TECHNICAL REPORT

PERCENTAGE-BASED COD DEFICIT: A NEW APPROACH TO STANDARDIZE

TIME- AND VELOCITY-DERIVED CALCULATIONS

Running Head: *COD Deficit Calculation*

ABSTRACT

Change of direction (COD) efforts are crucial in team-sports and an extensive body of research has been devoted to investigating this complex and multifaceted skill. Most studies have assessed players' ability to change direction by reporting completion time or average velocity in different COD tasks. However, it has been argued that these variables may not accurately portray an athlete's true capability to quickly change direction. In this context, new metrics such as the "COD Deficit" (CODD) have been proposed to provide complementary information on the efficiency to change direction. The current literature presents two different CODD computations: time-derived and velocity-derived calculations. Despite both being consistent and representing the same phenomenon, the decision of using one or the other may produce different outcomes, thus influencing coaches' decisions and training strategies. To overcome this issue, we propose a new approach to the computation of the CODD, based on the difference in percentage between linear sprint and COD abilities, in an attempt to standardize the estimation of this variable and simplify the evaluation of COD performance.

Keywords: change of direction speed; sprint; athletic performance; agility; directional change.

INTRODUCTION

Change of direction (COD) speed is essential in most team-sports since rapidly changing direction can lead to players being in advantageous situations (e.g., when fighting for the ball or positioning) that may ultimately impact match outcomes (26). In soccer, for example, players may execute up to 700 quick directional changes per match (2). Similarly, in rugby sevens, multiple COD efforts and successive high-intensity accelerations and decelerations are characteristic of training and competition, as evidenced by game analysis (9) and data gathered with global positioning systems and triaxial accelerometry (1). For these reasons, players must possess a wide set of skills to effectively perform numerous accelerations, decelerations, and cutting and turning maneuvers, at different intensities and in multiple directions (6, 26, 30, 33, 38).

According to Hewitt et al. (16), COD speed is underpinned by several physical (e.g., speed-power related qualities, anthropometric factors) and technical aspects (e.g., ground- and aerial-based movements), which emphasizes its multifaceted nature. Several investigations agree that the ability to change direction is complex, being associated with a series of performance variables such as linear sprint velocity, deceleration-acceleration capabilities, and lower-body strength and power (4, 5, 12-15, 17, 18, 23, 31, 34, 35). In competitive scenarios, the vast majority of directional changes are of unpredictable nature and executed in response to a varied set of external stimuli (e.g., opponents' actions or team-mates' movements) (30, 38), requiring athletes to perform COD maneuvers in multiple directions and at different angles (6).

Concerning COD assessment, no universal gold-standard test can be defined, as the outcomes of the task will necessarily be conditioned by the characteristics of the maneuver being performed (i.e., the COD angle and velocity) (6). With this in mind, coaches use a

multitude of COD tests to better evaluate their athletes, according to the characteristics and demands of each sport (7, 23, 26). When evaluating the ability to change direction, athletes are usually instructed to complete the task "as fast as possible" (5, 15, 17, 19, 26, 34). Therefore, most studies have considered total test completion time as the metric for COD speed, with athletes who conclude the task in the least amount of time being considered as faster and having superior performance (4, 5, 15, 17, 19, 37). Although this measure provides valuable information (in fact, when competing for ball possession in an action involving a COD maneuver, the player with the lower COD time has an advantage to get the ball), it has been argued that total time may not exactly represent the actual ability of athletes to effectively change direction (7, 11, 24, 27, 32).

Sayers (32) advocated that 505 total time was biased towards linear sprint velocity. The author observed a strong relationship between 505 and 20-m sprint times; however, when the COD distance decreased, the respective correlation also decreased. Correspondingly, a more detailed analysis of the 505 test revealed that athletes spent about 30% of the total time changing direction, which suggests that superior COD performances may be strongly influenced by linear sprint velocity (27). In practical terms, players may excel in COD tests if they are particularly faster over straight sprints, as this capability could "mask" a lower physical or technical proficiency to perform directional changes (27). To overcome this issue, the COD deficit (CODD) has recently been proposed as a complementary variable to evaluate COD performance (28). The present article discusses current practices regarding the assessment of COD ability, with a focus on the CODD. Specifically, we introduce a novel approach to the calculation of this variable to standardize and simplify its reporting and interpretation.

THE COD DEFICIT

Initially proposed in 2013 as a time-derived method (28), the CODD is a new parameter suggested to "separately" evaluate the ability to change direction (7, 14, 24, 27, 28). This variable represents the difference in time or velocity between a linear sprint and a COD task of equal distance, thus allowing the assessment of COD qualities independently of sprinting and acceleration capacities (22, 27, 28, 31). Therefore, CODD represents the efficiency of a given athlete to change direction, with respect to his or her maximum sprinting velocity (14, 22, 24, 31). A lower CODD indicates a greater efficiency to change direction as it means that the player has a superior ability to use his or her linear velocity to quickly execute a directional change (14, 24, 31).

The CODD has been used to better identify individuals more or less efficient at changing direction. Notably, previous studies have shown that faster and more powerful athletes tend to present greater CODD (7, 10-14, 20, 21, 23, 24, 31). Freitas et al. (14) demonstrated that team-sport players with higher half-squat strength and jump squat power were faster in linear sprinting actions but less efficient at changing direction (i.e., greater CODD). Similarly, in female soccer players, the CODD was found to be strongly related to 10-m sprint performance ($r = -0.77$), highlighting the large influence of linear sprint velocity on the CODD magnitude (20). The reduced ability of faster athletes to utilize their linear sprint capacity to change direction might be related to difficulties in handling high entry velocities (6) or to "inherent" consequences associated with being faster (i.e., higher sprint momentum and, consequently, inertia) (11, 13, 14, 24). Based on these aspects, it appears that both sprint velocity and sprint momentum (i.e., the product of velocity and body mass) may play a key role in the CODD magnitude (7, 10-14, 20, 23, 31).

COD DEFICIT COMPUTATION: INFLUENCE ON COD OUTCOMES

When examining the current literature, we can identify two different CODD calculations: 1) time-derived (CODDt) (7, 8, 10, 11, 20, 25, 27, 36), consisting of the time difference between COD tasks and linear sprints of equivalent distances (e.g., 505 test: $CODD_{505}$ = 505 time - 10-m sprint time); and 2) velocity-derived (CODDv) (3, 12-14, 21-24, 31), obtained by subtracting the velocities achieved during linear sprints and COD maneuvers of similar distances (e.g., 505 test: $CODD_{505}$ = 10-m sprint velocity - 505 velocity). Nevertheless, to date, it is not clear which measure is more sensitive to assess COD performance.

A simple computation reveals that results obtained from the two approaches can be quite different. For instance, an athlete completing a 10-m sprint in 2-s (i.e., velocity of 5 m·s^{-1}) and a 505 test in 2.6-s (3.85 m·s^{-1}) exhibits a CODD of 0.6-s and 1.15 m·s^{-1}, as calculated by time and velocity differences, respectively. Nonetheless, a second athlete with a 10-m sprint time of 1.7-s (5.88 m·s^{-1}) and a 505 time of 2.3-s (4.35 m·s^{-1}) displays an equal CODD according to the time-derived calculation (0.6-s), but a superior score when computed based on the velocity-derived approach (1.53 m·s^{-1}). To further exemplify this, Table 1 presents the 20-m sprint and Zigzag performance outcomes and the respective CODDt and CODDv from three athletes. The data presented were obtained from 43 male (rugby, n = 24; soccer, n = 19) and 45 female (rugby, n = 25; soccer, n = 20) professional team-sport players. All these athletes signed informed consent forms and the study protocols were approved by the local Ethics Committee.

TABLE 1 HERE

As it can be observed, three individuals may present the same CODDt but different CODDv. A consequence of this phenomenon is that, despite both calculations being valid and useful, the decision to use one or the other will certainly affect testing outcomes and, more importantly, coaching practices and training strategies. According to the approach used to estimate the CODD, two coaches may have different perspectives and interpretations on the same player. Figure 1 helps to illustrate this issue.

FIGURE 1 HERE

After calculating the Z-scores (Z-score = [individual score – group mean]/ group standard deviation) for the CODDt and CODDv obtained via the Zigzag test by elite female athletes from different sports, it is possible to observe different CODD magnitudes (and sometimes "directions") for some respective players in the same COD test. For example, in Figure 1C (i.e., female professional soccer players), focusing specifically on Player 15, it is clear that the CODDt and CODDv provide different information to the coach. If the CODD was calculated with the time-derived approach, Player 15 would be considered to be "below the average" for the sample analyzed (i.e., a positive Z-score value) in terms of her COD ability. However, by using the velocity-derived approach, the same player would have been classified as "above the average" (i.e., a negative Z-score). These distinct interpretations of COD ability are not specific to a single sport, testing configuration, or sex; in fact, according to our data, this holds true for both female and male rugby and soccer players (Figure 1).

In the same context, careful inspection of the male rugby Zigzag CODD data (Figure 1E), shows that 12 of the 24 players assessed (i.e., 50%) displayed opposite scores (i.e., Z-scores on opposite directions) when considering CODDt and CODDv. Assuming that

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practitioners use test scores to provide feedback, determine player characteristics, and define training standards, a consistent evaluation of COD performance is essential. This is particularly relevant if we consider that, in elite sport contexts, it is commonplace for coaches from different organizations (e.g., club and National Team) to share athletes' data with the aim of optimizing performance and reducing injury risks. The possibility of time- and velocity-derived CODD calculations producing contradictory results may lead different coaching staffs to detect divergent data for the same player, which could result in different training requirements and strategies.

It is important to emphasize that faster athletes in linear sprints tend to display greater CODD by both the time-derived (7, 10, 11, 20) and velocity-derived approaches (12-14, 23, 31). Since both calculations may represent the same phenomenon, it is not possible to conclude which computation method is more adequate (i.e., able to report more consistent results) to determine the "actual" COD ability. The issue here is clear: depending on the approach utilized, the same athlete may be required to perform two different training programs with the same goal: reducing CODD (and improving COD ability). Thus, it is necessary to develop a calculation able to provide similar outcomes for athletes, irrespective of the approach employed to determine the CODD (i.e., time- or velocity-based).

A NOVEL APPROACH TO DETERMINE THE COD DEFICIT

A possible solution for coaches and sport scientists to determine the CODD is to calculate this variable as a difference in percentage between linear sprint and COD velocity or linear sprint and COD time (i.e., CODD%). By reporting the CODD%, a given athlete can obtain the same outcome, regardless of the variable used by practitioners when collecting sprint or COD data (i.e., s, for time or m·s^{-1}, for velocity). In Table 2, where 20-m sprint and

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Zigzag performance outcomes (in time and velocity) are presented, the CODD is reported as "percentage"; therefore, the fastest player (i.e., *Athlete A*) displays exactly the same and higher CODD (i.e., 88%) and the slowest player exhibits the lower CODD (i.e., *Athlete C*; 79%), independently of applying time- or velocity-based calculations.

TABLE 2 HERE

Under the same perspective, focusing again on *Player 15* in Figure 1C, it is possible to observe that the CODD% leads to similar interpretations of her COD ability when using either the time- or velocity-derived approach. This is evident for all sports, sex, or COD tests analyzed herein (Figure 1). The proposed approach consists of standardizing the reporting of the CODD, thus simplifying the interpretation and comprehension of the data as the CODD% reports the difference in percentage between linear sprint and COD capabilities. The CODD% is a quick and easy calculation, able to provide consistent and stable reporting of COD efficiency, using either time- or velocity-derived data. Using the 505 as an example, when considering sprint and COD time, the CODD% should be calculated as follows:

$$CODD\% \ t = ([505 \text{ time} - 10\text{-m sprint time}]/10\text{-m sprint time}) * 100$$

Alternatively, when utilizing sprint and COD velocity data, the following calculation should be used:

$$CODD\% \ v = ([10\text{-m sprint velocity} - 505 \text{ velocity}]/505 \text{ velocity}) * 100$$

Applying the previous equations to the data of *Athlete B* (Table 2), the CODD% calculation for the Zigzag test would be performed as follows:

$$CODD\% \ t = ([5.56 - 3.04]/3.04) * 100 = 83\%$$

$$CODD\% \ v = ([6.59 - 3.60]/3.60) * 100 = 83\%$$

In practical terms, the score obtained by *Athlete B* means that he is 83% "slower" when performing a COD drill (i.e., the Zigzag test) than when completing an equal distance during a linear sprint. The use of the CODD% may be advantageous for practitioners as it reports CODD in a comprehensive, uniform, and consistent manner.

The two existing computations (i.e., time- and velocity-derived methods) and the new approach proposed here (i.e., percentage-based) are very strongly associated ($r \sim 0.90$ for all tested correlations), as observed in the male and female samples displayed in Figure 2A and 2B. It is worth noting that no significant proportional bias was detected between percentage-based, time-derived, or velocity-derived calculations (i.e., the 95% confidence intervals of both slopes included the value 1) (29), but that a poor agreement between these last two CODD calculations was found (i.e., the 95% confidence interval in Figure 2C does not contain the value 1). In summary, it seems that a systematic bias exists when comparing the two methods; therefore, an athlete with a higher CODD would perform significantly better (i.e., displaying a lower CODD) using the velocity-derived method, whereas an athlete with a lower CODD would perform significantly better (i.e., exhibiting a lower CODD) when using the time-based method. As such, the good agreement observed between the CODD% and the CODDt and CODDv and the consistency and stability detected when employing the

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first computation advocates for its utilization over the other methods. We should emphasize that a CODD of 50% does not necessarily represent the same value (in terms of efficiency or deficiency) in, for example, the modified 505 (i.e., 10-m total distance and a 180º COD) or Pro-Agility tests (i.e., 20-m total distance and two 180º COD); thus, coaches should avoid direct comparisons of different testing outcomes (26). However, by reporting the CODD%, coaches can better examine if a given player is less or more efficient than other players at changing direction, by simply comparing the percentage differences between COD and linear sprint performances (as presented in Table 2).

FIGURE 2 HERE

Briefly, the utilization of CODD% may enable practitioners from different contexts (e.g., club and National Team staff) to share player data, hence improving athlete management. Moreover, under this novel approach, sport scientists and coaches can better and more precisely assess their athletes and define normative data for different COD measurements, comprising players from different sports, age categories, and playing positions. Finally, and more importantly, this standardized calculation may be used to develop more effective and tailored training schemes, directed to the actual needs and characteristics of athletes, regardless of the method used to measure and determine the CODD.

PRACTICAL APPLICATIONS

The present study aimed to address a potentially problematic issue when determining the CODD via different calculations (i.e., time- and velocity-derived). On the one hand, it is possible that two athletes display similar magnitudes of CODDt but different CODDv for the same test (Table 1). On the other, a given athlete may have different evaluations of his or her COD efficiency (when compared to his or her peers) based on the approach used by the coach to calculate the CODD (Figure 1). This phenomenon may occur with different tests (e.g., 505, Zigzag, L-drill, Pro-agility), in multiple sports (e.g., soccer, handball, futsal, or rugby) and in both male and female athletes. The novel approach to determine the CODD as percentage differences, based on linear sprint and COD test time or velocity, allows standardizing the reporting of this variable in relative terms (as opposed to absolute values reported either in s or m·s^{-1}). In addition, this method of computation may avoid practitioners making contradictory decisions that may affect training prescription. Strength and conditioning coaches are recommended to calculate the CODD% since this computation provides more consistent information regarding COD performance, regardless of the variables used for determining linear sprint and COD capacities (i.e., s, for time or m·s^{-1}, for velocity).

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Table 1. Example of COD deficit calculations for the Zigzag test of athletes from different sports.

	Sport	20-m Sprint Time (s)	Zigzag Time (s)	CODDt (s)	20-m Sprint VEL (m·s⁻¹)	Zigzag VEL (m·s⁻¹)	CODDv (m·s⁻¹)
Athlete A	Soccer	2.88	5.40	2.52	6.94	3.70	3.24
Athlete B	Soccer	3.04	5.56	2.52	6.59	3.60	2.99
Athlete C	Rugby	3.19	5.71	2.52	6.25	3.50	2.75

CODDt: change of direction deficit time-derived; CODDv: change of direction deficit velocity-derived; VEL: velocity.

Table 2. Example of COD deficit calculations for the Zigzag test of athletes from different sports using the CODD%.

	Sport	20-m Sprint Time (s)	Zigzag Time (s)	CODDt (%)	20-m Sprint VEL (m·s⁻¹)	Zigzag VEL (m·s⁻¹)	CODDv (%)
Athlete A	Soccer	2.88	5.40	88	6.94	3.70	88
Athlete B	Soccer	3.04	5.56	83	6.59	3.60	83
Athlete C	Rugby	3.19	5.71	79	6.25	3.50	79

CODDt: change of direction deficit time-derived; CODDv: change of direction deficit velocity-derived; CODD%: change of direction deficit percentage-based; VEL: velocity.
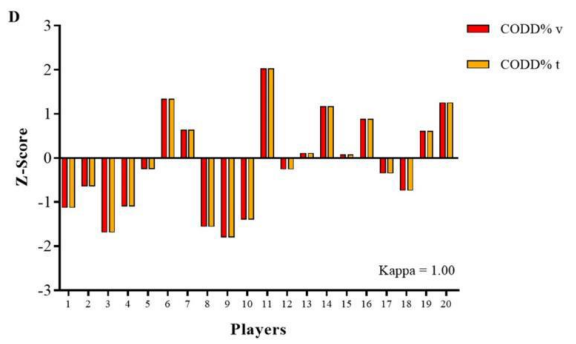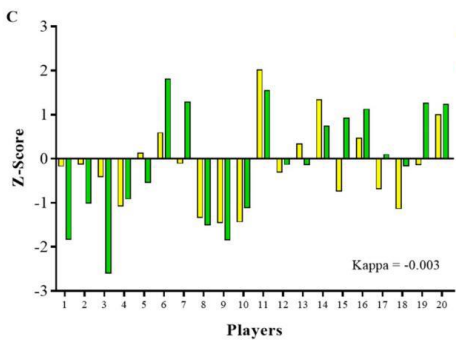
FIGURE CAPTIONS

Figure 1. Change of direction deficits of female and male team-sport athletes (standardized scores in the Zigzag test) calculated via the time-derived (CODDt), velocity-derived (CODDv) and percentage-based (CODD% t and CODD% v; 1B, 1D and 1F) approaches.

Figure 2. Linear regressions between change of direction deficits (standardized scores in the Zigzag test) calculated via the different approaches in female rugby players and male soccer athletes: A) percentage-based (CODD%) and velocity-derived (CODDv); B) percentage-based (CODD%) and time-derived (CODDt); and C) velocity-derived (CODDv) and time-derived (CODDt).
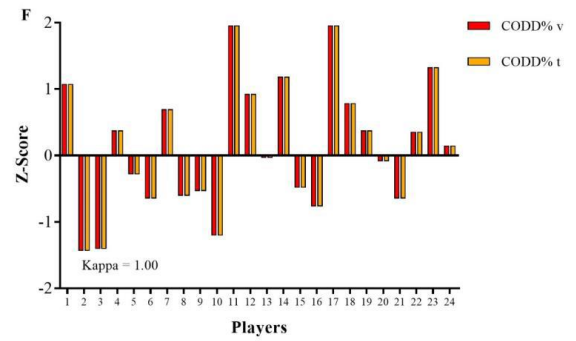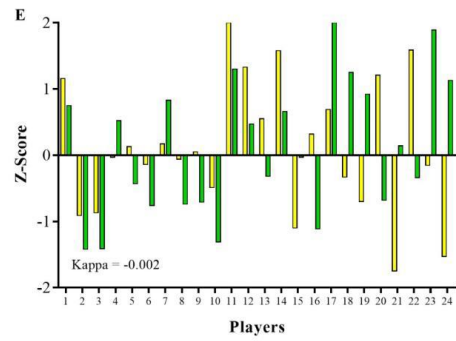
Zigzag - Female Rugby
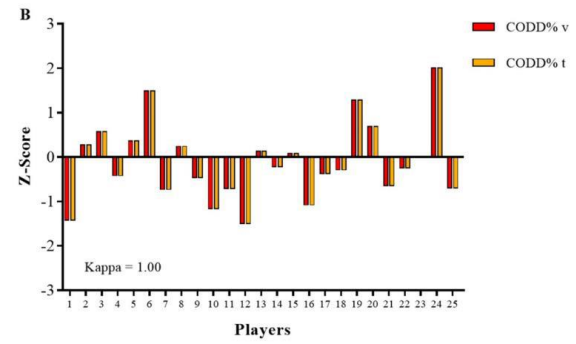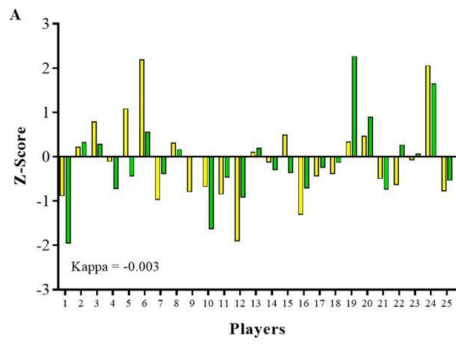
Zigzag - Female Soccer

Zigzag - Male Rugby

Zigzag - Male Soccer

A

Male Soccer   Female Rugby

$r = 0.90$
$P < 0.0001$
95 % CI Slope: 0.75 to 1.01

Z-Score CODD% vs Z-Score CODDv

B

$r = 0.89$
$P < 0.0001$
95 % CI Slope: 0.74 to 1.02

Z-Score CODD% vs Z-Score CODDt

C

$r = 0.61$
$P < 0.0001$
95 % CI Slope: 0.38 to 0.89

Z-Score CODDv vs Z-Score CODDt