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Effects of a low-frequency program of plyometrics and sprints with changes of direction on youth soccer players' power indexes

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Abstract
Introduction. **Plyometric training (PT) and change of direction (COD) exercises are used to train soccer players because of their well-known positive impact on physical performance indicators.** Aim of Study. **The aim of this study was to evaluate effects of a low-volume, low-frequency intervention program, that included plyometric exercises in one session and COD exercises in another session, on anaerobic indexes in soccer players under 16 years of age (U16).** Material and Methods. **The study included 28 players divided into an exercise group (EG) (n = 14) and a control group (CG) (n = 14). The intervention program was conducted for eight weeks. The two-way repeated measures ANOVA was used for data analysis.** Results. **The results showed that the EG improved its performance in all speed tests (5 m: 0.98-0.95, $\eta^2 = 0.948$; 10 m: 1.75-1.70, $\eta^2 = 0.966$; 20 m: 3.10-3.01, $\eta^2 = 0.963$; 30 m: 4.42-4.29, $\eta^2 = 0.964$; $p < 0.001$) and in all jumping tests (squat jump, SJ: 28.0-28.9, $\eta^2 = 0.523$; countermovement jump, CMJ: 29.4-30.9, $\eta^2 = 0.797$; CMJ right leg: 15.7-16.5, $\eta^2 = 0.913$; CMJ left leg: 16.8-17.6, $\eta^2 = 0.926$; $p < 0.001$). Furthermore, EG performance significantly differed from CG performance in postintervention measurements for the 5-m ($p < 0.001$) sprints, the10-m sprints and the CMJ left leg tests ($p < 0.05$). No changes in performance were observed in the CG.** Conclusions. **In conclusion, the application of a weekly program combining the plyometric and COD exercises can positively affect young soccer players' performance.**

KEYWORDS: **adolescence, countermovement jump, velocity, agility, squat jump, jumping exercises.**

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Introduction

Soccer involves a combination of high- and low-intensity activities that alternate throughout a game [32]. In developmental ages (under 13 to under 18, U13-U18), it has been reported that players cover 7-8 km [7, 30] and perform 2-18 sprints every 120 seconds, with an average duration of 2 seconds [8]. Previous studies have stated that high-intensity actions are the ones that determine performance of both individual soccer players and an entire team [27]. Such actions include sprints, jumps, accelerations, decelerations, and changes of direction (CODs).

All of the above movements are based on the stretch-shortening cycle (SSC). This process occurs in muscle contraction during a rapid transition from eccentric contraction to concentric contraction [18, 19]. It is also mentioned that exercises activating the SSC utilize elastic energy stored in connective tissue and muscle fibers during a negative phase, releasing it during a positive phase, thus enhancing muscle strength and power produced [13, 19].

Plyometric training (PT) is utilized for developing athletes' power and is particularly widespread in soccer [19]. PT includes various forms of unilateral and bilateral jumps [26] that can be easily implemented in combination with other fitness activities without requiring much space and equipment [20, 21]. Additionally, PT can be easily adapted to an athletes' level, as plyometric exercises can be differentiated in terms of intensity. Specifically, athletes with little experience can use low-intensity exercises (e.g., two-legged jumps at low height), while experienced athletes can perform single-leg jumps with maximum effort.

The benefits of PT have been extensively studied in adults, and its positive impact on various physical fitness parameters has been established [16]. However, although several studies have been conducted in adolescents and children in recent years [1, 23], variety of plyometric exercises, different tolerances at various developmental ages, and application of diverse programs leave space for further research. Previous studies implementing plyometric exercise programs in young athletes have shown improvement in jumping ability and speed [10, 14, 21]. More specifically, in one of the early studies [21] conducted on preadolescent soccer players, it was evident that implementation of a plyometric program could enhance speed, vertical jumping ability, and performance in specialized soccer tests. In another study [14] involving adolescent soccer players, researchers observed, among other things, that a plyometric intervention program improved their speed and vertical jumping ability.

As mentioned earlier, soccer players perform numerous CODs during a match [4]. This skill depends on strength levels and the SSC, and appears to be particularly crucial for players' performance [5]. Coaches recognize the significance of this skill, using COD exercises to train their soccer players. Through this training, they aim to enhance neuromuscular function [36] and improve running economy in actions involving accelerations, decelerations, and COD [9].

A common characteristic of a training process for soccer players, regardless of their level, is a combination of plyometric exercises with COD exercises. Recent studies have investigated an impact of combined PT and COD on physical performance indicators in young soccer players [2, 11, 15, 17], improving their overall performance. In a recent study [1], researchers observed that after implementing a combined intervention program (plyometrics and COD) twice a week, adolescent soccer players improved their performance in speed, jumps, and directional change. Similar results were noted by researchers [15] who studied an impact of two different plyometric programs, both of which improved soccer players' performances.

According to the literature review, it appears that a number of studies utilizing combined programs, such as those mentioned above, is limited [1, 2, 15, 17]. Additionally, applying different intervention programs to various age groups will provide information on characteristics these programs should have in order to be effective. Moreover, in most studies, combined programs of plyometric and COD exercises are implemented twice within a weekly microcycle. On the other hand, coaches aim to save time for training technical-tactical elements, and it would be particularly beneficial for them to find programs with low frequency and volume that improve physical condition of their soccer players.

The aim of the present study was to examine effects of a low-frequency combined program of plyometric and COD exercises (once a week for each) on anaerobic performance indicators in soccer players under 16 years (U16). It has been hypothesized that implementing the above program (one day of the PT exercises and one day of the COD exercises) for eight weeks would improve performance of young soccer players (the exercise group, EG) in anaerobic performance indicators (jumping, speed, COD) compared to application of a standard soccer training program alone (the control group, CG).

Material and Methods

Participants

To determine a number of participants, a power analysis was conducted based on previous studies with a similar design [22]. The results of this analysis indicated that, for interaction between the two groups (the EG and the CG) and time points of measurements to be statistically significant, at least 14 soccer players needed to participate (effect size > 0.55, probability error of 0.05, power of 0.95). Subsequently, players and parents from two local academies were asked if they would like to participate in the study. Thirty-eight Greek male soccer players expressed a desire to participate, but ultimately, only 28 of them completed the study, meeting participation criteria. These criteria included: 1) attending at least 95% of the training sessions, 2) having no musculoskeletal injuries in the last four months, and 3) not receiving any pharmaceutical treatment. Initially, the players were separated by a competitive position and then they were randomly divided into two groups. This was done so that there were players from every competitive position in each group. The research took place during a competitive season, with players participating in three

75-minute training sessions weekly, along with one official match.

Participants and their parents were briefed on the study's advantages and potential risks, and parental consent was secured. The study received approval from the local Institutional Review Board in adherence to the Helsinki Declaration (approval no. 169/2023). Characteristics of the participants are outlined in Table 1.

Table 1. Participants' physical characteristics

	CG (n = 14)		EG (n = 14)	
	Pre-training	Post-training	Pre-training	Post-training
Age (years)	15.7 ± 0.1	15.8 ± 0.1	15.5 ± 0.3	15.6 ± 0.3
Height (cm)	173 ± 6	173 ± 6	178 ± 6	178 ± 7
Weight (kg)	68.2 ± 7.3	68.4 ± 6.5	69.3 ± 8.3	70.6 ± 8.5
Body fat (%)	14.3 ± 2.8	14.2 ± 2.7	13.9 ± 2.5	13,5 ± 2.4
Training age (years)	7.1 ± 0.3	7.2 ± 0.3	7.0 ± 0.5	7.1 ± 0.5

Note: CG – control group, EG – exercise group

Study design

Independent variables in the study were the soccer training performed by the CG (n = 14) and the intervention combining the PT and COD exercises in the EG (n = 14). The performance indicators (countermovement jump, CMJ; single-leg countermovement jump, SCMJ; squat jump, SJ; sprint at 5 m, 10 m, 20 m, 30 m; the Illinois agility test) served as dependent variables. The study utilized the randomized two-group repeated measures experimental design.

Initially, the participants familiarized themselves with the measurements used in the study to minimize a learning effect error. The familiarization took place two weeks before a start of the intervention program, ensuring that all participants performed the tests with proper technique. Additionally, the EG familiarized themselves with the exercises of the intervention program. Body measurements were taken during an initial session after the participants were introduced to procedures. The following two training sessions involved assessing physical fitness indicators, and these assessments were repeated eight weeks later, following the same sequence. In addition to the regular soccer training, the EG incorporated the intervention program. All assessments were conducted on synthetic grass on a soccer field, with the participants wearing soccer shoes. The overall training duration for both groups remained consistent.

At the beginning of every training session, a 15-minute warm-up was conducted, followed by a 10-minute cool-down period at the end of the session. Throughout the study, each participant engaged in a total of eight matches. None of the players were taking any ergogenic aids (according to their statements). Regarding nutrition, general guidelines were followed, where the players were advised to have their last meal at least 3 hours before a session. Adequate hydration was maintained during both training and testing, with the participants having unrestricted access to water.

Intervention training program

As mentioned earlier, the intervention program lasted eight weeks. In the CG, only the soccer training was implemented, including technical exercises (~10 minutes), individual tactics (~25 minutes), and small-sided games (SSG) (~20 minutes). The SSG without a goalkeeper were structured as follows: in the first training session, they implemented three 7-minute sets, with a 3-minute break, playing 7 vs 7 with a ratio of 100 m^2/player. In the second training session, they applied four 4-minute sets, with a 3-minute break, playing 4 vs 4 with a ratio of 150 m^2/player. In the third training session, they implemented four 4-minute sets, with a 3-minute break, playing 4 vs 4 with a ratio of 100 m^2/player. In the EG, 20 minutes of the intervention program replaced some parts of the SSG exercises and the individual tactics part. Total training time for both groups was ~75 minutes. The intervention program was based on a previous study [1] and was divided into two parts. An initial segment incorporated the plyometric exercises and was administered during the second training session of the week, whereas a subsequent segment involved the COD exercises and took place in the third training session of the week. A 48-hour gap separated these two sessions (2nd and 3rd). Weekly schedule is presented in Figure 1. The model "MD±" [34] was used to describe the training days during each microcycle. The use of a "+" symbol indicates the first two days (recovery content) and a "–" symbol helps to better distinguish load fluctuation during a week: recovery – load – tapering. The characteristics of the trainings are presented in Table 2. The intervention program was executed at the beginning of the training session, immediately after the warm-up, to guarantee optimal neuromuscular activation. The characteristics of the program are presented in Table 3 and the types of exercises are shown in Figure 2. Both in the plyometric

Table 2. Trainings characteristics and their duration

CG	EG
Warm-up – 15’	Warm-up – 15’
Technical exercises – 10’	Technical exercises – 10’
Individual tactics – 15’	Individual tactics – 10’
SSG – 25’	SSG – 10’
Cool-down – 10’	Intervention program – 20’
	Cool-down – 10’

Note: CG – control group, EG – exercise group, SSG – small-sided games

Table 3. Volume characteristics of the plyometric and change of direction intervention program

Plyometric training program (sets × reps)					
Week	Drill 1	Drill 2	Drill 3	Drill 4	Total
1st	3 × 6	3 × 6	3 × 6	3 × 6	72
2nd	3 × 6	3 × 6	3 × 6	3 × 6	72
3rd	4 × 6	4 × 6	4 × 6	4 × 6	96
4th	4 × 6	4 × 6	4 × 6	4 × 6	96
5th	5 × 6	5 × 6	5 × 6	5 × 6	120
6th	5 × 6	5 × 6	5 × 6	5 × 6	120
7th	6 × 6	6 × 6	6 × 6	6 × 6	144
8th	6 × 6	6 × 6	6 × 6	6 × 6	144
Change of direction program (reps × m)					
Week	Drill 1	Drill 2	Drill 3	Drill 4	Total
1st	3 × 15	3 × 9.9	3 × 9.9	3 × 15	149.8
2nd	3 × 15	3 × 9.9	3 × 9.9	3 × 15	149.8
3rd	4 × 15	4 × 9.9	4 × 9.9	4 × 15	199.8
4th	4 × 15	4 × 9.9	4 × 9.9	4 × 15	199.8
5th	5 × 15	5 × 9.9	5 × 9.9	5 × 15	249.8
6th	5 × 15	5 × 9.9	5 × 9.9	5 × 15	249.8
7th	6 × 15	6 × 9.9	6 × 9.9	6 × 15	319.8
8th	6 × 15	6 × 9.9	6 × 9.9	6 × 15	319.8

and COD exercises, the volume increased every two weeks. The number of jumps started at 72 and reached 144 jumps in the 7th-8th week. The distances in the COD exercises started at 149.8 m and reached 319.8 m. The

MD	MD+1	MD+2	MD-4	MD-3	MD-2	MD-1	MD
Game	Off	Training	PT	Off	COD	Off	GAME

Note: MD – match day, PT – plyometric training, COD – change of direction training

Figure 1. Weekly schedule (microcycle)

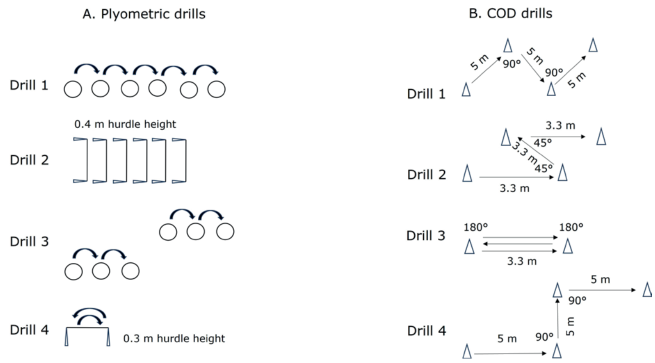

Figure 2. A. Plyometric drills; B. Change of direction (COD) drills. Plyometric drills: Drill 1: 6 bouncy strides; Drill 2: 6 hurdle jumps; Drill 3: 6 single-leg hop jumps (3 with a right leg and 3 with a left leg); Drill 4: 6 lateral hurdle jumps (3 to the left and 3 to the right)

progressive increase in the volume of the intervention program was based on previous studies [1].

Anthropometric measurements

Body mass was measured with a precision of 0.1 kg (Seca 220e, Hamburg, Germany) and the participants wore only their underwear. Body height was measured with an accuracy of 0.1 cm (Seca 220e, Hamburg, Germany). Body fat was calculated by measuring skinfold thickness with the Lange skinfold caliper (Lange, Beta Technology, Santa Cruz, CA, USA) at four points (biceps, triceps, suprailiac, subscapular) on the right side of each participant’s body. Specifically, these skinfold thickness measurements were used in the Durnin and Rahaman equation [11] to calculate body density, and the Siri equation [31] was then applied to determine a percentage of body fat.

Speed

For an assessment of acceleration and speed, distances of 5 m, 10 m, 20 m, and 30 m were utilized. Specifically, time taken by the participants to cover the aforementioned distances was measured. For this purpose, five photocell gates (Chronojump, Boscosystem, Barcelona, Spain) were employed, positioned at a starting point, 5 m, 10 m, 20 m, and 30 m. Starting from an upright position 0.3 m behind a starting line, the participants were subjected to the photocells positioned 0.6 m above the ground to prevent inaccurate recordings caused by hand movements. Two attempts were made by each participant, and the shorter time was utilized for statistical analysis. There was a 3-minute break between the two attempts. Coefficients of variation (CVs) for test-retest trials for 5 m, 10 m, 20 m, and 30 m were 3.6%, 3.7%, 3.8%, and 3.8%, respectively.

Jumping ability

To assess jumping ability, the study utilized the SJ, CMJ, and SCMJ exercises. Throughout these jumps, the participants kept their hands on their waists. During the CMJ, the participants flexed their knees to a 90° angle and executed a maximal vertical jump. In the SCMJ, the participants raised one leg, executed a countermovement to a self-selected depth, and swiftly propelled themselves upward. In the SJ, the participants leaped as high as possible from a seated position (knees at 90°) without any prior tension or downward body movement. The participants made two attempts for each jump, and the best performance was used for statistical analysis. There was a 1-minute break between the attempts. Special attention was paid to the technique, and if it was not correct, the attempt was repeated. The Chronojump electronic leap mat from Boscosystem (Chronojump, Boscosystem, Barcelona, Spain) was utilized. CVs for test-retest trials for the CMJ, SCMJ, and SJ were 3.6%, 3.7%, and 3.8%, respectively.

Agility

To measure the COD skill, the Illinois agility test was used, starting twice from the point A (right foot – one more turn to the right than to the left) and twice from the point F (left foot – one more turn to the left than to the right). The best time from each side was used for statistical analysis. Beginning at A, the participants sprinted from A to B and from there to C. They slalomed to D and returned the same way to C. From there, they sprinted to E, and then to F. Two photocell gates (Chronojump, Boscosystem, Barcelona, Spain) were placed at the points A and F to measure time. A CV for the right side was 3.9%, and for the left side – 4.1%. The test is illustrated in Figure 3.

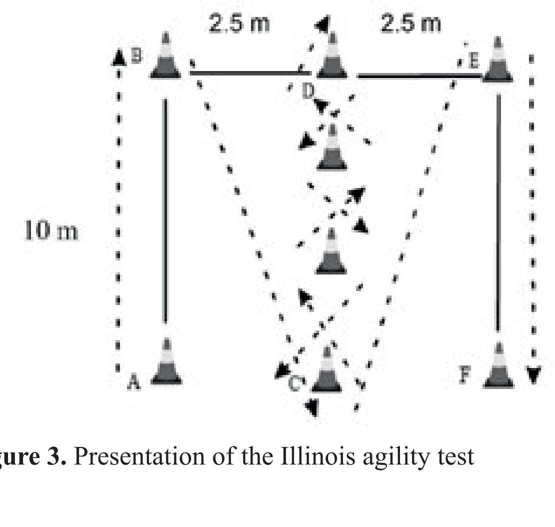

Figure 3. Presentation of the Illinois agility test

Statistical analysis

The data are presented as means ± standard deviation (SD). Additionally, confidence intervals (CI, 95%) are provided for each variable. Initially, the one-sample Kolmogorov–Smirnov test was applied to assess if parametric tests could be applied to the data. The results indicated a normal distribution of the data. The two-way (group by time) repeated measures ANOVA was employed to assess an impact of the intervention program. When a significant effect was identified, the Bonferroni post hoc correction was applied. The partial eta square was utilized to estimate an effect size, which was classified as small (0.01-0.059), moderate (0.06-0.137), and large (>0.138) [28]. Furthermore, CVs are reported to assess reliability of each measurement. A level of significance was set at $p < 0.05$. SPSS version 25.0 was utilized for all analyses (SPSS Inc., Chicago, IL, USA).

Results

The outcomes indicated no variations between the two groups in most of the variables during the initial measurement, except for the 5-m sprint. There was a difference between the two groups in the initial measurement of the players performance at the 5-m sprint ($p = 0.009$). In the SJ, a notable interaction effect (group × time) was identified ($p = 0.002$). Furthermore, a significant time effect was observed within the EG ($p < 0.001$), demonstrating an enhancement in the performance between the two measurements. The detailed performance changes for the SJ are outlined in Table 4, while statistical indicators for all variables are presented in Table 5. For the CMJ, a significant interaction (group × time) was evident ($p < 0.001$), along with a primary time effect ($p < 0.001$) for the EG, indicating an improvement in the performance between the two measurements. The similar results were observed for single-leg countermovement jumps (CMJ L and CMJ R). In the Illinois agility test, no main effects of the factors or interaction were observed ($p > 0.05$). In all speed tests (5 m, 10 m, 20 m, 30 m), a significant interaction (group × time) was observed ($p < 0.001$). Furthermore, a primary time effect was evident across all tests for the EG ($p < 0.001$).

Table 4. Changes in the performance of the two groups after the implementation of the program

		EG		CG	
		Pre	Post	Pre	Post
SJ	Mean ± SD	28.0 ± 5.5	28.9 ± 5.7	27.6 ± 4.9	27.7 ± 4.5
	CI	25.0-31.0	25.9-31.8	24.6-30.6	24.7-30.6
CMJ	Mean ± SD	29.4 ± 6.5	30.9 ± 6.8	30.3 ± 4.9	30.2 ± 4.6
	CI	26.1-32.7	27.5-34.2	27.0-33.6	26.9-33.6
CMJ R	Mean ± SD	15.7 ± 4.2	16.5 ± 4.4	15.9 ± 2.4	15.8 ± 2.4
	CI	13.7-17.6	14.5-18.5	14.0-17.9	13.8-17.8
CMJ L	Mean ± SD	16.8 ± 4.4	17.6 ± 4.6	14.5 ± 3.1	14.4 ± 3.1
	CI	14.6-18.9	15.4-19.8	12.3-16.6	12.2-16.6
Illin. R	Mean ± SD	17.0 ± 1.3	17.0 ± 1.2	16.6 ± 0.54	16.6 ± 0.4
	CI	16.4-17.5	16.5-17.5	16.0-17.1	16.1-17.1
Illin. L	Mean ± SD	17.3 ± 1.5	17.2 ± 1.3	16.6 ± 0.5	16.6 ± 0.5
	CI	16.6-17.9	16.6-17.7	16.0-17.2	16.1-17.2
5 m	Mean ± SD	0.98 ± 0.08	0.95 ± 0.08	1.06 ± 0.06	1.06 ± 0.06
	CI	0.94-1.02	0.91-0.99	1.02-1.10	1.02-1.11
10 m	Mean ± SD	1.75 ± 0.15	1.70 ± 0.15	1.81 ± 0.08	1.81 ± 0.08
	CI	1.68-1.82	1.63-1.76	1.74-1.88	1.74-1.88
20 m	Mean ± SD	3.10 ± 0.29	3.01 ± 0.28	3.16 ± 0.14	3.15 ± 0.14
	CI	2.97-3.23	2.88-3.13	3.03-3.29	3.04-3.29
30 m	Mean ± SD	4.42 ± 0.46	4.29 ± 0.44	4.43 ± 0.19	4.44 ± 0.18
	CI	4.22-4.62	4.10-4.48	4.23-4.63	4.25-4.63

Note: EG – exercise group, CG – control group, SJ – squat jump, CMJ – countermovement jump, CMJ R – countermovement jump with a right leg, CMJ L – countermovement jump with a left leg, Illin. – the Illinois agility test, SD – standard deviation, CI – confidence interval

Table 5. Statistical indexes of the two-way repeated measures ANOVA

	Time		Group		Interaction	
	p	η^2	p	η^2	p	η^2
SJ	<0.001	0.371	0.682	0.007	0.002	0.338
CMJ	<0.001	0.625	0.950	0.001	<0.001	0.695
CMJ R	<0.001	0.798	0.880	0.001	<0.001	0.871
CMJ L	<0.001	0.832	0.083	0.121	<0.001	0.886
Illin. R	0.669	0.008	0.324	0.041	0.464	0.023
Illin. L	0.718	0.006	0.134	0.091	0.459	0.023
5 m	<0.001	0.889	0.002	0.327	<0.001	0.911
10 m	<0.001	0.927	0.078	0.124	<0.001	0.940
20 m	<0.001	0.923	0.244	0.056	<0.001	0.935
30 m	<0.001	0.921	0.564	0.014	<0.001	0.940

Note: SJ – squat jump, CMJ – countermovement jump, CMJ R – countermovement jump with a right leg, CMJ L – countermovement jump with a left leg, Illin. – the Illinois agility test, η^2 – partial eta square

Discussion

The results of the current study presented that the combined program of the low-volume plyometric exercises and the COD drills with low-frequency application improves performance in the 5-m and 10-m sprints. No differences were noted in other variables between the two groups. Additionally, the EG improved its performance in the 20-m and 30-m speed tests, as well as in all jump tests. In contrast, the CG did not enhance their performance in any of the tests.

As previously mentioned, this study found no discernible differences in the jumps between the groups. Following the application of the intervention program, a boost in the performance was noted in the EG. Similar findings are reported in recent studies [1, 15, 22, 29]. However, it should be noted that in the mentioned studies, an intervention was applied at least twice a week, resulting in higher overall program volume. For example, compared to the study by Aloui et al. [1], from which the plyometric program was adopted, only half of the jumps were performed in the present study. In contrast to the above, some studies found no significant effects on jumping performance [23] after an implementation of an intervention program. The lack of adaptations could be attributed to limited duration and volume of the program.

According to the available literature, it seems that there are studies providing support for the idea that one training session per week can improve athletes' performance. Specifically, Yanci et al. [35] examined an impact of a training program with the same volume but different weekly frequencies (once or twice per week). Results showed that both programs similarly improved performance in a 15-m sprint, COD exercises, and a horizontal jump. Interestingly, once-a-week frequency had a greater impact on repeated sprint ability compared to a twice-a-week program. This study involved adult futsal players. Additionally, in a recent study [6] conducted on youth soccer players, researchers investigated effectiveness of different training frequencies (once or twice per week) while maintaining the same training volume. Results indicated that after eight weeks of an intervention, both programs yielded similar results in applied physical fitness tests.

In the present study, the intervention program resulted in the improved EG performance between the two measurements (pre and post). Also, in the post-measurement, the EG differed significantly from the CG in the 5-m and 10-m sprints. Existing literature includes studies conducted on youth soccer players which have documented enhancements in sprint performance following an implementation of plyometric programs [21, 22] or combined plyometric programs with COD exercises [1, 2, 14, 17]. Similarly to jumps, Michailidis et al. [23] did not observe significant effects of an intervention on sprint performance, which was attributed to inadequate stimulus. In all these studies, the frequency of applying intervention programs was twice a week. Yanci et al. [35], in their study applying an intervention once a week, observed improvement in 15-m sprint performance in adult futsal players. Bouguezzi et al. [6], in a recent study, observed improvement in 15-m sprint performance, but not in 10-m, 20-m, and 30-m sprints in youth soccer players.

In this study, there no alterations were observed in the performance of the young soccer players in the COD (the Illinois agility test). Similar findings were reported in a recent study [3], in which researchers compared effects of a combined plyometric and COD exercise program with a program that included only COD exercises on various performance indicators in elite youth soccer players. The findings indicated that the intervention program, implemented twice a week for six weeks, did not impact performance in the COD test. In contrast to these findings, several studies have reported improvements in soccer players' performance after an implementation of intervention programs involving plyometrics and COD exercises [1, 2, 14, 17, 23]. Yanci et al. [35] observed a moderate effect (effect size, ES = –0.67) of a plyometric exercise intervention on COD performance (the 505 test). Bouguezzi et al. [6] observed significant improvements in COD performance after both once-a-week and twice-a-week frequency programs.

As mentioned earlier, the SSC is crucial for performance in all physical fitness tests, which primarily involve speed and power [24]. The SSC is categorized into two types based on ground contact time: the fast SSC (less than 250 ms) and the slow SSC (more than 250 ms). PT has demonstrated its effectiveness in enhancing the function of this physiological mechanism (the SSC). Thus, when PT is applied with an emphasis on developing the fast SSC (short ground contact time during jumps), performance in power and speed movements improves. In the present study, special attention was paid to the jumping technique and the short ground contact time. It has been suggested that improving performance through the SSC mechanism is due to the storage of energy during the eccentric phase, which is released during the subsequent concentric phase, enhancing performance [33]. In this study, the enhancement in the SSC could explain the performance improvement in most of the tests. However, this explanation is speculative, as measurements of factors affecting the SSC function, such as pre-activation, cross-bridge kinetics, and residual force enhancement [12], were not conducted.

Also, in PT, the training principle of specialization appears to be applicable. More specifically, a previous study [25] has been mentioned, indicating that applying horizontal jumps is more likely to improve performance in movements with horizontal characteristics, such as sprints. In the present study, the intervention included both vertical and horizontal jumps, a factor that may have influenced the improvement in jumping tests' performance (the intervention's vertical jumps) as well as in sprints (the intervention's horizontal jumps).

This research has certain constraints, including a restricted sample size, comprising solely the male youth soccer players aged below 16. Consequently, ability to generalize the findings to other developmental stages and genders is limited. Additionally, the very specific intervention program was utilized, limiting ability to compare with other studies. Furthermore, biological maturation, which can influence performance in physical fitness tests, has not been measured. Another factor that can influence players performance and was not considered is diet. Recording and analyzing athletes' diets before assessments could be conducted. Finally, the total playing time for each football player was not the same, and because it may be considered as training volume, it is mentioned in the limitations. Therefore, studies with larger samples, across different age groups, measuring biological maturation, and including both genders, will provide clearer conclusions about the impact of low-volume, high-frequency plyometric and COD exercise programs on power and speed indexes.

Conclusions

In conclusion, the present study supports that an intervention program incorporating plyometric exercises in one session and COD exercises in the other session can enhance 5-m and 10-m speed in young soccer players under 16. Additionally, the intervention program of the EG improved the players' performance in the jumps and the speed tests at 20 m and 30 m, however no differences were found between the two groups. The lack of adaptations in the agility test may be attributed to the program's characteristics (volume, frequency).

Conflict of Interest

The authors have no conflict of interest.

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