

# Effects of combined plyometric, strength and running technique training program on change-of-direction and countermovement jump: A two-armed parallel study design on young soccer players

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## ABSTRACT

**Context and objective:** Players must be capable to have a good change-of-direction (COD) skill aiming to be the fastest as possible to react immediately to the opponent or even to help players to be more agile since COD is a physical determinant of agility. Thus, the aim of this study was to test the effects of a six-week combined training intervention in the COD and countermovement jump (CMJ) of young soccer players, while comparing with a control group only performing the regular field-based training sessions.

**Methods:** A sample of 80 non-professional players (40 experimental group and 40 control group) between the ages of ten and twelve was taken [(Age:  $10.70 \pm 1.02$ )]. The tests that were carried out from the beginning to the end of the intervention were: CMJ test, 505COD Test and Illinois Test. Paired sample t-test was used for determining differences as a repeated measures analysis (pre–post). An ANCOVA test was performed using the pretest as a covariate and the times pre and post as factors.

**Results and conclusions:** Repeated measures ANCOVA revealed significant influence of baseline level on the 5–0–5 COD ( $p = 0.001$ ;  $\eta_p^2 = 0.170$ ), the Illinois ( $p = 0.018$ ;  $\eta_p^2 = 0.070$ ) and the CMJ ( $p = 0.047$ ;  $\eta_p^2 = 0.050$ ). Significant interactions group\*time ( $p < 0.001$ ;  $\eta_p^2 = 0.137$ ), 5–0–5 COD ( $p < 0.001$ ;  $\eta_p^2 = 0.274$ ), and CMJ ( $p < 0.001$ ;  $\eta_p^2 = 0.392$ ) were found, while no significant interactions were found in Illinois ( $p = 0.293$ ;  $\eta_p^2 = 0.014$ ). The current research revealed that a combined training intervention consisting of strength training, plyometrics, and running techniques can be significantly beneficial for improving COD performance and CMJ.

## 1. Introduction

The game of soccer is an intermittent exercise, in which periods of low-to-moderate efforts are interspaced by intensification moments to near to maximum efforts [1]. Although a majority of research in adult soccer players [2,3], it is also well-established research and information about game demands occurring in youth populations [4]. Youth soccer

players below twelve years old usually cover between 50 and 100 m per minute during an official match [5–7]. This can represent an amount between 2229 m for under-8 up to 5967 m for under-12. From the distance covered, values above 4.1 m/s can vary between 4% and 24% of the overall distance covered [4].

In the number of movements occurring in soccer, accelerating and decelerating while turning movements can occur up to 1200 times [8],

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which means that players must be capable to have a good change-of-direction (COD) skill aiming to be the fastest as possible to react immediately to the opponent or even to help players to be more agile since COD is a physical determinant of agility [9]. Actually, a good COD ability is also a good determinant of the more skilled and talented players [10,11]. Additionally, to COD, players must also perform power actions such as fast acceleration, or even using their reactive force and stretch-to-shortening cycle to be fastest in specific actions such as sprinting, high-acceleration, or even COD [12]. To do that, players must also hold good lower-limb power as well as present good stretch-to-shortening cycle optimization [13,14]. This can be confirmed by the strong and linear relationships between the countermovement jump (CMJ) and specific powerful actions such as sprinting or COD [15, 16].

The development of COD performance, speed, or lower-limb power is a need that should be considered while programming the training process, even in youth [17,18]. Despite different options, the basic approaches to strength and power training [19], and emphasizing some approaches to force transfer during running technique can be important for beginner players [20]. As an example, a randomized study comparing soccer-specific drills vs. running technique training revealed the last approach was significantly more effective in improving sprint than soccer-specific training [20]. Moreover, plyometric training (as a reactive force training method) has been also suggested as highly effective for youth athletic performance (e.g., COD, countermovement jump, sprinting) as reported in some systematic reviews [21,22].

The effectiveness of combined training programs (e.g., strength, plyometric, running-technique) can help youth soccer players to improve their physical fitness, while possibly improving their chances to cope with physical demands and improve the overall performance in match. Although such a possibility, the introduction of combined strength- and running-based training programs in young soccer players is no so common in the literature [23]. Thus, it is important to understand how a combined strength-running technique training can improve physical qualities as COD or lower-limb power in young soccer players. Thus, the aim of this study was to test the effects of a six-week combined training intervention in the COD and CMJ of young soccer players, while comparing with a control group only performing the regular field-based training sessions.

## 2. Method

### 2.1. Experimental approach to the problem

The study was conducted between March and May of 2022. (See Table 1, for more information). A parallel longitudinal design of two groups (pre, post) with a training program for a period of six weeks was used. Young Soccer players were assigned and paired into two groups, an experimental group (EG) and a control group (CG). To investigate the effect of a six-week program of specific strength, plyometric, and running technique intervention in young soccer players, CG players were asked to maintain their training routines, while EG players modified their training sessions by introducing 30 min of implementation of the program. Regarding the day of training, it was preceded by 48 h of absence of high effort.

**Table 1**  
Timeline of this study.

2022								
Months		March		May				
Week		1	2	3	4	5	6	
EG	Pre	Specific strength, plyometric, and running technique intervention						Post
CG	Pre	Maintain routines						Post

### 2.2. Subjects

A sample of 80 non-professional players (40 experimental group and 40 control group) between the ages of ten and twelve was taken [(Age:  $10.70 \pm 1.02$ )]. It should be noted that all the participants performed a total of two days a week (90 min per training session and played one match a week). The training sessions were based on the principles of Tactical Periodization [24]. Generally, training sessions comprised a warm-up, main part, and cooldown. Likewise, they competed in both provincial categories of the province of Granada (Andalusia), being the 2021/2022 season. A priori sample size calculation was performed using a free on-line tool, G\*Power (www.gpower.hhu.de), with a power level of 95% and an  $\alpha$  level of 0.05 and based in previous and similar studies [25], revealed that the sample size of  $> 40$  would be sufficient for the analysis.

Inclusion criteria for the participants in this study were (i) reported normal vision and no history of any neuropsychological impairments that could affect the results of the experiment, (ii) not presenting any injuries during the previous two months, (iii), giving their informed consent, and (iv) being an active player with a federation license and participate in all training sessions during the intervention program.

Finally, the parents of the participants obtained information about the main objectives of the research and signed informed consent forms. All soccer players in this research were treated according to the guidelines of the American Psychological Association (APA), so the anonymity of the participants' responses was guaranteed. The study was conducted in accordance with the ethical principles of Helsinki Declaration for human research, was approved by the Research Ethics Committee of the Pontifical University of Comillas (2021/86).

### 2.3. Procedure

#### 2.3.1. Pre- intervention

During the months of February and March (half of the regular season), the coaches of the participating teams were informed of the procedure that was going to be applied throughout the following weeks, highlighting the coaches' commitment to data collection.

During the data collection session, anthropometric data, including body mass, standing height, and sitting height, were also collected. All the participants were measured under the same fasting conditions and without having previously performed physical exercise. Participants completed a familiarization session with the 505COD test, Illinois Agility Test and CMJ seven days before the first week of intervention. To account for circadian variability [26], both data collection sessions were completed at the same time of the day and during the participants' regular training times. Pre- and post-test sessions were completed within a minimum of 48 h after a competitive match and in the absence of strenuous exercise within the preceding 24 h.

Before performing any tests, participants performed a standardized warm-up consisting of light aerobic activation, dynamic stretching and mobility, progressive sprinting, and preplanned submaximal changes of direction. All tests were carried out under favorable conditions and there were no rainy atmospheric conditions in any of the two tests days, with an average temperature of  $19^{\circ}\text{C}$  ( $19.2 \pm 2.4^{\circ}\text{C}$ ). The field in which the data collection has been carried out is made of synthetic artificial turf (4 G). Each test that was carried out was monitored by the main researcher and applied by the physical trainers of the teams, who were fully trained to record accurate and reliable data.

#### 2.3.2. Intervention

At the end of the data collection, the young soccer players proceeded to carry out a training program twice a week with a total duration of 6 weeks. The planning of the research consisted of the first week of data collection, six weeks of development of the intervention program and the last week for post data collection.

Likewise, all the training sessions detailed in Table 2 consisted of a

**Table 2**

Intervention program. Description of 6 weeks of training combining plyometrics, strength and running technique.

	W1					W2					W3			
	P1				—	P3				—	P5			
S1	TE	S	R	D		TE	S	R	D		TE	S	R	D
	I					I					I			
	b	2–4	10–15	A		c	2–4	10–15	A		a	2–4	15–20	B
	d	2–4	10–15	A		f	2–4	10–15	A		b	2–4	15–20	B
	e	2–4	10–15	A		g	2–4	10–15	A		d	2–4	15–20	B
	g	2–4	10–15	A		h	2–4	10–15	A		g	2–4	15–20	B
	i	2–4	10–15	A										
	II					II					II			
	j	2–4	10–15	A		j	2–4	10–15	A		l	2–4	15–20	B
	n	2–4	10–15	A		l	2–4	10–15	A		m	2–4	15–20	B
	n̄	2–4	10–15	A		m	2–4	10–15	A		n	2–4	15–20	B
	o	2–4	10–15	A		n	2–4	10–15	A		n̄	2–4	15–20	B
						o	2–4	10–15	A		o	2–4	15–20	B
	III					III					III			
	p	2–4	10–15	A		p	2–4	10–15	A		p	2–4	15–20	B
	q	2–4	10–15	A		q	2–4	10–15	A		q	2–4	15–20	B
	r	2–4	10–15	A		r	2–4	10–15	A		r	2–4	15–20	B
	s	2–4	10–15	A		s	2–4	10–15	A		s	2–4	15–20	B
	W4					W5					W6			
	P10					P11					P12			
S2	TE	S	R	D		TE	S	R	D		TE	S	R	D
	I					I					I			
	a	2–4	15–20	B		a	2–4	20–25	C		a	2–4	20–25	C
	b	2–4	15–20	B		c	2–4	20–25	C		c	2–4	20–25	C
	d	2–4	15–20	B		d	2–4	20–25	C		d	2–4	20–25	C
	g	2–4	15–20	B		f	2–4	20–25	C		f	2–4	20–25	C
	h	2–4	15–20	B		g	2–4	20–25	C		g	2–4	20–25	C
	II					II					II			
	l	2–4	15–20	B		II	2–4	20–25	C		II	2–4	20–25	C
	m	2–4	15–20	B		k	2–4	20–25	C		k	2–4	20–25	C
	n	2–4	15–20	B		m	2–4	20–25	C		m	2–4	20–25	C
	n̄	2–4	15–20	B		n̄	2–4	20–25	C		n̄	2–4	20–25	C
	o	2–4	15–20	B										
	III					III					III			
	p	2–4	15–20	B		p	2–4	20–25	C		p	2–4	20–25	C
	q	2–4	15–20	B		q	2–4	20–25	C		q	2–4	20–25	C
	r	2–4	15–20	B		s	2–4	20–25	C		s	2–4	20–25	C
	s	2–4	15–20	B										

**Notes:** (P): Proposal 1–12; (SE): Session; (S): Series; (R): Repetition; (W1–7): Week; (D) Difficulty: (A) Basic; (B) Medium; (C): High (TE): Type of exercise; (I) Strength exercises: (a) lunges; (b) CORE; (c) abs; (d) push-ups; (e) jump squat; (f) plank; (g) burpees; (h) Bulgarian Squat; (i) Resisted sprint (II) Plyometric exercises: (j) bilateral box jumps; (k) agility ladder; (l) forward-backward multi-jumps; (m) lateral jumps; (n): front jumps; (n̄) Lateral multi-jumps; (o) header jumps (III) Running technique exercises: (p) sprint max; (q) change of direction drills; (r) running technique with ball; (s): running drills.

warm-up, a main part and a cool-down, counting in each of them plyometric, strength and running technique exercises.

### 2.3.3. Post-intervention

At six weeks, after carrying out the scheduled sessions, all the tests that were carried out in the pre-intervention (505 test, Illinois test and CMJ test) were repeated. These tests were evaluated in the same place, at the same time as the first time and with the same climatic conditions.

## 2.4. Tests

As mentioned above, the tests that were carried out from the beginning to the end of the intervention were: CMJ test, 505COD Test and Illinois Test.

### 2.4.1. 505COD test

The 505COD test is a deceleration-change of direction test. The 505-agility test was conducted as follows:

The soccer player ran from the 15 m marker towards the line (entry distance is for speed building) and through the 5 m markers, turned at the line and ran back through the 5 m markers. Time was stopped once the athlete passed the 10 m line for the second time and over the timing gates using the Chronojump-Boscosystem® (Barcelona, Spain) photocells developed by de Blas et al. [27]. Each soccer player completed the

test twice. Between test and test he had a break of between 3 and 5 min to recover.

### 2.4.2. Illinois test

The Illinois agility test is a course that the length is 10 m and the width (distance between the start and finish points) is 5 m.

The athlete began the test lying face down on the ground with the head just behind the starting line, the arms bent and the hands under the shoulders. The physical trainer responsible of the test stood in line with the start and finish line and counted "three, two, one now". Saying "go", the footballer had to stand up as quickly as possible and accelerate towards the first cone and complete a 180° turn and then sprint towards the second cone and complete another 180° turn. Next, he had to go in and out of 4 cones over a distance of 10 m, complete a 180° turn and go through all 4 cones again.

Finally, the soccer player completed a 180° turn, will run forward 10 m to the penultimate cone, completed another 180° turn and ran 10 m to the finish line. Time was stopped once the athlete passed the finish line/timing gates using the Chronojump-Boscosystem® (Barcelona, Spain) photocells developed by de Blas et al. [27]. The soccer player completed the test twice. Between test and test he had a break of between 3 and 5 min to recover.

### 2.4.3. CMJ test

The CMJ was evaluated using the jump platform Chronojump-Boscosystem® (Barcelona, Spain) developed by de Blas et al. [27], who revealed intraclass correlation test levels between 0.821 and 0.949 to measure jumping height. This system was connected to an ASUS Rog Strix (Windows 11 Pro). The values were analyzed with a chronograph and recorded by Chronojump version 2.2.1. After warming up, the players performed the CMJ test three times on a contact platform, with 20 s of recovery between attempts to minimize the effect of fatigue. The average between jumps (in cm) was considered as the final result. They were instructed to jump as high as possible after reaching a knee angle of  $\sim 90^\circ$ . If any of these requirements were not met, the jump was repeated.

### 2.5. Statistical analysis

Data were analyzed using Statistica software (version 13.1; Statsoft, Inc., Tulsa, OK, USA) and the significance level was set at  $p < 0.05$ . Normal distribution and homogeneity tests (Kolmogorov–Smirnov and Levene's, respectively) were conducted on all metrics. Paired sample *t*-test was used for determining differences as a repeated measures analysis (pre– post). Cohen *d* was the effect size indicator. To interpret the magnitude of the effect size, we adopted the following criteria:  $d = 0.20$ , small;  $d = 0.50$ , medium; and  $d = 0.80$ , large. To discover between-group differences, an ANCOVA test was performed using the pretest as a covariate and the times pre and post as factors. To interpret the magnitude of the effect size of ANCOVA we adopted the following criteria:  $\eta_p^2 = 0.02$ , small;  $\eta_p^2 = 0.06$ , medium; and  $\eta_p^2 = 0.14$ , large.

### 3. Results

Repeated measures ANCOVA revealed no significant influence of baseline level on the variations occurring on body mass ( $p = 0.324$ ;  $\eta_p^2 = 0.013$ ), while baseline levels significantly influenced the 5–0–5 COD ( $p = 0.001$ ;  $\eta_p^2 = 0.170$ ), the Illinois ( $p = 0.018$ ;  $\eta_p^2 = 0.070$ ) and the CMJ ( $p = 0.047$ ;  $\eta_p^2 = 0.050$ ). Significant interactions group\*time ( $p < 0.001$ ;  $\eta_p^2 = 0.137$ ), 5–0–5 COD ( $p < 0.001$ ;  $\eta_p^2 = 0.274$ ), and CMJ ( $p < 0.001$ ;  $\eta_p^2 = 0.392$ ) were found, while no significant interactions were found in Illinois ( $p = 0.293$ ;  $\eta_p^2 = 0.014$ ). For more information about between group in baseline and intervention, see Table 3.

The within-group analysis with body mass, dataset revealed that experimental group significantly decreased (0.69%;  $p = 0.001$ ;  $d = 0.08$ ), while control group did not significantly body mass decreased (0.54%;  $p = 0.73$ ;  $d = 0.01$ ). Regarding within-group analysis with 505 COD, revealed that experimental group significantly improved (2.05%;

$p = 0.001$ ;  $d = 0.83$ ), while control group did not significantly 505 COD decreased (1.14%;  $p = 0.06$ ;  $d = 0.18$ ). A new within-group analysis with Illinois agility test, revealed that experimental group significantly improved (1.41%;  $p = 0.01$ ;  $d = 0.29$ ), while control group did not significantly Illinois agility test improved (1.35%;  $p = 0.85$ ;  $d = 0.08$ ). Last, the within-group analysis with CMJ, revealed that experimental group significantly improved (3.37%;  $p = 0.001$ ;  $d = 0.55$ ), while control group did not significantly CMJ improved (1.74%;  $p = 2.11$ ;  $d = 0.01$ ). See Figs. 1, 2 and 3.

### 4. Discussion

The current two-armed study conducted in eighty players revealed that the experimental group was significantly benefited by the combined training programme on the COD and CMJ performances. On the other hand, the control group only improved in the 5–0–5 test, with no significant improvements on the Illinois test and CMJ.

The training intervention performed over six weeks consisting in plyometrics, strength and running technique conducted to improvements of 5.25%, 1.94% and 7.78% on the 5–0–5 test, Illinois test and CMJ, respectively. On the other hand, the control group (only exposed to regular field-based training sessions) improved by 1.08% the 5–0–5 test, 0.55% the Illinois test and 0.03% the CMJ. The benefits of combined training program are evident and can be confirmed by previous studies that have used plyometrics [28], strength [29] and running technique [20] isolated programs for improving similar outcomes. Both 5–0–5 and Illinois test combines information from COD ability but also are highly dependent from linear speed [30,31]. In fact, the introduction of outcomes as COD deficit emphasizes the relevance of isolating COD ability from COD time [32]. In our study, we have only monitored COD time which in fact may provide us information from COD, but also from linear speed [33]. Considering that short-distances are highly influenced by acceleration and the mechanics associated with that (e.g., greater horizontal force, greater force application to overcome inertia) [34] it would be expectable that an emphasis of strength training in concentric mode would help in to generate greater force output [35] with final beneficial consequences for both COD time in 5–0–5 and Illinois.

The addition of plyometric training may also play a role for supporting the improvement of the ability to be fast in linear speed, while increasing the power in braking and acceleration phases. Although plyometrics can be more useful for linear speed phase (since improve leg stiffness, decreasing ground contact time) [36], it has been also observed a significant effect of plyometrics on COD ability as stated in a meta-analysis performed in different sports [37]. Finally, a contribution of the running technique may represent an important combination with

**Table 3**  
Performance variables before (pretest) and after (posttest) the intervention period (mean  $\pm$  SD).

Control Group (n = 40)					Experimental Group (n = 40)				Differences between
	Pretest	Posttest	%	RM <i>t</i> -test ( <i>p</i> )	Pretest	Posttest	%	RM <i>t</i> -test ( <i>p</i> )	Groups (ANCOVA)
<b>Anthropometric measures</b>									
Age (yrs)	10.70 $\pm$ 1.02	-	-	-	10.43 $\pm$ 1.06	-	-	-	
Height (cm)	144.55 $\pm$ 6.62	-	-	-	141.60 $\pm$ 9.31	-	-	-	
Weight (kg)	37.95 $\pm$ 5.69	37.92 $\pm$ 5.77	0.54 $\pm$ 0.32	$p = 0.73$ $d = 0.01$	36.89 $\pm$ 6.40	36.41 $\pm$ 6.24	0.69 $\pm$ 0.54	$p = 0.001$ * * $d = 0.08$	$p < 0.001$ $\eta_p^2 = 0.137$
<b>Physical Fitness</b>									
505	2.92 $\pm$ 0.19	2.89 $\pm$ 0.15	1.14 $\pm$ 0.90	$p = 0.06$ $d = 0.18$	2.97 $\pm$ 0.18	2.83 $\pm$ 0.18	2.05 $\pm$ 1.19	$p = 0.001$ * * $d = 0.83$	$p < 0.001$ ; $\eta_p^2 = 0.274$
Illinois	19.23 $\pm$ 1.21	19.13 $\pm$ 1.05	1.35 $\pm$ 1.18	$p = 0.47$ $d = 0.08$	19.51 $\pm$ 1.02	19.17 $\pm$ 1.33	1.41 $\pm$ 1.18	$p = 0.001$ * * $d = 0.29$	$p = 0.293$ ; $\eta_p^2 = 0.014$
CMJ	23.90 $\pm$ 4.07	23.92 $\pm$ 3.79	1.74 $\pm$ 1.84	$p = 0.95$ $d = 0.01$	23.27 $\pm$ 3.50	25.23 $\pm$ 3.65	3.37 $\pm$ 1.77	$p = 0.001$ * * $d = 0.55$	$p < 0.001$ ; $\eta_p^2 = 0.392$

Note: %: Percentage of change. \* Denotes significance at  $p < 0.05$ , and \* \* denotes significance at  $p < 0.01$

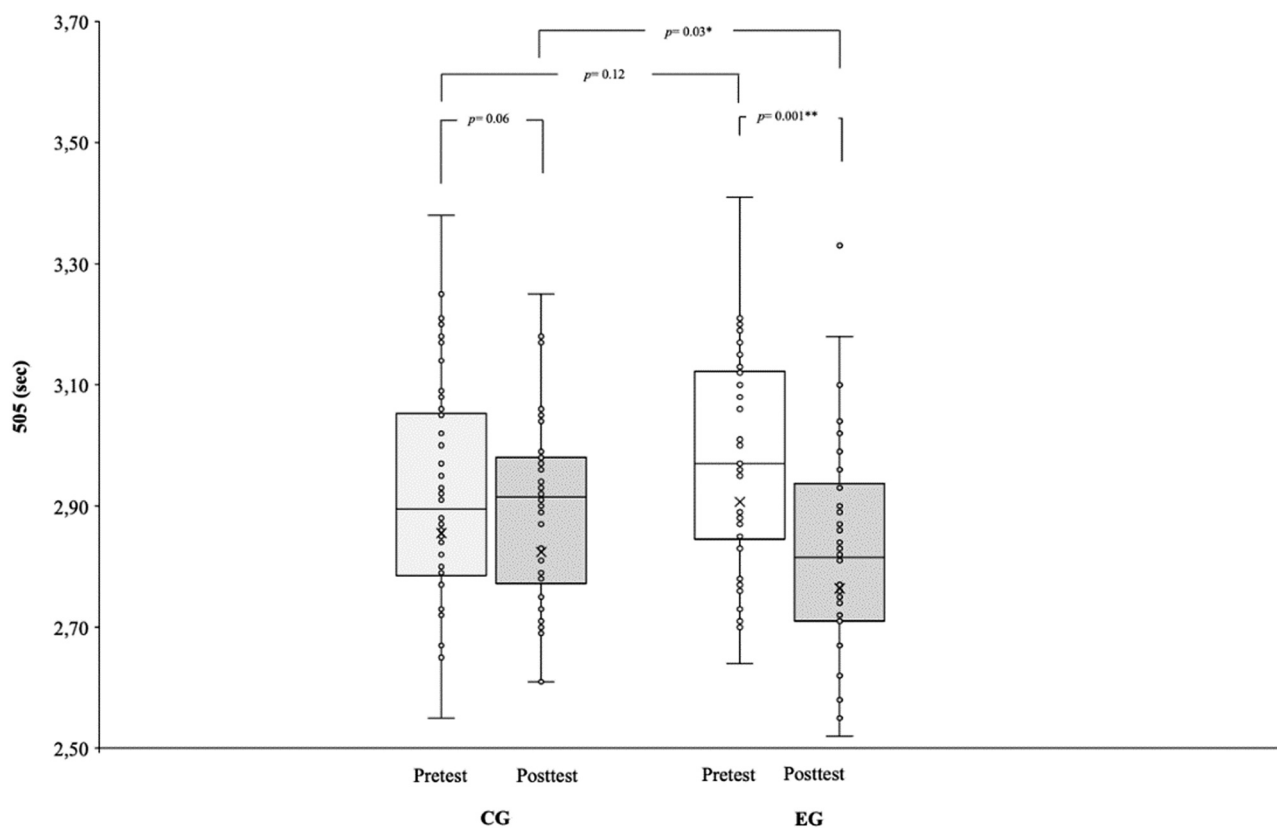


Fig. 1. Pre- and post-tests in CG and EG of physical fitness variables (505 test).

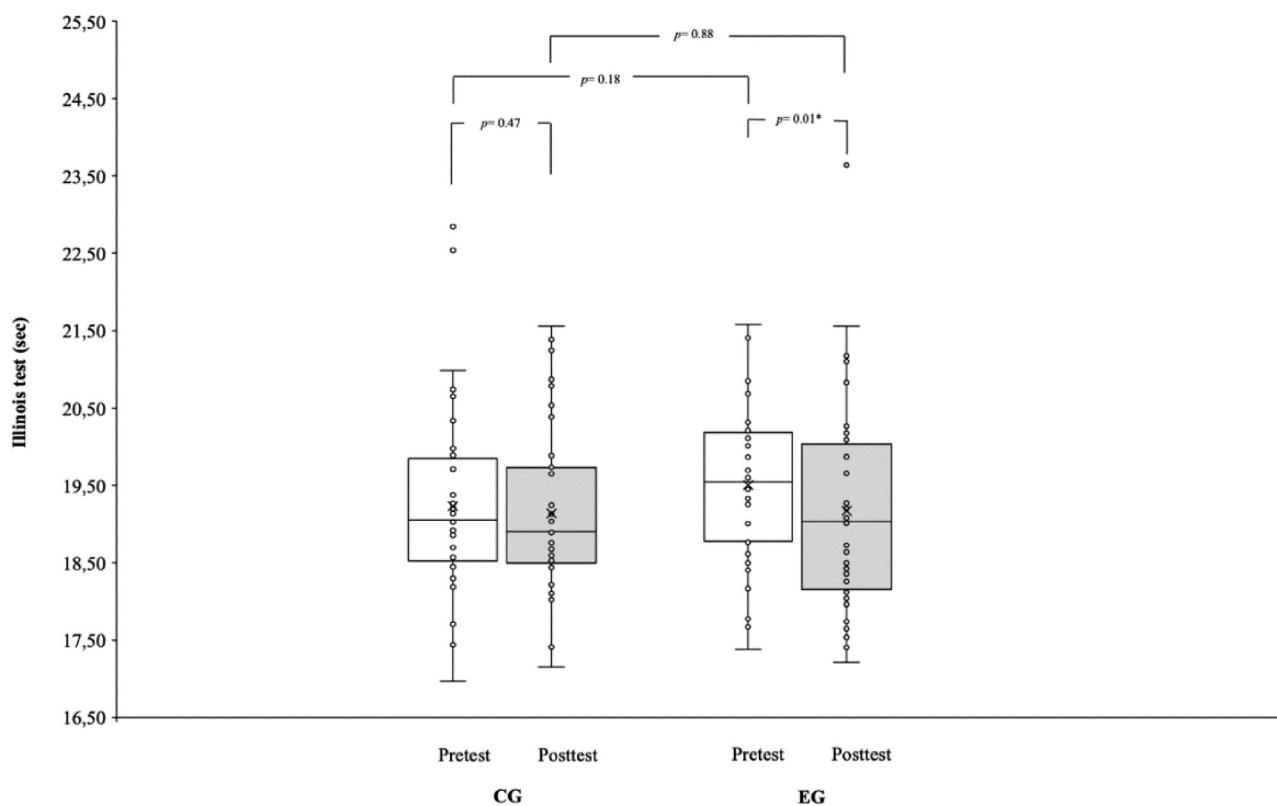


Fig. 2. Pre- and post-tests in CG and EG of physical fitness variables (Illinois test).

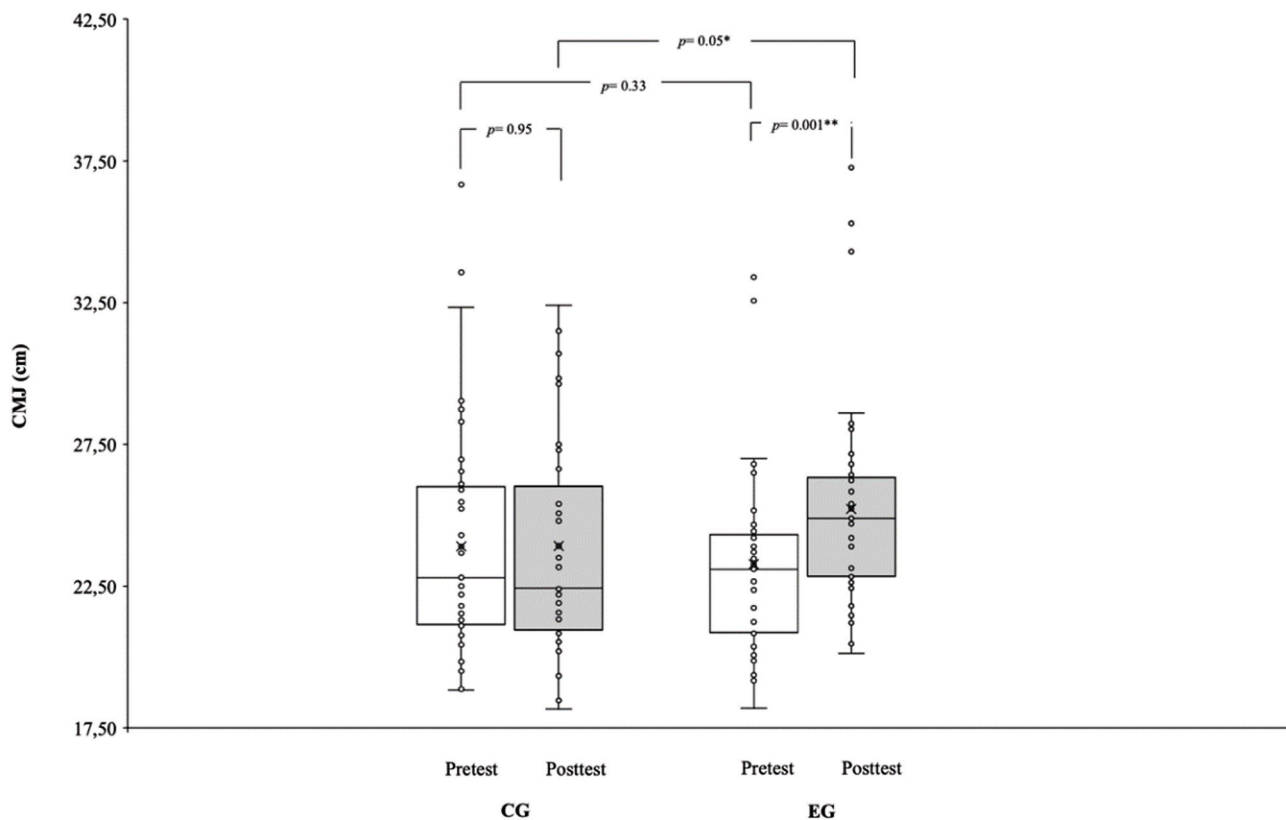


Fig. 3. Pre- and post-tests in CG and EG of physical fitness variables (CMJ).

gains coming from strength training and plyometrics since may improve the neural activation [38] of players to run with a better mechanical application of forces [39,40].

The CMJ performance was observed as being significantly benefited by the training intervention (7.78% in average), while control group had trivial changes (0.03%). The consequence of combining strength and plyometrics training can justify the adaptations and is in line with previous reports [41,42]. In fact, plyometrics and CMJ uses the same base of stretching-shortening cycle which is one of the reasons for jumping higher in CMJ [43]. Moreover, plyometrics increases the power and neural activation for a fast neuromuscular activation which is in line with the need for a greater performance in CMJ [44]. Additionally, the strength training may also play a role for increasing strength and with combination of neural activation promoted by the plyometrics training significantly contribute for a better performance in the CMJ [44,45].

In the current study, the COD, running technique and plyometric program was effective in promoting improvements in vertical jump ability, which is consistent with some recent studies that specifically used plyometric [46,47] training protocols to improve jumping ability in young soccer players. Possible adaptations may include increased neuronal activation of agonist muscles, improved intermuscular coordination, and changes in the mechanical properties of the muscle-tendon complex [48].

The study has some limitations. The COD performance did not consider COD deficit which is the main outcome associated with COD ability. This was caused by the limitation in the instruments. However, we cannot firmly argue if COD ability was significantly improved, or on the other side the linear speed which is closely related to COD time obtained as the main outcome. Additionally, this study tested a two-armed design in which a combined training program was performed. Since the combination included strength, plyometrics, and running technique training we cannot provide the main causes related to the positive adaptations performed. However, the combination provides us

with different information since is more realistic and follows a greater ecological approach to the training rather than just looking for isolated training interventions not combined with other approaches.

## 5. Practical applications

The current research revealed that a combined training intervention consisting of strength training, plyometrics, and running techniques can be significantly beneficial for improving COD performance and CMJ. The effects of the 6-week period were significant and also were better than those occurring in the control group (which does not improve performance in CMJ and Illinois).

It can be suggested that in order to maximize the lower body physical capabilities of young elite football players during the season phase, exercising within the optimal performance range for hip, knee and ankle extensor loads may be a valid possibility. COD, plyometric and running technique programs can also be incorporated simultaneously into football training sessions to provide variations in training stimuli to effectively improve a player's neuromuscular skills. This information will surely help coaches and sports scientists develop better and more effective training programs to improve performance.

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## CRediT authorship contribution statement

Authors contribution: research concept and study design (RM and FMC), literature review (RM and AF), data collection (RM and FTG),



data analysis and interpretation (FTG and FMC), statistical analyses (FTG), writing of the manuscript (RM, AF, FMC and FTG) and reviewing/editing a draft of the manuscript (FMC, RM and FTG).

## Declaration of Competing Interest

There are no financial or other relationships that might lead to a conflict of interest.

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