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Analyzing the Influence of Speed and Jumping Performance Metrics on Percentage Change of Direction Deficit in Adolescent Female Soccer Players

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Abstract: Studies show that although female soccer players often have shorter change of direction (COD) deficits than males, indicating different biomechanical profiles, there is lack of research on the impact of physical metrics on COD performance in females. The aim of this study was to analyze whether performance metrics based on speed, and jumping could explain the variation in %CODD in young female soccer players. Thirty-three highly trained adolescent female soccer players (age: 16. ± 0.95 years; height: 160.4 ± 5.22 cm; body mass: 55.7 ± 7.22 kg) performed COD180 tests, 10-m and 30-m sprint test and single leg countermovement and horizontal jumps. Acceleration in the first 10 meters of a sprint was identified as a significant predictor of COD180 performance (R2 = 28%), (R2 = 50%), ($p<0.01$), indicating that early sprint performance may largely determine an individual's change of direction ability. However, no predictors were found for %CODD. Significant correlations were observed between COD180 performance and %CODD, acceleration, linear speed, and horizontal jump performances ($r = -0.59$ to 0.70; $p<0.05$). The study suggests that specific physical performance metrics, particularly early acceleration, are crucial for enhancing COD skills in female soccer players, emphasizing the need for targeted training interventions.

Keywords: sprint; football; women; multidirectional speed; team-sport

1. Introduction

Women's soccer has grown exponentially in recent decades, with an increase of just over 24% from 2019 to 2023. At that time, 16.6 million women played soccer, 3.9 million federated female players (19,064 of these players are professionals), 55,622 women's clubs, and 48,202 female coaches [1]. Interest has also increased at the social and institutional level , and in 2019, the FIFA (Fédération Internationale de Football Association) presented the "Women's Football Strategy" [2]. Among the objectives of this strategy are to encourage the growth of the sport, to attract more female players, and to enable them to play for more years [2].

Soccer, as an intermittent sport, involves a multitude of brief, high-intensity actions that are repeated throughout a match, including shots on goal, sprints, jumps, and accelerations and decelerations. A significant part of these actions requires changes of direction (COD), which are decisive in determining the outcome of a match and serve as reliable indicators of performance levels in the sport [3]. These CODs require players to accelerate, decelerate and change direction as quickly as possible. Previous research highlights the importance of linear speed [4–6], lower limb power [3], [7], reactive strength [8,9], motor control [8] or a combination of these components [10] in improving

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COD performance. At the same time, the nature of football demands unilateral movement skills and usually involves multidirectional activities such as jumping or cutting [11]. Actions such as unilateral and bilateral jumps, linear and curvilinear sprints, zig-zag runs, side-steps, cross-cuts or repeated back-and-forth movements are common [11]. In particular, direct sprinting often becomes a critical action during goal or assist phases among professional female players. In competitive scenarios, elite female football players are known to cover a total distance of [9] to [11] kilometres, with 590 to 840 metres at high intensities of 15.6 to 20 km/h, and 198 to 379 metres via sprints at speeds above 20 km/hm [12].

The change of direction deficit (CODD), introduced by Nimphius et al. [13], serves as a measure to analyse COD capacity by emphasising the specific timing of COD actions, offering a more accurate comparison between groups through a percentage-based approach [14]. This method suggests a closer mirroring of actual COD performance, revealing that female athletes, particularly female soccer players, often exhibit shorter CODD than men, indicating sex-specific biomechanical and performance profiles [15,16]. Kobal et al. [17] found that athletes with higher sprint speeds may have greater CODD, implying that high speed does not necessarily correspond to efficient COD capacity. Female football players, in particular, show greater CODD compared to those in other team sports, suggesting lower efficiency in directional change despite their sprinting abilities [18]. The relationship between CODD and jumping power has also been explored, showing that better jumping ability correlates with better CODD performance in female athletes [7,8,19], reinforcing the value of CODD in the assessment and training of female football players. These results highlight the importance of specialised training and injury prevention strategies, taking into account the different needs of different sports and genders.

In recent years, there has been a rise in empirical studies investigating interlimb asymmetries in soccer players [20,21]. In addition, research regarding CODD asymmetry and its effects on performance, especially in different type of jumps, remains limited. Some authors explored the relationship between CODD asymmetry and various bilateral jumps, finding that greater asymmetry could correlate with poorer jumping performance [20,21]. These results reinforce the notion that greater unilateral jumping ability and concentric strength could enhance COD performance, fundamental during the turning phases of specific tests such as the 505. In contrast, Lockie et al. [22] and Dos'Santos et al. [23] did not identify significant correlations between CMJ asymmetries and physical fitness tests, and Fort-Vanmeerhaeghe et al. [24] also found no significant associations between CMJ asymmetry and COD in mixed team sport participants. This is consistent with the findings of Bishop et al. [25] and Loturco et al. [26], who reported no associations between vertical jump asymmetries and COD in elite female soccer players. These results suggest that the high level of both general and specific training among female soccer players may elucidate the influence of asymmetries on performance, mirroring the integral role of vertical jumps and COD actions in competitive soccer [25,27]. The paucity of studies on female soccer players further highlights the existing gap in sport science research, accentuating the demand for in-depth and gender-focused analyses to further enhance training strategies and performance strategies in women's team soccer.

In reviewing the existing literature, there are some studies that have shown that male soccer players categorised by their CODD, particularly those who exhibit greater speed, tend to show lower performance on CODD metrics [28]. However, there is a notable lack of research on whether performance metrics related to acceleration, speed, and jumping can explain variations in CODD among female soccer players. Moreover, to date, no study has further explored the analysis of these variations in terms of percentage CODD (%CODD) a novel method for calculating the COD deficit. This approach, based on the percentage difference between linear sprint and COD abilities rather than raw data, standardises this metric, thereby facilitating a more comprehensive understanding of COD ability in group comparisons [14]. Therefore, the present study aimed to examine whether performance metrics based on speed, and jumping could explain the variation in %CODD in young female soccer players.

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2. Materials and Methods

Participants

Thirty-three highly trained adolescent female soccer players (age: 16. ± 0.95 years; height: 160.4 ± 5.22 cm; body mass: 55.7 ± 7.22 kg) agreed to participate in the study. An a priori power analysis was conducted to determine the appropriate sample size using G*Power (version 3.1.9.3, Düsseldorf, Germany). Considering the study design, a within-group design looking at differences, an effect size at 0.5, an alpha level of 0.05, and a required power of 80%, a total sample of 27 participants was required. Thirty-three subjects were included in the current study resulting in the current power of 87%. These athletes had participated in soccer training at the club level for at least four years, performing three weekly technical and tactical sessions on the field of 90 min each. In addition, they performed a weekly physical training session, lasting 90 minutes, focusing on speed, agility, quickness, injury prevention, and coordination to maintain their physical condition. Competitions were regularly played on weekends, and teams participated in national and regional competitions. Written informed consent was obtained from the parents or guardians of all participants. The study adhered to the ethical guidelines of the Declaration of Helsinki (2013) and received approval from the local ethics committee (CP19/039, CEICA, Spain).

Procedures

Physical fitness assessments were performed sequentially on the same day, in the following order: unilateral horizontal and vertical jumps, linear sprint, and COD tests. It was recommended that no high-intensity activities be performed during the 48 h prior to the tests to minimize muscle fatigue. In addition, players were advised to avoid consuming caffeine or any other stimulant (i.e., energy drinks or dietary supplements) that could alter their natural performance. The importance of maintaining proper nutrition and optimal hydration in the 48 h before testing was also emphasized. All participants had previously performed these tests several times (i.e., at least five times), which ensured their familiarity with the procedures. To facilitate recovery and maintain consistency in performance, a 3-min rest interval was allowed between each test. Participants wore athletic shoes for the jumping tests and soccer boots for the linear sprint and COD tests. A warm-up protocol for the rise, activate, mobilize, and potentiate (RAMP) system was performed before the tests [29]. The "activation" phase consisted of dynamic movements and exercises specifically designed to activate the key muscle groups used in the tests. This was followed by the "mobilize" phase, which included dynamic stretching to improve the range of motion and joint mobility. Finally, the "potentiation" phase was designed to prepare the neuromuscular system, incorporating specific exercises that imitated the movement patterns and intensity of the tests to be performed.

Unilateral Countermovement Jump Test

The test was performed twice, with a 45-s rest interval between attempts, and the highest result was recorded. Participants were required to perform a jump on one leg, with the hands placed on the hips and the opposite leg flexed at a 90° angle at both the hip and knee for CMJ with a left and right leg (CMJL and CMJR, respectively, using the Optojump system (Microgate, Bolzano, Italy). A jump was considered invalid if the technique was incorrect, such as not keeping the hands on the hips or not landing on the same leg. It was allowed to swing the flexed leg in the air, and upon landing, participants had to maintain balance on the leg they had jumped for 3 seconds to ensure a valid attempt. The intraclass correlation coefficient (ICC) was 0.99, and the coefficient of variation (CV) was 3.6%.

Unilateral Horizontal Jump Test

Performance (i.e., distance) in the left and right horizontal jumps (HJL and HJR) was measured using a tape measure over two attempts, with a 45-s rest between each jump. The longest jump was selected for analysis. Swinging the leg for momentum was allowed, and landing on one leg was

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required. Only jumps where the participant could maintain balance and hold the position at the end for 3 seconds were considered. The reliability of the test was high, with an ICC of 0.98 and CV of 1.6%.

10-m and 30-m Sprint Test

Running speed was assessed by a 40-min sprint, with split times recorded at 10 and 30 m. Timing was performed using double-beam photoelectric cells (Witty, Microgate, Bolzano, Italy). The starting position required the front foot to be placed 0.5 m behind the first timing gate, and a two-point staggered stance was adopted. The timing gates were placed at a height of 0.75 m and a distance of 1.5 m between each other. The placement of timing gates at varying distances made it possible to distinguish between acceleration capability (0 to 10 meters) and maximum speed capability (30 to 40 meters). Each participant completed the 40-m sprint twice, with a minimum of 3 min of passive recovery between attempts. The reliability was 0.96 and of 1% for ICC and CV, respectively.

180°. Change of Direction Test

A 10-m shuttle sprint test was conducted. Participants sprinted from the start/finish line to the 5-m mark, touching it with either foot, and then made a 180° turn to sprint back. Participants had to ensure that the outside foot crossed the finish line to consider a trial successful. They started with the front foot 0.5 m behind the first timing gate. Timing gates, located 0.75 m high and 1.5 m apart, recorded the times (Witty, Microgate, Bolzano, Italy). Each player completed two trials, one with the left foot in front and the other with the right, in alternating order, with a two-minute rest between them. The fastest time for each foot was used for the analysis. The variables analysed included 180 COD with left (COD180L) and right (COD180R) legs. The ICC value was 0.80 and CV was 1%. The percentage-based change in direction deficit was calculated using the formula: ((COD time–10 m sprint time)/10 m sprint time)* 100)) [22].

Statistical Analyses

All statistical analyses were performed using SPSS (version 25, IBM, New York, NY, USA) and Microsoft Excel (version 2016, Microsoft Corp., Redmond, WA, USA). Data are presented as mean ± SD. Within-session reliability was assessed by the CV and ICC, using a spreadsheet specially designed for the calculations. Normality was assessed using the Shapiro-Wilk test and showed all variables as normally distributed variables, except for inter-limb asymmetries. Multiple linear regression models (stepwise backward elimination procedure) with COD times and the %CODD as the dependent variables were also used. Independent variables were anthropometry, unilateral vertical and horizontal jumping, 10-m, 30-40-m, and inter-limb asymmetries. In the backward procedure, variables with p-value > 0.05 were removed from the model. Relationships between COD times and the %CODD with the rest of variables were assessed using Pearson's product-moment correlation. According to Hopkins et al. [30], the magnitude of correlation coefficients was considered trivial (r < 0.01), small (r = 0.1 to <0.3), moderate (r = 0.3 to <0.5), large (r = 0.5 to <0.7), very large (r = 0.7 to <0.9), nearly perfect (r = 0.9 to <1) and perfect (r = 1).

Players were divided into Good or Bad %CODD through the median split technique. Differences between the two conditions (Good vs. Bad) were analysed using paired t-tests. Friedman's analysis of variance was conducted to determine differences in asymmetry scores, with statistical significance set at p<0.05. The magnitude of difference between both groups was calculated using Cohen's d ESs using the formula: (MeanCOD1 – MeanCOD2)/SDpooled, where COD1 and COD2 represent the respective COD angles in question (e.g., COD45, COD90, COD135, COD180). These were interpreted in line with Hopkins et al. [30] where <0.2 = trivial; >0.2–0.6 = small; >0.6–1.2 = moderate; >1.2–2.0 =large; >2.0–4.0 = very large; and >4.0 = near perfect.

3. Results

The descriptive physical performance and asymmetries data are reported in Table 1.

Table 1. Descriptive data for all physical performance tests.

Variable	Mean ± SD	Asymmetry (%)
CMJR (cm)	12.6 ± 2.19	10.2 ± 9.1
CMJL (cm)	12.4 ± 3.27	
HJR (cm)	129.0 ± 13.9	4.68 ± 7.08
HJL (cm)	126.8 ± 11.4	
COD180R (s)	2.97 ± 0.15	2.56 ± 1.67
COD180L (s)	2.97 ± 0.15	
10-m (s)	2.03 ± 0.07	
30-40 m (s)	1.47 ± 0.08	
%CODDR (%)	46.8 ± 6.44	7.85 ± 5.04
%CODDL (%)	46.3 ± 5.34	

CMJR and CMJL: unilateral countermovement jump with right and left legs; HJR and HJL: unilateral horizontal jump with right and left legs; 10-m: linear sprint of 10 m; COD180R and COD180L: 10-m shuttle-sprint with one change of direction to right or left; %CODDR and %CODDL: the percentage-based change of direction deficit to right of left.

COD180L, COD180R, %CODDR, and %CODDL were significantly (p<0.05) and largely (r = 0.63 to 0.82) related (Table 2). Furthermore, significant (p<0.05) relationships were found between both COD180 and horizontal jumping with either right (r = -0.59 to -0.47) or left (r = -0.53 to -0.49) legs, 10 m (r = 0.53 to 0.70), and 30–40m (r = 0.51 to 0.65) (Table 2).

Table 2. Pearson correlation coefficients (r) between COD, %CODD, and all performance scores for each test.

	COD180L	%CODDR	%CODDL	Body mass	Height	CMJR	CMJL	Asy CMJ	HJR	HJL	Asy HJ	Asy COD	10-m	30-40 m	Asy %COD
COD180R	**0.82 (0.66; 0.91)**	**0.71 (0.48; 0.85)**	**0.63 (0.37; 0.80)**	0.15 (-0.20; 0.47)	-0.06 (-0.39; 0.29)	-0.19 (0.50; 0.16)	-0.21 (-0.51; 0.15)	0.00 (-0.34; 0.35)	**-0.47 (-0.69; -0.15)**	**-0.53 (-0.74; -0.22)**	-0.00 (-0.34; 0.34)	-0.14 (-0.46; 0.21)	**0.53 (0.23; 0.74)**	**0.51 (0.20; 0.72)**	-0.23 (-0.53; 0.12)
COD180L	—	**0.35 (0.00; 0.62)**	**0.72 (0.49; 0.85)**	0.33 (-0.02; 0.60)	0.04 (-0.31; 0.38)	-0.27 (-0.56; 0.08)	-0.17 (-0.49; 0.18)	-0.16 (-0.48; 0.18)	**-0.59 (-0.77; -0.31)**	**-0.49 (-0.72; -0.18)**	-0.17 (-0.48; 0.19)	-0.22 (-0.52; 0.13)	**0.70 (0.48; 0.84)**	**0.65 (0.39; 0.81)**	-0.27 (-0.56; 0.08)
%CODDR	—	—	0.71 (0.48; 0.85)	-0.08 (-0.41; 0.27)	-0.07 (-0.41; 0.28)	0.12 (-0.23; 0.45)	0.05 (-0.30; 0.39)	0.01 (-0.33; 0.36)	0.01 (-0.33; 0.36)	-0.12 (-0.44; 0.23)	0.34 (-0.00; 0.61)	0.03 (-0.31; 0.37)	-0.22 (-0.53; 0.13)	0.00 (-0.34; 0.34)	-0.09 (-0.42; 0.26)
%CODDL	—	—	—	0.16 (-	0.05 (-	0.03 (-	0.09 (-	-0.22 (-	-0.19 (-	-0.12 (-	0.16 (-	-0.09 (-	0.01 (-	0.23 (-0.12;	-0.18 (-

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	0.20; 0.47)	0.29; 0.39)	0.32; 0.37)	0.25; 0.43)	0.52; 0.13)	0.50; 0.16)	0.45; 0.23)	0.19; 0.48)	0.42; 0.26)	0.33; 0.35)	0.53)	0.49 ; 0.17)

CMJR and CMJL: unilateral countermovement jump with right and left legs; Asy CMJ: between-limbs CMJ asymmetry; HJR and HJL: unilateral horizontal jump with right and left legs; Asy HJ: between-limbs HJ asymmetry; 10-m: linear sprint of 10 m; COD180R and COD180L: 10-m shuttle-sprint with one change of direction to right or left; Asy COD: between limbs COD asymmetry; %CODDR and %CODDL: the percentage-based change of direction deficit to right of left; Asy %CODD: between-limbs %CODD asymmetry.

The single best predictor of COD180 right and left was performance in the 10-m sprint, with and explained variables of 28% and 50%, respectively ($p<0.01$). On the other hand, no regression model was predictive of %CODD on either limb.

Table 3. Model linear regression analysis with measures of COD and %CODD.

		Variables	SC	Partial *r*	*p*	R2	r	Rating
COD180R	Model 1	Intercept 10-m	0.53	0.53	0.01	0.28	0.53	Moderate
COD180L	Model 1	Intercept 10-m	0.71	0.71	<0.01	0.50	0.71	Large

*No variables in %CODDR and %CODDL models. COD180R and COD180L: 10-m shuttle-sprint with one change of direction to right or left; SC: Standardized coefficient; %CODDR and %CODDL: the percentage-based change of direction deficit to right of left.

When the cohort was divided using a median split technique by the mean %CODD (Table 4), the subgroups exhibiting good %CODD were better in the HJ asymmetry, COD180R, 10-m, and %CODD for both right and left, with "moderate and large" ES's ranging from 0.63 to 2.39.

Table 4. Analysis of all variables between good and bad %CODD groups.

	Good %CODD (n=16)	Bad %CODD (n=17)	ES (CI95%)	*p*
Age (yr)	16.3 ± 0.93	15.7 ± 0.91	0.62 (-0.08; 1.32)	0.08*
Body mass (kg)	57.1 ± 6.67	54.3 ± 7.65	0.39 (-0.29; 1.08)	
Height (cm)	161.2 ± 4.93	159.6 ± 5.53	0.30 (-0.38; 0.98)	
CMJR (cm)	12.4 ± 2.32	12.6 ± 2.12	0.09 (-0.56; 0.77)	
CMJL (cm)	12.2 ± 3.68	12.6 ± 2.92	0.13 (-0.56; 0.81)	
Asy CMJ (%)	11.0 ± 11.1	9.50 ± 6.85	0.17 (-0.52; 0.85)	
HJR (cm)	128.0 ± 9.81	130.0 ± 17.1	0.14 (-0.54; 0.82)	
HJL (cm)	128.1 ± 12.7	125.7 ± 10.4	0.21 (-0.47; 0.89)	
Asy HJ (%)	2.14 ± 7.29	7.07 ± 6.14	0.73 (0.22; 1.43)	0.04*
COD180R (s)	2.91 ± 0.12	3.04 ± 0.15	0.98 (0.25; 1.70)	0.008*
COD180L (s)	2.92 ± 0.11	3.01 ± 0.18	0.53 (-0.17; 1.22)	
Asy COD (%)	2.72 ± 1.62	2.41 ± 1.75	0.18 (-0.50; 0.86)	
10-m (s)	2.05 ± 0.06	2.00 ± 0.08	0.63 (-0.08; 1.32)	0.08*
30-40 m (s)	1.47 ± 0.07	1.47 ± 0.10	0.01 (-0.67; 0.69)	
%CODDR (%)	41.7 ± 3.66	51.6 ± 4.50	2.39 (1.48; 3.28)	<0.001*
%CODDL (%)	42.6 ± 2.94	49.8 ± 4.75	1.80 (0.97; 2.61)	<0.001*
Asy %CODD (%)	8.82 ± 5.16	6.93 ± 4.91	0.37 (-0.32; 1.06)	

CMJR and CMJL: unilateral countermovement jump with right and left legs; Asy CMJ: between-limbs CMJ asymmetry; HJR and HJL: unilateral horizontal jump with right and left legs; Asy HJ: between-limbs HJ asymmetry; 10-m: linear sprint of 10 m; COD180R and COD180L: 10-m shuttle-sprint with one change of direction to right or left; Asy COD: between limbs COD asymmetry; %CODDR and %CODDL: the percentage-based change of direction deficit to right of left; Asy %CODD: between-limbs %CODD asymmetry; CI:

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confidence intervals; ES: effect size. * indicates a significant difference between good and bad %CODD groups ($p < 0.05$).

4. Discussion

The present study examined whether performance metrics based on speed, and jumping could explain the variation in %CODD in young female soccer players. Regression analyses revealed the 10-m distance as a predictor of both legs in COD180; however, no predictors were identified for the %CODD. These findings suggest that individual variance in COD180 right/left can be explained by the 10-m distance (acceleration phase). Significant correlations were found between COD180 right/left and %CODD right/left, 10-m, 30-40-m, and horizontal jump right/left, whereas %CODD right/left was only significantly related to COD times. When dividing the group by the %CODD performance, effect sizes indicated that the subgroup with good COD (indicating faster COD ability) exhibits a quicker COD180 change, has a lower %CODD, and shows a lower horizontal jumping asymmetry, indicating that the current female soccer players maintain greater mean speed during COD in both directions, as they could apply horizontal force symmetrically.

In soccer performance, the ability to accelerate in the fastest possible time is related to greater lower body power and, in turn, faster COD [31]. The current results indicate that a 10-m distance (acceleration) was predictive of better COD performance tests. Emmonds et al. [8] also reported that 10-m and 20-m times were good predictors of better COD performance in elite female soccer players. Acceleration has been described as a task that is more dependent on concentric propulsion [32], and maximal sprinting velocity seems to be more dependent on the stretch-shortening cycle (SSC) [33]. This implies that jumps in which countermovement is performed involve the SSC, which could lead to a lack of relationship between such jumps and shorter sprint distances (5-m to 20-m). This statement is reinforced by Young et al. [34], who found a strong relationship between concentric strength during squat jump (SJ) and 2.5-m sprint time, and by Baker and Nance [35], who reported similar significant results between concentric strength and 10-m sprinting time, while it was not found for 40-m sprint time. Another study in adolescent and collegiate female athletes has provided moderate to very large relationships between SJ and 20-m sprint ($r = -0.32$ to -0.76) [35–37]. Regarding of strength, Nimphius et al. [38] found moderate to very large relationships ($r = -0.50$ to -0.75) between relative dynamic maximal strength (1RM/Body Weight) and dominant leg COD performance in female soccer players. Therefore, it seems that concentric propulsion exercises such as plyometric split squats, jump squats, or box jumps focusing on the concentric phase of the movement may be useful in the design of training programs aimed at improving acceleration and COD in female soccer players.

In the present study, significant relationships were found between COD180 and 10-m ($r=0.53$ to 0.70) and 30-40-m ($r=0.51$ to 0.65). In the same line, a recent study showed large correlations between 10-m speed and COD (Pro Agility test/5-10-5 $r=0.59$; Zig-Zag test $r=0.55$) [39]. On the other hand, Lockie et al. [3] found heterogeneous results in collegiate women's soccer players. In National Collegiate Athletic Association (NCAA) Division I players, the modified T-test was not significantly related to 10-m linear velocity ($r=0.18$) and, on the other hand, the 505 test was positively correlated with 10-m sprint ($r=0.35$). In NCAA Division II players, the modified T-test and 505 test showed a large relationship with 10-m sprinting ($r=0.66$ and $r=0.55$, respectively) [3]. No studies have been found in female soccer players analysing the relationship between COD and 30-40 m time. However, studies analysing the relationship between COD tests and 30-m time have been found. One study showed large correlations between 30-m speed and COD (Pro Agility test/5-10-5 $r=0.66$; Zig-Zag test $r=0.55$; 9-6-3-6-9 test $r=0.58$) in elite female soccer players [39]. Another study analysed male soccer players and found a large correlation between linear speed (30-m) and the Zig-Zag test ($r=0.56$-0.60) [40,41]. As such, further studies analyzing the impact of maximal linear sprinting or long sprinting distances (40-m) and its relationships with the total distance covered, the distance prior COD and/or the number of CODs during a COD test should be considered in female soccer players.

In soccer, as in other sports, unilateral propulsion in the vertical and horizontal directions is determinant in most actions. Previous studies have found high correlations between unilateral

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horizontal jumping and acceleration [42]. Kugler et al. [43] confirmed that horizontal forces are important for acceleration; however, forward propulsion requires maximal force in this direction and also optimal horizontal force application. A recent systematic review and meta-analysis of highly trained athletes over 18 years of age indicated that horizontal jumping distance is positively associated with sprinting performance, showing that an athlete who jumps more may sprint faster [44]. According to this meta-analysis, this result is because both tasks involve several similarities, such as: strength (horizontal force generation and power output) and movement characteristics (unilateral ground contacts and triple joint extension), among others [44]. Along the same lines, Robbins and Young [45] conducted an analysis of the possible relationship between sprinting ability (peak velocity or acceleration) and horizontal jumping in elite college soccer players, finding moderate correlation coefficients between long jumping distances with peak velocity performance (r = 0.35 to 0.47), and acceleration performance (r = 0.35 to 0.43). In reference to COD, it is likely that unilateral jumps (in horizontal, vertical and lateral directions) resemble the action of changing direction itself [46]. In the current study, significant relationships were found between COD180 and HJR (r = -0.59 to -0.47) and HJL (r = -0.53 to -0.49). These results are in agreement with those presented by Lockie et al. [47], in which a significant relationship was observed between horizontal jumping and the 505 test in female university rugby players (r = -0.71). The same COD test was used to analyse these variables in male team sports players, also finding significant correlations between the HJR and the 505 with both legs (left leg r = -0.30; right leg r = -0.48) and the HJL and the 505 (left leg r = -0.37; right leg r = -0.53) [22]. Therefore, it is imperative to integrate unilateral horizontal and vertical jumping exercises into training programs to improve both acceleration and COD capabilities. Coaches and physical trainers are encouraged to focus on developing horizontal force production and optimization by taking advantage of drills that simulate real game situations to improve players' ability to apply power effectively in multiple directions, such as lateral plyometric jumps, single-leg forward and backward jumps and lateral movements, ladder agility drills, or resisted sprints using bands or sleds to improve explosive power through forward propulsion.

A previous study recommended the use of CODD instead of normal COD to analyse this particular action and eliminate the first part of the linear sprint from the test (i.e. the time recorded in 10-m) [38]. However, two different calculations are currently proposed for the CODD (time-based or speed-based), which can lead to confusion for physical trainers and coaches. To standardize the measurement, Freitas et al. [14] proposed the use of the % CODD, which is based on the percentage difference between the linear sprint and COD capacities. In the present research, this measurement was used, and it was observed that when dividing the sample into two groups (players with a better %CODD versus players with a worse %CODD), the subgroup with a good %CODD showed better results in the COD180R (ES=0.98), the %CODD for both the right (ES = 1.80) and the left legs (ES = 2.39), and the horizontal jumping asymmetry (ES = 0.73). Nevertheless, the group with the worst %CODD recorded a significantly lower time in the 10 m sprint (ES = 0.63). Fernandes et al. [28] analysed a sample of adolescent professional soccer players and divided them into two groups: those with better CODD and those with lower CODD. In that study, players with better CODD showed significant correlations between CODS and CODD on both the left (r = 0.69) and right sides (r = 0.65). On the other hand, no significant associations were found between acceleration (10 m sprint) and CODD for either limb (left r = -0.34 and right r = -0.39). Other studies analysing male team athletes obtained similar results for both CODD and the COD 505 test (r = 0.74-0.81) and the 10-m sprint (r = -0.11 to 0.10) [38]. Similarly, the study by Lockie et al. [3] also identified that NCAA female football players with higher acceleration (10 m sprint) showed worse CODD results (NCAA Division I r = -0.88 and NCAA Division II r = -0.77). In relation to the higher horizontal jumping asymmetry and lower COD performance, previous studies in male athletes have found associations between this higher HJ asymmetry and poorer COD ability (r = 0.60) [9]. Fernandes et al. [28] suggested that the possible reason why athletes who accelerate faster perform worse in the COD is that the greater the impulse, the greater the braking requirement, which depends on eccentric strength. Other studies have shown that COD performance is associated to a greater extent with eccentric strength compared with isometric or concentric strength, mainly because of the importance of the braking phase mentioned above [48]. On this basis, training programs that include exercises with eccentric loading (e.g. isoinertial training) and to improve the specific technique of COD could be justified [11].

A possible limitation of the present study is that the sample was not divided by playing positions because of the small number of players, something that has been done in previous research [27,49]. Another limitation is the scarcity of literature related to the %CODD, specifically in female soccer players. However, the data cannot be extrapolated to other populations such as men's soccer, different age groups, or other team sports. In addition, consideration of the maturation stage can provide additional information. Despite these considerations, this study provides relevant data on the relationship between COD performance and other variables that are also key factors in soccer performance.

5. Conclusions

Acceleration in the first 10-m of a sprint is a strong predictor of COD180 performance, and individual differences in this test are largely explained by performance in these initial meters. No predictors were found for the %CODD, but significant correlations exist between COD180 and %CODD performance, acceleration, linear velocity, and horizontal jump. In addition, the %CODD correlates with COD180 times. Subgroups with better %CODD showed higher performance in COD ability, while those with lower %CODD showed poorer acceleration.

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