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Effects of Plyometric and Short Sprint with Change-of-Direction Training in Male U17 Soccer Players

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Featured Application: This project investigated the effect of the addition of 8 weeks of bi-weekly training incorporating plyometric and short sprinting with change-of-direction into a standard training program for elite young soccer players. The results from this experiment suggest this type of additive intervention improves vertical and horizontal jump performance, sprinting, change-of-direction ability, repeated sprint ability, and balance.

Abstract: This project investigated the effect of adding 8 weeks of bi-weekly plyometric and short sprint with change-of-direction (PSSCoD) training into standard training for elite youth soccer players from Tunisia. A training group (n = 18; age: 16.6 ± 0.5 years; body mass: 63.2 ± 4.8 kg; stature: 1.73 ± 0.07 m; body fat: 11.2 ± 1.7%), and control group (n = 16; age: 16.6 ± 0.5 years; body mass: 63.6 ± 4.3 kg; height: 1.73 ± 0.06 m; body fat: 11.6 ± 1.5%) participated. The pre- and post-intervention measures were squat-jump (SJ), countermovement jump (CMJ), standing long jump (SLJ), 5 m and 20 m sprint, change-of-direction ability (4 × 5 m sprint test (S 4 × 5 m)), repeated sprint ability (RSA), and static balance (stork balance test). The training group displayed superior jump (all $p < 0.05$; d > 0.49), sprint ($p < 0.05$; d > 0.52), change-of-direction ability ($p < 0.01$; d = 0.78), RSA ($p < 0.01$; d > 0.70), and static balance ($p < 0.05$; d > 0.49) improvements. Adding bi-weekly PSSCoD improves the athletic performance of young soccer players.

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

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1. Introduction

Soccer is a team invasion game, involving high-intensity efforts performed intermittently, and it requires divergent athletic traits (i.e., power, strength, endurance, agility, speed) for successful performance in competition [1]. During matches, decisive moments (i.e., gaining possession, conceding possession, and periods around goals) occur primarily during high-speed sprints [2]. In elite soccer, physical capacity, such as jumping, sprinting, and change-of-direction speed, are the determining factors in performance [3]. Time and motion analyses have shown sprints account for ~3% of the total distance covered during matches between young soccer players [4]. Furthermore, the ability to change direction is an important physical attribute, given the wide range of in-game situations that allow for a sudden change-of-direction (CoD) [5].

Plyometrics is an important component of several team sports [6], and training is recognized as a safe and effective method to improve explosive actions and should be an important component of fitness programs for soccer players. Furthermore, plyometric exercises are often performed using jump training, and they improve muscle power [7–9]. Discussions around the optimal form of plyometric training continue. De Villareal et al. [10] suggested that short-term plyometric training using a moderate volume of jumps produced similar enhancements in jumping performance, but greater training efficiency, compared with training using a high volume of jumps. Ramirez-Campillo et al. [11] found that if a moderate plyometric training volume was employed on a hard surface, the efficiency of adaptations in reactive strength would be doubled.

Plyometrics consist of an eccentric contraction of the musculotendinous unit followed immediately by a concentric contraction (termed the stretch–shortening cycle (SSC)) [8]. The SSC improves the ability of the musculotendinous unit to produce maximum force in the shortest possible time [8]. Plyometric training is considered safe and efficacious for improving explosive movements, and should be a primary component of fitness programs in invasion games [12,13]. Furthermore, Davids et al. [14] noted that change-of-direction ability represents an important physical trait that should be included in training programs for youth soccer players. Recent review papers and meta-analyses have reported that ~8 weeks of bi-weekly plyometric training improved high-intensity physical abilities (e.g., jumping, sprinting, agility) [15–18]. Previous studies have recommended the incorporation of combined PSSCoD training into the soccer season to improve jumping, sprinting, and change-of-direction ability. Makhlouf et al. [19] reported that such training enhanced change-of-direction ability (Illinois agility test (ICODT) without a ball and 4 m × 9 m shuttle run test (agility 4 m × 9 m)) in prepubertal male soccer players. Additionally, Michailidis et al. [20] noted that such training improved vertical and horizontal jump performance (squat jump and long jump), change-of-direction ability, and sprint performance over 10 m in prepubertal male soccer players. Furthermore, Hammami et al. [6] studied the effects of combined plyometric and short sprint with change-of-direction (PSSCoD) training in male U15 handball players. These authors reported significant yet small improvements in vertical and horizontal jump performance (39%, 29%, and 13% for squat jump, countermovement jump, and five-jump tests, respectively). These researchers reported significant yet trivial to small improvements in 5, 10, 20, and 30 m sprint times (9%, 7%, 7%, and 9%, respectively), but no gains in all repeated sprint ability (RSA) parameters.

To the best of our knowledge, the present investigation is the first to have studied the effects of combined PSSCoD training in elite young soccer players (U17). Thus, the aim of this study was to evaluate the effects of replacing normal training in-season with combined PSSCoD training in elite male soccer players (U17). Pertinently, we examined vertical and horizontal jump performance (i.e., SJ, CMJ, SLJ), sprint performance (i.e., 5 m and 20 m sprint), change-of-direction ability (sprint 4 × 5 m test (S 4 × 5 m)), RSA, and static balance (stork balance test). The present investigation evaluated the effects of replacing a part of elite adolescent soccer players' normal in-season training with training including PSSCoD on elite adolescent soccer players' performance-related abilities. We hypothesized a priori that replacing part of the regular in-season training with 8 weeks of bi-weekly training of this type would increase horizontal and vertical jumps, sprint performance, and change-of-direction ability when compared with the control group, who maintained their habitual training during the season.

2. Materials and Methods

2.1. Participants

Thirty-four participants from all playing positions and a single male soccer team competing in the Tunisia National first division took part. The playing experience was 6.5 ± 0.9 years. Before participating, the subjects underwent an examination by the team physician, with a focus on orthopedics or conditions that would preclude the intended training. Participants were randomly assigned to an experimental group (n = 18; age: 16.6 ± 0.5 years; body mass: 63.2 ± 4.8 kg; height: 1.73 ± 0.07 m; body fat: 11.2 ± 1.7%) or a control group (n = 16; age: 16.6 ± 0.5 years; body mass: 63.6 ± 4.3 kg; height: 1.73 ± 0.06 m; body fat: 11.6 ± 1.5%). No initial group differences of anthropometric characteristics ($p \leq 0.05$) were observed.

Participants had already completed an 8-week pre-season training macrocycle with 5–6 sessions per week. For the first 5 weeks, resistance training targeting muscle hypertrophy (60–70% 1 repetition maximum (1 RM)) and muscle strength (80–95% 1 RM) was performed. After this, the subsequent 3 weeks targeted power output with light–moderate loads (40–60% 1 RM) and non-competitive matches every weekend. During the in-season period, participants maintained five sessions per week (~90 min each session).

2.2. Experimental Design

Participants did not partake in physical training other than with the team for the duration of the experiment. The experimental and control groups' training comprised five ~90 min sessions per week, plus a competitive game every weekend. Physical training was undertaken twice weekly; the first session trained the aerobic fitness of the players through high-intensity interval training (HIIT) and small-sided games. The second session was aimed at developing anaerobic fitness through half squats, overhead lunges, and countermovement and squat jumps. The remaining sessions targeted tactical technical skills (60% of session time) and physical abilities (40% of session time). Participants took part in weekly 1 h long physical education classes at school (Table 1).

Table 1. Details of general training routine during the week undertaken by both control and experimental groups over the 8-week intervention.

Days	Objectives
Mondays	Rest
Tuesdays	Aerobic training and defensive tactics training
Wednesdays	Maximum power, aerobic training and defensive tactics training
Thursdays	Power anaerobic training and defensive and offensive tactics training
Fridays	Technical training and offensive tactics training
Saturdays	Technical training and offensive tactics training
Sunday	Official games

The University Institutional Review Committee approved the procedures (reference number KS000002020 and date of approval 10 November 2020). Participants (and their guardians, in the case of minors) read and signed informed consent documentation. Two familiarization sessions were performed 2 weeks before testing, which was 2 months after the competitive season started.

2.3. Details of Combined PSSCoD Training

The training program consisted of four principal workshops, twice per week (Figure 1).

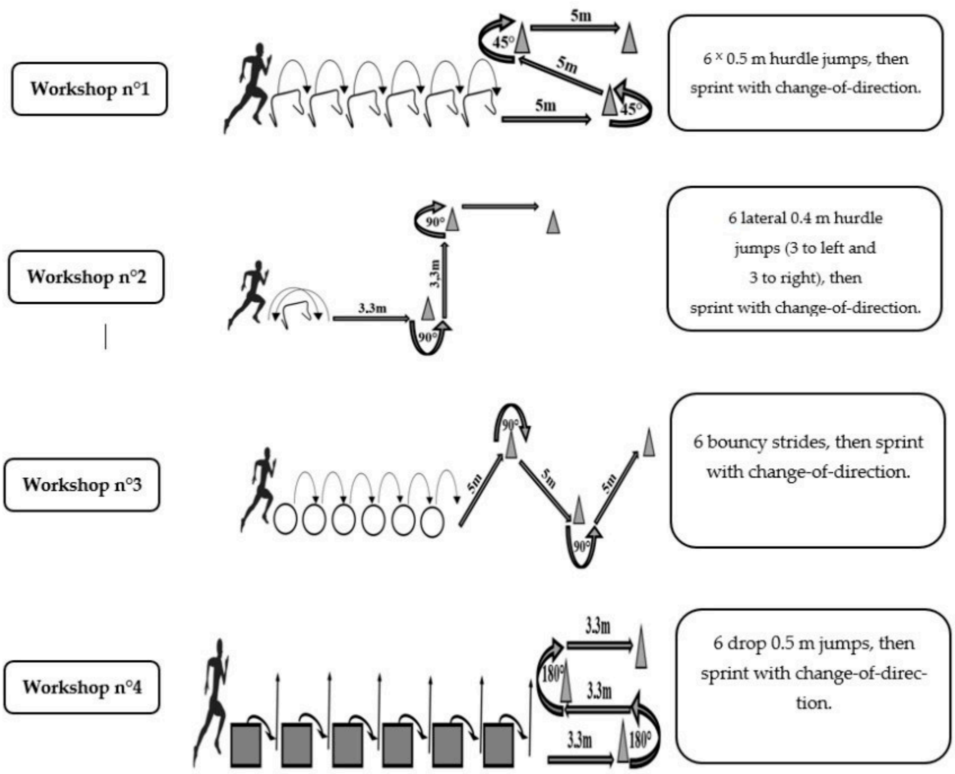

Figure 1. Exercise used in combined plyometric training program.

Each workshop began with plyometric exercises (hurdle jumps, lateral hurdle jumps, bouncy strides, and drop jumps) and finished with a short change-of-direction sprint (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 combined plyometric training protocol (training volume and intensity; direction change angles) was based on published recommendations for from Bedoya et al. [12] and Beato et al. [21].

2.4. Testing Schedule

Testing was conducted ≥3 days after a competitive match and 5–9 days after the last training session. On a tartan surface, all measurements were integrated into the weekly training schedule. Standardized warm-up procedures preceded each test. On the first test day, anthropometric assessment was followed by SJ and CMJ, and concluded with the sprint 4 × 5 m test (S 4 × 5 m). The second day was devoted to the dynamic balance test assessments (Stork balance test) and sprinting over 20 m. The third day was devoted to the SLJ and the RSA tests.

2.4.1. Day 1

Anthropometry

Body mass and body fat percentage were determined, barefoot, in the morning (7–8 a.m.), following overnight fast, using bioelectrical impedance analysis (BIA; BC-602, Tanita Co., Tokyo, Japan) [22]. Stature was determined using a SECA 214 stadiometer, accurate to 1 mm.

Squat and Countermovement Jumps

Jump height was determined using an infrared photocell mat connected to a computer (OptoJump System; Microgate SARL, Bolzano, Italy). Contact time and flight time were measured with a sampling frequency of 1 kHz. Participants began the SJ with a knee angle of 90°, avoiding downward movement. Subsequently, participants performed a vertical jump by driving themselves up, keeping straight legs throughout the flight time. The CMJ was similar but began from upright, followed by a downward movement to a knee angle of 90° then a maximal upwards jump [23]. One minute of rest was allowed between the three trials of each test. The best jump performance from the SJ and CMJ was used in subsequent analyses [23].

Sprint 4 × 5 m (S 4 × 5 m)

For the S 4 × 5m test, five cones were placed 5 m apart and participants started with feet apart and a cone between their feet. Following an acoustic signal indicating the start of the test, participants sprinted 5 m to point A, made a 90° turn to the right and sprinted 5 m to point B. After a second 90° turn, they sprinted to point C, made a 180° turn and sprinted to the finish line [24].

2.4.2. Day 2

Static Balance Performance

To assess static balance, we utilized the stork balance test [25]. Subjects stood with their opposite foot against the inside of the supporting knee with both hands on the hips. On the "go" signal, subjects raised the heel from the floor and held this position for as long as possible. The test was terminated when the heel of the supporting leg touched the ground, or the foot moved away from the kneecap. The test was timed using a stopwatch.

Sprint Performance (5 m and 20 m)

Sprint times were measured at 5 m and 20 m intervals using an infrared photoelectric timing system (Microgate, Bolzano, Italy). Participants started from a standing start 30 cm behind the first timing gate, 75 cm above ground (to ensure trunk movement was captured and to avoid false start signals via limb motion) [26]. Three photoelectric gates were placed at 0 m, 5 m, and 20 m.

2.4.3. Day 3

Standing Long Jump

Participants stood with their feet at shoulders' width behind a line on the ground with hands in a neutral position. Then, participants jumped with maximal effort in a horizontal direction. Participants had to land with both feet at the same time and were not permitted to fall forward or backward. The distance between the starting line and the heel of the rear foot was measured via tape measure to the nearest 1 cm and retained for analysis [26].

Repeated Sprint Ability Test

Subjects completed a pre-test shuttle sprint test, using a photocell system (Microgate). This trial provided a criterion value for the definitive shuttle sprint test [27]. Participants rested 5 min before starting the definitive test. If their performance in the first definitive sprint was 2.5% worse than their criterion score, it was repeated following a further 5 min rest. Subjects performed six 20 + 20 m sprints with 180° turns, interspersed with 20 s passive recovery [27]. Five seconds prior to each sprint, participants assumed their starting position and were given a five-second countdown to an acoustic signal. From the start line, participants sprinted 20 m, touched a second line with 1 foot, and returned to the starting line in as short a time as possible. After 20 s recovery, this was repeated. The best trial performance (RSA best), mean trial performance (RSA mean), and total time (RSA total) were recorded for analysis, and RSA decrement was calculated according to the formula [28]:

$$\text{RSA fatigue index} = 100 \times (\text{total sprint time} \div \text{ideal sprint time})) - 100.$$

where:

$$\text{Total sprint} = \text{Sum of times from all sprints.}$$

$$\text{Ideal sprint} = \text{The number of sprints} \times \text{fastest sprint time.}$$

2.5. Statistical Analyses

Statistical analyses were performed using SPSS version 25.0 for Windows (IBM, Armonk, NY, USA).

Normality of data was tested using the Shapiro–Wilk test. The results showed that 50% (12/24) of the performance parameters (SJ2, SLJ1, sprint 20 m1 and 2, RSA mean1, RSAtotal1, RSAdecrement1 and 2, storck balance test right and left1 and 2) were not normally distributed.

Independent t-tests examined between-group differences at baseline. Training effects were assessed by a mixed two-way (group × time) analysis of variance (ANOVA) with repeated measures. Tukey's post hoc procedure was applied to test for pairwise differences. Paired sample t-tests evaluated within-group pre to post performance changes.

Effect sizes were determined by converting partial eta-squared to Cohen's d [29] and the magnitudes were interpreted as small ($0 \leq d \leq 0.49$), medium ($0.50 \leq d \leq 0.79$), or large ($d \geq 0.80$).

Reliability was assessed using intra-class correlation coefficients (ICC) [30] and coefficients of variation (CV) over pairs of intra-participant trials [31]. Change of direction, vertical jumping and sprinting had an ICC > 0.80 and a CV < 5%.

Alpha was set a priori at $p \leq 0.05$, and the data are presented as mean ± standard deviation (SD).

3. Results

Intraclass correlation coefficients, CIs, and CV for sprint times, change of direction, jumps, and balance tests are summarized in Table 3. All parameters showed no initial group differences.

Table 3. Interclass correlation coefficient (ICC, 95% confidence intervals (95% CI)) and coefficient of variation (CV) showing acceptable reliability for all performance measures.

	ICC (95% CI)	CV (95% CI) (%)
	Sprint times	
5 m (s)	0.96 (0.92–0.98)	1.7 (1.3–2.1)
20 m (s)	0.97 (0.93–0.99)	1.3 (1.1–1.6)
	Change of direction test	
Sprint 4 × 5 m (s)	0.94 (0.90–0.98)	1.1 (1.1–1.2)
	Vertical jump	
SJ (cm)	0.97 (0.93–0.99)	2.2 (1.8–2.7)
CMJ (cm)	0.97 (0.94–0.99)	2.5 (2.0–3.1)
	Horizontal jump	
SLJ (cm)	0.97 (0.94–0.99)	3.7 (2.8–4.8)
	Stork balance test	
Right leg (s)	0.84 (0.69–0.90)	3.1 (2.3–4.1)
Left leg (s)	0.82 (0.67–0.88)	3.1 (2.4–4.2)

SJ—squat jump; CMJ—countermovement jump; SLJ—standing long jump.

3.1. *Effect of Training on Jump Performance*

For vertical and horizontal jump performance, intervention effects (group × time interaction) were evident, with the experimental group improving more than the control (Δ19%, $p < 0.05$, d = 0.53 on squat jump Δ21%; $p < 0.05$, d = 0.63 on CMJ; Δ13%, $p < 0.05$, d = 0.49 on standing long jump Δ21% for the experimental group) (Table 4).

Table 4. Test performances in experimental and control groups before and after 8-week intervention.

	Experimental (n = 18)			**Paired *t*-Test**		**Control (n = 16)**			**Paired *t*-Test**		**ANOVA (Group × Time)**	
	Pre	**Post**	**% Δ**	***p*-Value**	**ES**	**Pre**	**Post**	**% Δ**	***p*-Value**	**ES**	***p*-Value**	**ES**
Vertical jump												
SJ (cm)	26.7 ± 3.8	31.8 ± 4.4	19.1 ± 2.4	0.001	1.23	27.1 ± 3.5	28.2 ± 3.5	4.1 ± 1.8	0.001	0.26	0.037	0.53 (medium)
CMJ (cm)	28.9 ± 3.9	34.9 ± 3.5	20.9 ± 3.5	0.001	1.54	29.2 ± 3.0	30.7 ± 3.3	5.2 ± 2.1	0.001	0.30	0.014	0.63 (medium)
Horizontal jump												
SLJ (m)	1.8 ± 0.2	2.0 ± 0.2	13.3 ± 1.9	0.001	1.11	1.8 ± 0.2	1.8 ± 0.2	2.7 ± 1.9	0.001	0.10	0.053	0.49 (small)
Sprint												
5 m (s)	1.2 ± 0.1	1.1 ± 0.1	−10.6 ± 0.0	0.001	1.62	1.2 ± 0.1	1.7 ± 0.1	−2.4 ± 1.0	0.001	0.08	0.042	0.52 (medium)
20 m (s)	3.4 ± 0.1	3.1 ± 0.1	−8.2 ± 1.3	0.001	2.17	3.4 ± 0.2	3.3 ± 0.2	−2.1 ± 0.6	0.001	0.06	0.013	0.64 (medium)
Change-of-Direction Performance												
Sprint 4 × 5 m (s)	6.4 ± 0.3	5.8 ± 0.25	−9.4 ± 0.7	0.001	2.38	6.4 ± 0.3	6.22 ± 0.2	−2.1 ± 0.8	0.001	0.11	0.003	0.78 (medium)
Repeated Shuttle Sprint Ability parameters												
Fastest time (s)	7.9 ± 0.4	7.3 ± 0.4	−7.5 ± 0.7	0.001	1.62	7.8 ± 0.4	7.7 ± 0.4	−1.3 ± 0.2	0.001	0.26	0.007	0.70 (medium)
Mean time (s)	8.1 ± 0.4	7.5 ± 0.4	−7.8 ± 0.9	0.001	1.82	8.0 ± 0.4	7.9 ± 0.37	−1.4 ± 0.7	0.001	0.30	0.004	0.74 (medium)
Total time (s)	48.5 ± 2.2	44.7 ± 1.9	−7.8 ± 0.9	0.001	1.82	48.1 ± 2.2	47.4 ± 2.2	−1.4 ± 0.7	0.001	0.18	0.004	0.74 (medium)
Fatigue index (%)	2.6 ± 1.5	2.3 ± 1.2	−2.3 ± 40.2	0.216	0.20	2.2 ± 0.8	2.2 ± 0.9	−0.0 ± 30.6	0.716	0.30	0.705	0.09 (small)
Stork balance test												
Right leg (s)	12.4 ± 7.5	22.7 ± 13.5	82.9 ± 3.0	0.001	0.93	12.8 ± 8.2	13.6 ± 8.7	6.8 ± 3.7	0.001	0.11	0.054	0.49 (small)
Left leg (s)	10.7 ± 6.2	18.2 ± 10.5	70.7 ± 3.8	0.001	0.87	10.9 ± 3.9	11.9 ± 4.7	9.1 ± 2.8	0.001	0.15	0.053	0.49 (small)

Note: A 2-way analysis of variance (group × time) assessed the statistical significance of training-related effects. SJ—squat jump; CMJ—countermovement jump; SLJ—standing long jump.

3.2. *Effect of Training on Sprint Performance*

Intervention effects were evident with the experimental group improving more than the control in sprint performance (Δ–1%, $p < 0.05$, d = 0.52 and Δ8%, $p < 0.05$, d = 0.64 over distances of 5 and 20 m, respectively, for the experimental group) (Table 4).

3.3. *Effect of Training on Change of Direction Ability*

The S 4 × 5 m showed an intervention effect, with the experimental group improving more than the control (Δ–9%, $p < 0.01$, d = 0.78) (Table 4).

3.4. *Effect of Training on Repeated Shuttle Sprint Ability*

The RSA test also showed group × time interaction for most of its parameters (RSA best, RSA mean and RSA total), with time reductions of Δ–8% ($p < 0.01$, d = 0.70), Δ–8% ($p < 0.01$, d = 0.74), and Δ–8% ($p < 0.01$, d = 0.74), respectively (Table 4).

3.5. *Effect of Training on Balance Performance*

In terms of balance, the stork balance test showed an intervention effect favoring the experimental group compared to the control group (Δ83%, $p < 0.05$, d = 0.49 and Δ71%, $p < 0.05$, d = 0.49 for right and left leg, respectively, for the experimental group; Table 4).

4. Discussion

Here, we aimed to assess the effectiveness of 8 weeks of combined PSSCoD training for improving athletic performance in elite youth soccer players. The data suggest that replacing some aspects of habitual training with combined PSSCoD training improves vertical and horizontal jump performance, sprinting, change-of-direction ability, RSA, and balance.

4.1. Effect of Training on Jump Performance

Jump ability is an important performance characteristic in team sports, particularly in soccer [32]. Significant differences in vertical jump heights exist among soccer players of different competition levels [32]. There are few studies evaluating jump performance after a combined PSSCoD training program. Our data are in accordance with the existing literature, which has reported improved jump performance after several programs, including combined PSSCoD training, plyometric training with and without external load, change-of-direction training, and resistance training [1,9,19,20,22–25,31,33].

Recently, Michailidis et al. [20] studied the effects of the combination of 6-week plyometric training and change-of-direction exercises in prepubertal male soccer players, reporting improved jump performance (squat jump and long jump) but no gain in countermovement jump performance and multiple 5 bound. Additionally, Beato et al. [21] studied the effects of 6 weeks of plyometric and change-of-direction training in elite youth soccer players (U18), and found that both types of training improve the horizontal jump performance. Indeed, gains in vertical and horizontal jumping as a result of combined plyometric and sprint with change-of-direction training in male U15 handball players have been observed [6]. Improved jump performance as a result of plyometric training may be partially attributable to improved motor recruitment, the elastic benefits to the SSC, and/or a muscle typology shifts [9,34].

4.2. Effect of Training on Sprint Performance

Linear sprints and short accelerations are considered the two most important actions in soccer, since they frequently precede decisive match moments [35]. Our results showed the experimental group exhibited superior sprint adaptations compared to control. This corroborated the findings of Michailidis et al. [20], who studied the effects of the combination of 6-week plyometric training and change-of-direction exercises in prepubertal male soccer players, and noted improved sprint performance over 10 m, but not 30 m. Moreover, Hammami et al. [6] observed significant increases in 5, 10, 20, and 30 m sprint times following combined PSSCoD training in male U15 handball players. However, improved sprint performance following plyometric training is not a ubiquitous finding [36–38]. This disparity in results could be due to the type of training and differences in the sample population. Improvements in sprint performance occur mainly due to neural factors, such as improved intermuscular coordination, increased nerve conduction velocity, enhanced motor unit recruitment strategy, and increased excitability of the Hoffman reflex (H-reflex) [34–40]. However, it is also possible that changes in single-fiber mechanics, changes in muscle architecture and size, and changes in the mechanical characteristics of the muscle–tendon complex may have occurred in our participants [34,41].

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

The ability to perform changes of direction is considered a valid test for the evaluation of training status in soccer players of different competitive levels, ages, and genders [31,42,43]. We report an improved change-of-direction ability herein, which corroborates the findings of Michailidis et al. [20], who reported that the combination of 6-week plyometric training and change-of-direction exercises improved change-of-direction ability in prepubertal male soccer players. Makhlouf et al. [19] also reported increased change-of-direction ability (Illinois agility test (ICODT) without a ball and 4 m × 9 m shuttle run test (agility 4 m × 9 m)) following combined PSSCoD training in prepubertal male soccer players. Conversely, Beato et al. [21] reported no gain in change-of-direction ability after 6 weeks of plyometric and change-of-direction training in elite youth soccer players (U18). Differences in acute program variables (intensity, frequency, duration) and methodology (age of players, competitive level of players, and duration of studies) could contribute to divergences between studies.

In terms of training volume, intensity, and exercise selection, we followed the principle of progressive overload single-joint exercises, starting with lower-intensity, less complex exercise techniques, and multi-joint exercise, progressing to higher intensities and more complex techniques [44,45]. Improvements in change-of-direction performance following plyometric training may have occurred due to the interaction of several neuromuscular adaptations, as well as the improvement of neural drive to agonist muscles, patterns that allow athletes to promptly alternate between decelerating and accelerating movements (higher efficiency of the SSC) [9], and muscle activation strategies (inter- and intra-muscular coordination) [34,46].

4.4. Effect of Training on Repeated Sprint Ability

To the best of our knowledge, the present investigation is the first to have studied the effects of a combined PSSCoD training program on RSA in youth soccer players. The ability to perform repeated sprints and changes of direction is a key determinant of soccer performance [47]. In this context, we report that the intervention was efficacious in improving RSA in this experiment. Our results contradict those of Hammami et al. [6], who reported no improvement in RSA following combined PSSCoD training in male U15 handball players. One potential explanation for the lack of change in RSA could be its poor reproducibility [27], or differences in study design, type of training, and the competition level and age of the players.

4.5. Effect of Training on Balance

The experimental group in this study improved static balance compared to the control group, which corroborates the data of Makhlouf et al. [19], who reported improved static (stork balance test) and dynamic (Y-balance test) balance performance as a result of an 8-week plyometric and change-of-direction exercise program in prepubertal male soccer players. On the other hand, Hammami et al. [6] showed no effects in the experimental group compared to the control group for both static (stork balance test) and dynamic (Y-balance test) balance performance, following combined PSSCoD training in male U15 handball players. Balance is a physical trait commonly overlooked in soccer, yet Ricotti et al. [48] emphasized its importance, and observed a significant difference in static and dynamic balance between soccer players of different competitive levels (regional or national). The significant improvement observed following training in this study could be due to an enhancement in motor coordination [49,50], and the improved neuromuscular control of lower limb muscle groups [51].

4.6. Practical Applications

This study demonstrated that 8 weeks of twice weekly combined PSSCoD training enhanced jumping, sprinting, change-of-direction ability, RSA, and balance in elite adolescent soccer players during the in-season period. Therefore, it appears reasonable to integrate this form of training into traditional in-season technical and tactical soccer training to augment physical fitness. This type of training does not require resource commitment and is simple to implement for a strength and conditioning coach, so coaches should consider including combined PSSCoD training in-season. Our observations to date are primarily applicable to one category of elite adolescent soccer players.

The main limitation of the present study is its cross-sectional design, wherein sexual maturation was not considered. Future studies should include an assessment of sexual maturation when examining the relationship between anthropometry and physical performance in youth soccer players.

Future studies should extend these observations to other age groups, female players, and other skill levels. There is also a need to compare gains in test performances with performance analysis to determine whether improved fitness translates to enhanced match performance. Furthermore, different load terms (e.g., number of training sessions per week (2 or 3 times weekly), duration of training sessions (1 or 1.5 h), number of repetitions) should be assessed. The age effect (training in younger vs. older athletes) or the effects of different patterns of plyometric and short sprint with COD training are also very interesting from a practical point of view.

5. Conclusions

In conclusion, adding combined PSSCoD training to standard training improved jump performance, sprinting, change-of-direction ability, RSA, and balance. Therefore, soccer coaches and practitioners should incorporate combined plyometric and short sprints with change-of-direction training into soccer training to enhance specific and non-specific fitness.

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