [[CrossRef](#)]
30. Adams, K.; O'Shea, J.; O'Shea, K.; Climstein, M. The effects of six weeks of squat, plyometric and squat-plyometric training on power development. *J. Appl. Sports Sci. Res.* **1992**, *6*, 36–41.
31. Karahan, M. Effect of skill-based training vs. small-sided games on physical performance improvement in young soccer players. *Biol. Sport* **2020**, *37*, 305–312. [[CrossRef](#)]
32. Pinthong, M.; Bunlum, N.; Limroongreungrat, W. Effect of hurdle heights on jumping mechanics in youth male soccer players. *J. Sports Sci. Tec.* **2015**, *15*, 9–16.
33. Attene, G.; Iuliano, E.; Di Cagno, A.; Calcagno, G.; Moalla, W.; Aquino, G.; Padulo, J. Improving neuromuscular performance in young basketball players: Plyometric vs. technique training. *J. Sports Med. Phys. Fit.* **2014**, *55*, 1–8.
34. Bedoya, A.; Miltenberger, M.; Lopez, R. Plyometric training effects on athletic performance in youth soccer athletes: A systematic review. *J. Strength Cond. Res.* **2015**, *29*, 2351–2360. [[CrossRef](#)]
35. Beato, M.; Bianchi, M.; Coratella, G.; Merlini, M.; Drust, B. Effects of plyometric and directional training on speed and jump performance in elite youth soccer players. *J. Strength Cond. Res.* **2018**, *32*, 289–296. [[CrossRef](#)]
36. Hammami, M.; Ramirez-Campillo, R.; Gaamouri, N.; Aloui, G.; Shephard, R.J.; Chelly, M.S. Effects of a combined upper- and lower-limb plyometric training program on high-intensity actions in female U14 handball players. *Pediatric Exerc. Sci.* **2019**, *31*, 465–472. [[CrossRef](#)]
37. Sporis, G.; Jukic, I.; Milanovic, L.; Vucetic, V. Reliability and factorial validity of agility tests for soccer players. *J. Strength Cond. Res.* **2010**, *24*, 679–686. [[CrossRef](#)]
38. Gribble, P.A.; Hertel, J. Considerations for normalizing measures of the star excursion balance test. *Meas. Phys. Educ. Exerc. Sci.* **2003**, *7*, 89–100. [[CrossRef](#)]
39. Hammami, M.; Negra, Y.; Aouadi, R.; Shephard, R.J.; Chelly, M.S. Effects of an in-season plyometric training program on repeated change of direction and sprint performance in the junior soccer player. *J. Strength Cond. Res.* **2016**, *30*, 3312–3320. [[CrossRef](#)] [[PubMed](#)]
40. Negra, Y.; Chaabene, H.; Sammoud, S.; Bouguezzi, R.; Abbes, M.A.; Hachana, Y.; Granacher, U. Effects of plyometric training on physical fitness in prepuberal soccer athletes. *Int. J. Sports Med.* **2017**, *38*, 370–377. [[CrossRef](#)] [[PubMed](#)]
41. Glaister, M.; Howatson, G.; Pattison, J.R.; McInnes, G. The reliability and validity of fatigue measures during multiple-sprint work: An issue revisited. *J. Strength Cond. Res.* **2008**, *22*, 1597–1601. [[CrossRef](#)] [[PubMed](#)]
42. Hurlbert, S.; Levine, R.; Utts, J. Coup de Grâce for a tough old bull: “Statistically Significant” expires. *Am. Stat.* **2019**, *73*, 352–357. [[CrossRef](#)]
43. Cohen, J. *Statistical Power Analysis for the Behavioural Science*, 2nd ed.; Lawrence Erlbaum: Hillsdale, NJ, USA, 1988; ISBN 0805802835.
44. Vincent, W. *Statistics in Kinesiology*; Human Kinetics: Champaign, IL, USA, 1995.
45. Schabert, E.J.; Hopkins, W.G.; Hawley, J.A. Reproducibility of self-paced treadmill performance of trained endurance runners. *Int. J. Sports Med.* **1998**, *19*, 48–51. [[CrossRef](#)] [[PubMed](#)]
46. Haugen, T.A.; Tønnessen, E.; Seiler, S. Anaerobic performance testing of professional soccer players 1995–2010. *Int. J. Sports Physiol. Perform.* **2013**, *8*, 148–156. [[CrossRef](#)]
47. Arnason, A.; Sigurdsson, S.B.; Gudmundsson, A.; Holme, I.; Engebretsen, L.; Bahr, R. Physical fitness, injuries, and team performance in soccer. *Med. Sci. Sports Exerc.* **2004**, *36*, 278–285. [[CrossRef](#)]
48. Markovic, G.; Mikulic, P. Neuro-musculoskeletal and performance adaptations to lower-extremity plyometric training. *Sports Med.* **2010**, *40*, 859–895. [[CrossRef](#)]
49. Cronin, J.B.; Brughelli, M.; Gamble, P.; Brown, S.R.; McKenzie, C. Acute kinematic and kinetic augmentation in horizontal jump performance using haltere type handheld loading. *J. Strength Cond. Res.* **2014**, *28*, 1559–1564. [[CrossRef](#)]
50. Hammami, M.; Gaamouri, N.; Aloui, G.; Shephard, R.J.; Chelly, M.S. Effects of combined plyometric and short sprint with change-of-direction training on athletic performance of male U15 handball players. *J. Strength Cond. Res.* **2019**, *33*, 662–675. [[CrossRef](#)] [[PubMed](#)]

51. Herrero, J.A.; Izquierdo, M.; Maffiuletti, N.A.; García-López, J. Electromyostimulation and plyometric training effects on jumping and sprint time. *Int. J. Sports Med.* **2006**, *27*, 533–539. [[CrossRef](#)] [[PubMed](#)]
52. Markovic, G.; Jukic, I.; Milanovic, D.; Metikos, D. Effects of sprint and plyometric training on muscle function and athletic performance. *J. Strength Cond. Res.* **2007**, *21*, 543–549. [[CrossRef](#)] [[PubMed](#)]
53. Thomas, K.; French, D.; Hayes, P.R. The effect of two plyometric training techniques on muscular power and agility in youth soccer players. *J. Strength Cond. Res.* **2009**, *23*, 332–335. [[CrossRef](#)]
54. Cronin, J.; Hansen, K. Resisted sprint training for the acceleration phase of sprinting. *Strength Cond. J.* **2006**, *28*, 42–51. [[CrossRef](#)]
55. Clark, K.P.; Stearne, D.J.; Walts, C.T.; Miller, A.D. The longitudinal effects of resisted sprint training using weighted sleds vs. weighted vests. *J. Strength Cond. Res.* **2010**, *24*, 3287–3295. [[CrossRef](#)] [[PubMed](#)]
56. West, D.J.; Cunningham, D.J.; Bracken, R.M.; Bevan, H.R.; Crewther, B.T.; Cook, C.J.; Kilduff, L.P. Effects of resisted sprint training on acceleration in professional rugby union players. *J. Strength Cond Res.* **2013**, *27*, 1014–1018. [[CrossRef](#)] [[PubMed](#)]
57. Morin, J.B.; Petrakos, G.; Jiménez-Reyes, P.; Brown, S.R.; Samozino, P.; Cross, M.R. Very-heavy sled training for improving horizontal-force output in soccer players. *Int. J. Sports Physiol. Perform.* **2017**, *12*, 840–844. [[CrossRef](#)]
58. McMorrow, B.J.; 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*, 1066–1073. [[CrossRef](#)]
59. Rampinini, E.; Bishop, D.; Marcora, S.M.; Ferrari Bravo, D.; Sassi, R.; Impellizzeri, F.M. Validity of simple field tests as indicators of match-related physical performance in top-level professional soccer players. *Int. J. Sports Med.* **2007**, *28*, 228–235. [[CrossRef](#)]
60. Ricotti, L.; Rigosa, J.; Niosi, A.; Menciassi, A. Analysis of balance, rapidity, force and reaction times of soccer players at different levels of competition. *PLoS ONE* **2013**, *8*, e77264. [[CrossRef](#)]
61. Hrysomallis, C.; McLaughlin, P.; Goodman, C. Balance and injury in elite Australian footballers. *Int. J. Sports Med.* **2007**, *28*, 844–847. [[CrossRef](#)]
62. Zech, A.; Hübscher, M.; Vogt, L.; Banzer, W.; Hänsel, F.; Pfeifer, K. Balance training for neuromuscular control and performance enhancement: A systematic review. *J. Athl. Train.* **2010**, *45*, 392–403. [[CrossRef](#)]
63. Ozer, D.; Duzgun, I.; Baltaci, G.; Karacan, S.; Colakoglu, F. The effects of rope or weighted rope jump training on strength, coordination and proprioception in adolescent female volleyball players. *J. Sports Med. Phys. Fit.* **2011**, *51*, 211–219.