

**Research article**

**CHANGE-OF-DIRECTION DEFICIT IN COLLEGIATE  
WOMEN'S RUGBY UNION PLAYERS**

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**Abstract.** *Change-of-direction (COD) ability is an essential component of rugby union. As most COD tests use total time to measure COD performance, the COD deficit has been developed as a metric to isolate COD ability independent of linear sprint speed. This study investigated relationships between sprint time, 505 time, and COD deficit in collegiate women's rugby union players. Seventeen players from the one team performed a 20-m sprint (0-5, 0-10, and 0-20 m intervals were measured), and the 505 from each leg. The COD deficit for both legs was calculated as the difference between average 505 and 10-m time. Correlations were calculated between the 505 and COD deficit with the sprint intervals ( $p \leq 0.05$ ). To compare 505 time and COD deficit, z-scores were derived; the difference in these scores were evaluated for each participant. The COD deficit did not correlate with the sprint interval times ( $r = -0.370$  to  $-0.045$ ). Right-leg 505 time did correlate with the 0-10 and 0-20 m intervals ( $r = 0.483$ - $0.552$ ). Six of 17 participants for the left leg, and five of 17 for the right leg, were classified differently for COD ability when comparing standardized scores for 505 time versus COD deficit. More than half the participants (53-59%) had meaningful differences between 505 time and COD deficit for each leg. These results suggested that the COD deficit may be a more isolated measure of COD ability and provided a different measure of this ability compared to 505 time in collegiate women's rugby union players.*

**Key words:** 505; agility; change-of-direction speed; females; team sports

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## INTRODUCTION

Women's rugby union, or rugby as it is often called, has been recognized as an emerging sport by the National Collegiate Athletic Association (NCAA) in the USA (NCAA, 2015). The structure of the game is similar for both women and men at amateur and professional levels of competition. Match-play predominantly features low-intensity activities such as walking and jogging, which are interspersed with high-intensity actions such as running, sprinting, and sport-specific tasks (e.g. ball catching, passing, and kicking, rucking and mauling, tackling) (Deutsch, Kearney, & Rehrer, 2007; Docherty, Wenger, & Neary, 1988; McLean, 1992; Suarez-Arrones et al., 2014; Virr, Game, Bell, & Syrotuik, 2014). For example, in an analysis of elite women's rugby union players, Suarez-Arrones et al. (2014) found players spent approximately 87.5% of match time completing low-intensity actions, 11.3% running at a medium-to-high intensity, and 1.2% of the match sprinting. Due to the different movements and actions required during match-play, rugby union places great stress on a number of different physiological capacities. This includes upper- and lower-body strength and power; aerobic and anaerobic capacity; and linear speed, change-of-direction (COD) speed, and agility (Argus, Gill, & Keogh, 2012; Hene, Bassett, & Andrews, 2011; Nicholas, 1997; Quarrie, Handcock, Toomey, & Waller, 1996).

One essential characteristic for rugby union players is COD speed, which is the ability to change direction as quickly and efficiently as possible. COD speed is the underlying physical component of agility, and incorporates an individual's movement technique, acceleration and deceleration capacities, leg strength and power, and anthropometry (Sheppard & Young, 2006). Due to the importance of COD speed, it is vital that this characteristic is accurately assessed in rugby union players. Some prevalent tests of COD speed or ability for female athletes include the pro-agility shuttle (Vescovi, Brown, & Murray, 2006; Vescovi & McGuigan, 2008), T-test (Lockie et al., 2015b; Pauole et al., 2000), Illinois agility test (Vescovi & McGuigan, 2008), and 505 (Lockie, Callaghan, & Jeffriess, 2015a; Lockie et al., 2016d; Nimphius, McGuigan, & Newton, 2012). The 505 is a popular COD assessment as it is reliable (Gabbett, Kelly, & Sheppard, 2008; Sayers, 2015; Stewart, Turner, & Miller, 2014), and can be used to investigate COD ability from both legs (Lockie et al., 2014; Lockie et al., 2015a; Nimphius, Callaghan, Spiteri, & Lockie, 2016).

A limitation of many common COD speed and ability tests, including the 505, is the influence that linear speed may have on test performance (Nimphius et al., 2016; Nimphius, Geib, Spiteri, & Carlisle, 2013; Sayers, 2015). For instance, Nimphius et al. (2013) stated that due to the design of the 505 test, only about 31% of the time is actually spent changing direction; the majority of the total time to complete the test can be explained by an athlete's ability to linearly accelerate. As a result, a metric termed the COD deficit has been developed (Nimphius et al., 2016; Nimphius et al., 2013). The COD deficit provides an alternative assessment of COD ability as it measures the impact that one direction change has upon a sprint when compared to a linear speed test over an equivalent distance. When utilizing the 505 for this measure, linear 10-meter (m) sprint time is subtracted from the 505 time (as the COD in the 505 is completed in between two 5-m linear sprints for a 10-m total distance) to produce the COD deficit measured in seconds (s) (Nimphius et al., 2016). Nimphius et al. (2016) found that the COD deficit did not significantly correlate with 0-10 m and 0-30 m sprint times in male cricketers, which suggested this metric reduced the influence of linear speed. Furthermore, Nimphius et al. (2016) found that the

majority of the 17 cricketers analyzed in their study (88-94%) had a meaningful difference in how their COD ability was assessed by the 505 total time and COD deficit for each leg. Accordingly, depending on the metric used (e.g. 505 total time or COD deficit), a practitioner could draw different conclusions as to the COD ability of an athlete (Nimphius, Callaghan, Bezodis, & Lockie, 2018; Nimphius et al., 2016). This requires further investigation in other athletic populations to ascertain whether COD deficit does provide a different measure of COD ability specific to different athletes.

Despite the increase in popularity of collegiate women's rugby union (NCAA, 2015), there have been few analyses of athletes from this population (Lockie et al., 2016a). Therefore, this study investigated the COD deficit derived from the 505 in collegiate women's rugby union players. The methods for this study were based upon those from Nimphius et al. (2016), where there were two purposes. Firstly, this study evaluated the relationship between measures of linear speed (0-5 m, 0-10 m, and 0-20 m sprint interval times), and COD ability measured by the 505 time and COD deficit for each leg. The second purpose for this study was to determine if the COD deficit identified a different metric of COD ability for individuals when compared to the traditional 505 time. It was hypothesized that 505 time for each leg would correlate with linear sprint performance over the 20-m sprint intervals, while the COD deficit would not. It was further hypothesized that the 505 times and COD deficit would provide different identifications of COD ability in certain participants.

## METHODS

### Participants

A sample of convenience from the one Division I school comprising 17 collegiate women's rugby union players (age =  $21.88 \pm 1.67$  years; height =  $1.61 \pm 0.05$  m; body mass =  $64.45 \pm 8.76$  kilograms) was recruited for this study. Participants were recruited if they: (a) were 18 years of age or older; (b) were a member of the women's rugby union team for the school; (c) had a training history ( $\geq$ two times per week) in rugby union that extended over the previous year; (d) were currently training for rugby union ( $\geq$ three hours per week); and (e) did not have any medical conditions compromising study participation. Although the participants completed at least two structured rugby union training sessions per week, similar to other collegiate club-sport athletes (Steinhagen et al., 1998), any further strength and conditioning programs were completed at the individual-level only. Nevertheless, all participants were familiar with the tests performed in this study. The procedures were approved by the institutional ethics committee. All participants received an explanation of the research, including the risks and benefits of participation, and written informed consent was obtained prior to testing.

### Procedures

One testing session was utilized for this study (Lockie et al., 2016c). The participant's age, height, and body mass were recorded at the start of the session. Participants refrained from intensive lower-body exercise in the 24 hours prior to testing, and consumed water as required throughout the session. A dynamic warm-up was completed by all participants

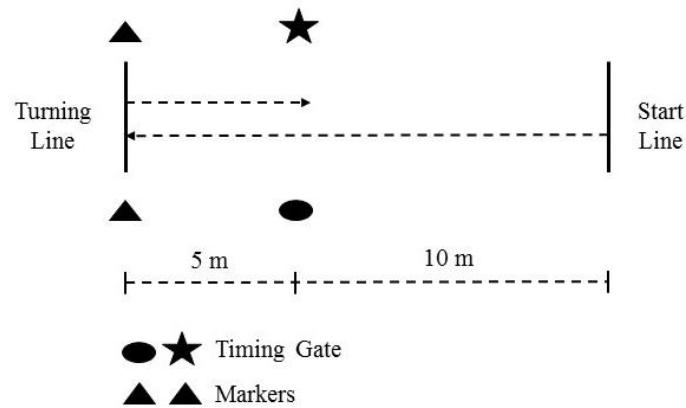
prior to testing, which consisted of 10 minutes of jogging at a self-selected pace, 10 minutes of dynamic stretching, followed by practice sprints over the test distances. Participants rotated through the 20-m sprint and 505 tests in alphabetical order, which meant that there was sufficient recovery between trials (i.e. greater than three minutes) (Lockie, Schultz, Callaghan, & Jeffriess, 2012). Participants were tested outdoors on a natural grass field in the evening at the university prior to a normal training session. The grass surface used for testing was dry, and weather conditions were typical of the Southern California climate during late winter. The 20-m sprint was performed first, followed by the 505. Participants wore their typical training attire and their own cleats.

### **20-m Sprint**

20-m sprint time was recorded by a timing lights system (Fusion Sports, Coopers Plains, Australia). Gates were positioned at 0 m, 5 m, 10 m, and 20 m, to measure the 0-5 m, 0-10 m, and 0-20 m intervals. These sprint intervals have been previously used to assess linear speed in collegiate women's rugby union players (Lockie et al., 2016a). Gate height was set at 1.2 m, and width at 1.5 m. Participants began the sprint from a standing start 50 centimeters behind the start line to trigger the first gate (Lockie et al., 2016b; Lockie et al., 2017b; Lockie et al., 2016e). Once ready, participants started in their own time, and were instructed to run maximally once they initiated their sprint. Participants completed two trials, and the average time for each interval was used for analysis. Time for each interval was recorded to the nearest 0.001 s. If the participant rocked backwards or forwards prior to starting, the trial was disregarded and repeated.

### **505 COD Test**

The methodology for the 505 was conducted as per established methods (Lockie et al., 2015a; Lockie et al., 2016b; Lockie et al., 2017a; Nimphius et al., 2016), and the set-up is shown in Figure 1. One timing gate (Fusion Sports, Coopers Plains, Australia) was utilized for this test. Participants used a standing start with the same body position as per the 20-m sprint. The participant sprinted through the timing gate to the turning line, indicated by a line marked on the grass and markers. Participants were to place either the left or right foot, depending on the trial, on or behind the turning line, before sprinting back through the gate. Two trials were recorded for turns off the left and right leg, the order of which was randomized amongst the participants. A researcher was positioned at the turning line, and if the participant changed direction before hitting the turning line, or turned off the incorrect foot, the trial was disregarded and reattempted. Time for 505 trials was recorded to the nearest 0.001 s, and the mean for the two trials for each leg was used for analysis. The COD deficit for each leg was calculated via the formula: *mean 505 time - mean 10-m time* (Nimphius et al., 2016). The mean 10-m time was taken from the 20-m sprint.



**Fig. 1** Structure and layout of the 505 test. m = meters

### Statistical analyses

Statistical analyses were processed using the Statistics Package for Social Sciences (Version 24.0; IBM Corporation, New York, USA). The statistical analyses used in this study were adapted from Nimphius et al. (2016). Pearson's two-tailed correlation analysis determined relationships between the 505 and COD deficit for each leg, and the 0-5 m, 0-10 m, and 0-20 m sprint intervals. An alpha level of  $p \leq 0.05$  was the criterion for significance. The strength of the correlation coefficient ( $r$ ) was designated as per Hopkins (2002). An  $r$  value between 0 to 0.10, or 0 to -0.10, was considered trivial; 0.11 to 0.3, or -0.11 to -0.3, small; 0.31 to 0.49, or -0.31 to -0.49, moderate; 0.5 to 0.69, or -0.5 to -0.69, large; 0.7 to 0.89, or -0.7 to -0.89, very large; and 0.9 to 1, or -0.9 to -1, near perfect for predicting relationships.

The second part of the investigation ascertained whether the 505 time and COD deficit provided a different assessment of COD ability (Nimphius et al., 2016). To conduct this analysis, 505 time and COD deficit for the left and right legs were converted to z-scores, via the formula:  $z\text{-score} = (\text{participant's test score} - \text{mean score from the sample}) / \text{standard deviation}$ . The left and right legs were analyzed separately, and the sample mean ( $n = 17$ ) was used to calculate the z-score (Lockie et al., 2016b; Nimphius et al., 2016). Similar to Lockie et al. (2016b), absolute values for z-scores were derived (e.g. the typical speed test time z-score, where a faster performance equates to a lower time, leads to a negative z-score, so this was converted into an absolute value). Accordingly, a positive score above zero represented a superior performance compared to the mean; a negative score was considered worse than the mean.

The difference in z-scores (COD deficit - 505 time) was also determined and compared to the smallest worthwhile change (SWC) for the sample (Nimphius et al., 2016). As described by Nimphius et al. (2016), the SWC is equal to the between-participant SD multiplied by 0.2. This is because 0.2 is the typical small effect (Hopkins, 2004). As these were standardized scores, the SD is 1.0, and thus the SWC is 0.2. Those participants that had a z-score difference that exceeded the SWC (i.e. above or equal to 0.2, or below or equal to -0.2) were deemed to have a

meaningful difference in the COD ability assessment provided by the 505 time and COD deficit. Therefore, a positive difference in z-scores indicated an underestimate of COD ability (i.e. COD deficit time was relatively better), and a negative difference in z-scores indicated an overestimate of COD ability (i.e. 505 time was relatively better).

## RESULTS

The descriptive data for the 20-m sprint intervals, 505 performed from both legs, and COD deficit for both legs, is shown in Table 1. The correlation data for the 505 and COD deficit with the 20-m sprint intervals is shown in Table 2. There were no significant correlations between the 505 and COD deficit with the 0-5 m interval. The right-leg 505 had significant positive relationships with both the 0-10 m and 0-20 m sprint intervals, which were moderate and large, respectively. The left-leg 505 had a moderate positive relationship with 0-20 m time, although the relationship was not significant. In addition to the 0-5 m interval, the COD deficit for the left or right leg did not significantly correlate with either the 0-10 m or 0-20 m sprint intervals.

**Table 1** Descriptive data (mean  $\pm$  SD; 95% CI) for the 0-5 m, 0-10 m, and 0-20 m interval times in a 20-m sprint, and 505 times and COD deficit for turns off the left and right legs in collegiate women's rugby union players (n = 17). All variables measured in seconds

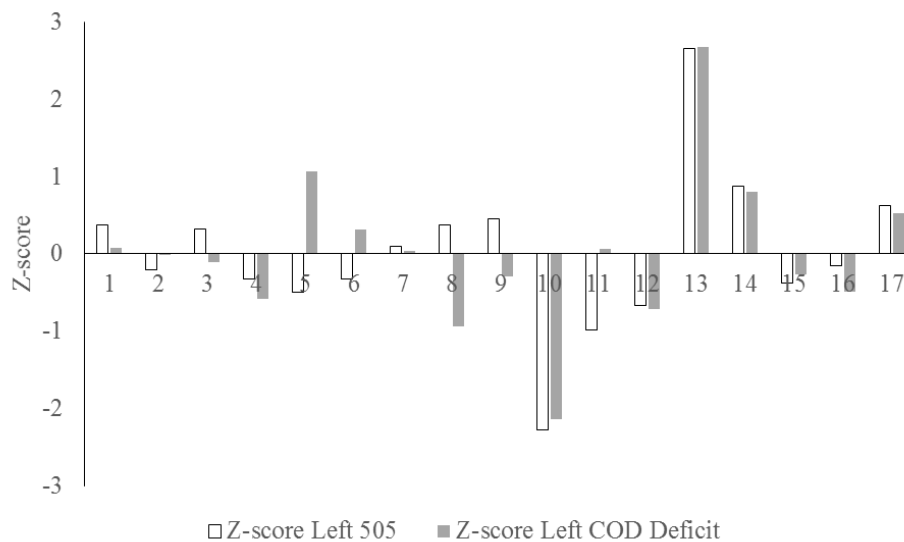
Test Variable	Mean $\pm$ SD (95% CI)
0-5 m	1.221 $\pm$ 0.096 (1.172-1.271)
0-10 m	2.101 $\pm$ 0.165 (2.016-2.187)
0-20 m	3.732 $\pm$ 0.326 (3.564-3.899)
Left-Leg 505	2.682 $\pm$ 0.260 (2.549-2.916)
Right-Leg 505	2.646 $\pm$ 0.276 (2.504-2.788)
Left-Leg COD Deficit	0.581 $\pm$ 0.248 (0.453-0.708)
Right-Leg COD Deficit	0.545 $\pm$ 0.244 (0.419-0.670)

The z-scores for the 505 time and COD deficit for the left and right legs are shown in Figures 2 and 3, respectively. For the left leg, six of 17 (35%) participants had 505 and COD deficit times that suggested opposite COD ability. For three participants, the 505 indicated better COD ability while the COD deficit suggested it was less than average; for the other three, the opposite was true. For the right leg, there were five of 17 (29%) participants who had 505 and COD deficit times that suggested opposite COD ability. For three participants, the 505 indicated better than average COD performance. For the other two, COD deficit indicated better COD performance.

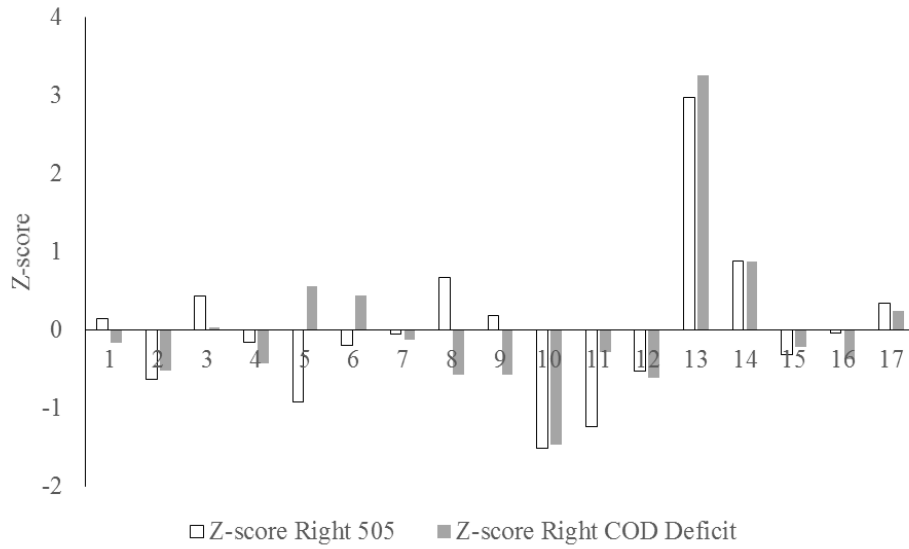
**Table 2** Pearson's correlations between the 505 times and COD deficit for turns off the left and right legs with the 0-5 m, 0-10 m, and 0-20 m interval times in a 20-m sprint in collegiate women's rugby union players (n = 17)

		0-5 m	0-10 m	0-20 m
Left-Leg 505	<i>r</i>	0.272	0.388	0.465
	<i>p</i>	0.291	0.124	0.060
Right-Leg 505	<i>r</i>	0.372	0.483*	0.552*
	<i>p</i>	0.141	0.050	0.022
Left-Leg COD Deficit	<i>r</i>	-0.370	-0.260	-0.170
	<i>p</i>	0.143	0.313	0.514
Right-Leg COD Deficit	<i>r</i>	-0.246	-0.133	-0.045
	<i>p</i>	0.341	0.612	0.864

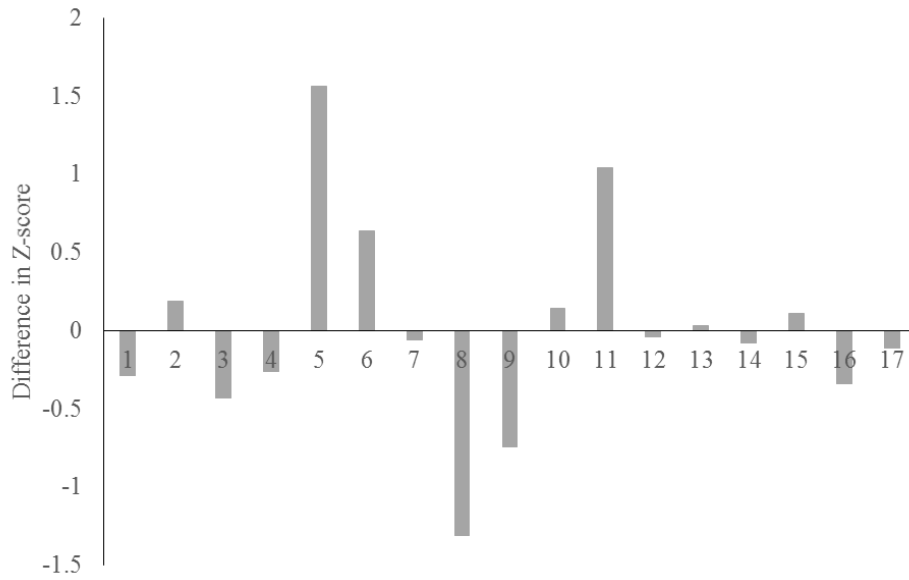
\* Significant ( $p \leq 0.05$ ) relationship between the two variables.

**Fig. 2** Z-score for the 505 time and COD deficit for each participant for the left leg in collegiate women's rugby union players (n = 17)

Figures 3 and 4 display the differences in the z-scores (COD deficit - 505 time) for the left and right legs, respectively. With regards to the left leg, there was a worthwhile difference between the standardized scores for nine of 17 participants (53%). Three participants had their COD ability underestimated, while six had theirs overestimated. For the right leg, 10 of 17 participants (59%) had a worthwhile difference; four participants had the COD ability underestimated, while six had theirs overestimated.

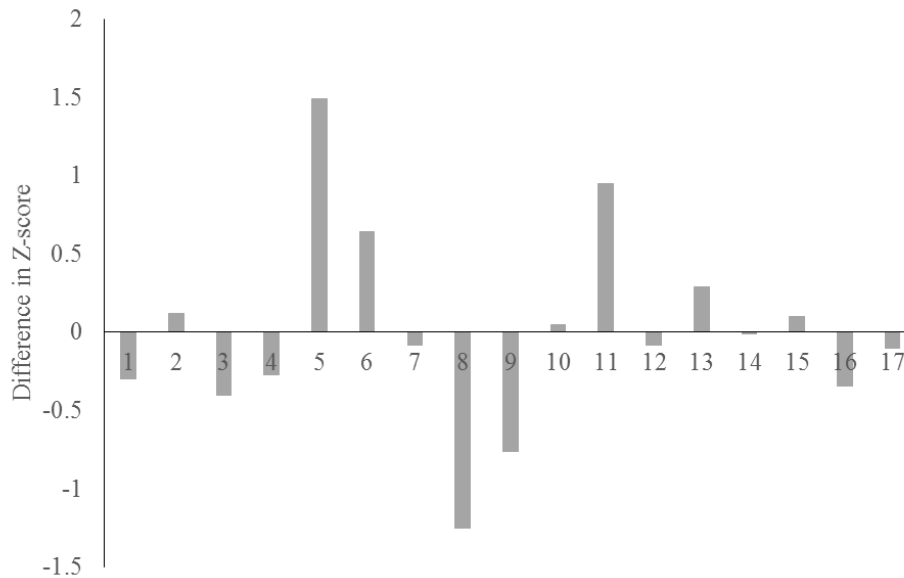


**Fig. 3** Z-score for the 505 time and COD deficit for each participant for the right leg in collegiate women’s rugby union players (n = 17)



**Fig. 4** Difference in standardized scores (COD deficit - 505 time) for the left leg in collegiate women’s rugby union players (n = 17)





**Fig. 5** Difference in standardized scores (COD deficit - 505 time) for the right leg in collegiate women's rugby union players (n = 17)

#### DISCUSSION

This study investigated the COD deficit in collegiate women's rugby union players to ascertain whether it provided a more isolated and different measure of COD ability. The participants from this study had 505 times that were faster than the collegiate rugby union players analyzed by Lockie et al. (2016a) (left leg =  $2.742 \pm 0.174$  s; right leg =  $2.704 \pm 0.073$  s). Furthermore, the participants in the current study also had superior COD deficit times when compared to the participants from Lockie et al. (2016a) (left leg =  $0.696 \pm 0.165$  s; right leg =  $0.659 \pm 0.119$  s). This provides some indication that the participants from the current study provided a good representation of collegiate women's rugby union players. The results indicated that the COD deficit did not correlate with linear 20-m sprint performance. In addition to this, 29-35% of participants had different assessments of COD ability from either leg depending on whether 505 total time or COD deficit were analyzed, and over half the sample had worthwhile differences between the standardized scores for the 505 and COD deficit. Similar to Nimphius et al. (2016), the results from this study suggested that the COD deficit provided a more isolated and different measure of COD ability in collegiate women's rugby union players. Women's rugby union and strength and conditioning coaches should consider using the COD deficit to assess the ability to change direction in their players.

Nimphius et al. (2016) found that in male cricketers, 505 times from the preferred (i.e. faster) and non-preferred (i.e. slower) legs positively correlated with 0-10 m and 0-30 m sprint times ( $r = 0.52-0.70$ ). In contrast, the COD deficit for both legs did not significantly correlate with either of these sprint intervals ( $r = -0.11-0.10$ ) (Hopkins, 2002). The results

from this study provided support to Nimphius et al. (2016). Although the left-leg 505 did not significantly correlate with the 20-m sprint intervals, the right-leg 505 did with the 0-10 m and 0-20 m intervals. Furthermore, the COD deficit did not significantly correlate with any of the 20-m sprint intervals. Taken together with the findings of Nimphius et al. (2016), the results suggested that the COD deficit provided a different measure of COD ability which limited the influence of linear speed in collegiate women's rugby union players.

This finding of the COD deficit being an alternate measure of COD ability was further established when considering the standardized scores for the 505 and COD deficit. When comparing the z-scores for the left leg, six participants had 505 time and COD deficit results that indicated contradictory COD abilities (i.e. a faster 505 time, but slower COD deficit, or vice-versa). For the right leg, this occurred for five participants. It is essential that a test of COD ability accurately reflects the physical quality it is supposed to measure (Nimphius et al., 2016), as this can drive the training practices of the coach (McGuigan, Cormack, & Gill, 2013). As noted by Nimphius et al. (2016), these divergent results with regards to COD ability are concerning, as a coach may use results from a test such as the 505 to design their training programs. The practical implication of these findings is that where possible, the coach should also consider using the COD deficit to assess COD ability. This could provide alternative information about COD ability that is not evident when total time is used as the measure from an assessment like the 505.

There were also worthwhile differences between the 505 time and COD deficit for the left and right legs in select participants from this study, which was similar to the findings of Nimphius et al. (2016) in male cricketers. Nimphius et al. (2016) found that 94% of their sample on the preferred leg, and 83% on the non-preferred leg, had a worthwhile difference between their 505 and COD deficit. In this study, 53% of the sample for the left leg, and 59% for the right leg, had a worthwhile difference between their 505 time and COD deficit. This meant that for the great majority of the participants assessed by Nimphius et al. (2016), and more than half the participants in this study, had their COD ability either underestimated or overestimated depending on the metric used (i.e. 505 time or COD deficit). This further emphasizes the need for coaches to understand some of the limitations associated with typical COD speed tests. Several authors have recommended attempting to measure COD speed over shorter distances (e.g. via time or exit velocity following a direction change) in order to better assess this quality (Nimphius et al., 2018; Sayers, 2015). However, this can be difficult to measure in the field, as variability in body position can influence the reliability of timing gates when the length of the measured intervals are decreased (Cronin & Templeton, 2008; Lockie et al., 2013; Sayers, 2015). This again highlights the usefulness of the COD deficit for collegiate women's rugby union players, as it may provide a more applicable measure of COD ability while also being practical for coaches to incorporate into their athlete testing battery.

There are certain study limitations that should be noted. Only a 180° COD provided from the 505 was investigated in this study. As a COD deficit may be specific to the angle of the direction change (Nimphius et al., 2016), and rugby union players need to move in multiple direction during a match (Deutsch et al., 2007), future research should investigate the COD deficit for different angles of direction changes in women's rugby union players. This study did not incorporate an analysis of positional differences in the COD deficit, which could have provided a further indication of the validity of this metric

in collegiate women players. As backs in rugby union tend to be faster in speed tests when compared to forwards (Duthie, Pyne, Marsh, & Hooper, 2006; Hene et al., 2011), this is an avenue for future research. This study also did not include technical analysis for COD ability, as all testing was field-based. Laboratory-based studies can provide more detailed technical information (Sayers, 2015; Spiteri et al., 2013), and future research should investigate relationships between the COD deficit and entry and exit velocities when changing direction in collegiate women's rugby union players. Nonetheless, within the context of these limitations, the results from the current research demonstrated the potential value of the COD deficit to assess COD ability specific to collegiate women's rugby union.

### CONCLUSION

In conclusion, the results from this study demonstrated that the COD deficit provided a different assessment of COD ability in collegiate women's rugby union players when compared to 505 total time. Similar to Nimphius et al. (2016), this appeared to be a more isolated measure as the COD deficit for either leg did not significantly relate to linear speed over 20 m. Furthermore, there were several players who could have their COD ability interpreted differently depending on whether 505 time or COD deficit was the metric utilized to measure this capacity by a coach. As a result, coaches should consider using the COD deficit as an assessment tool for COD ability, as it could indicate this quality while limiting the influence that linear speed has upon this metric.

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## SLABO RAZVIJENA SPOSOBNOST ZA PROMENU PRAVCA NA PRIMERU STUDENTKINJA UČESNICA UNIVERZITETSKE RAGBI LIGE

*Sposobnost promene pravca kretanja (COD) jedna je od osnovnih komponenti igre kao što je ragbi. U većini slučajeva, COD testovi oslanjaju se na ukupno vreme kako bi izmerili COD, a COD je razvijana kao metrijska odlika koja će izolovati COD nezavisno od brzine pri pravolinijskom sprintu. U ovom istraživanju analizirali smo odnos između vremena sprintsa, vremena za 505 test, i slabo razvijenu COD među studentkinjama koje ragbi igraju kao članovi univerzitetske ragbi lige. Ukupno je 17 učesnica trčalo 20-m sprint (0-5, 0-10, i 0-20 m intervali su mereni), i uradile 505 test za svaku nogu. Slabo razvijena COD za obe nego izračunata je kao razlika između prosečnog vremena za 505 test i vremena za trčanje na 10-m. Korelacije su izračunate između testa 505 i slabo razvijene COD sa intervalima sprintsa ( $p \leq 0.05$ ). Kako bi se poredilo vreme za 505 test i slabo razvijena COD, z-skorovi su izračunati; razlika između ovih skorova procenjena je za svaku učesnicu. Slabo razvijena COD nije bila u korelaciji sa intervalima za sprint ( $r = -0.370$  to  $-0.045$ ). Vreme za 505 test za desnu nogu nije bilo u korelaciji sa 0-10 i 0-20 m intervalima ( $r = 0.483$ - $0.552$ ). Šest od 17 učesnica je za levu nogu, a pet od 17 za desnu nogu, klasifikovano je drugačije za COD sposobnost kada su se poredili standardizovani skorovi za vreme za 505 test, u poređenju sa slabo razvijenom COD. Za više od jedne polovine učesnica (53-59%) utvrđene su značajne razlike između vremena za 505 test i slabo razvijene COD za svaku nogu. Rezultati su ukazali na to da bi slabo razvijena COD možda više bila izolovana mera COD i predložili drugačiju meru ove sposobnosti u poređenju sa vremenom za 505 test na primeru studentkinja koje kao učesnice univerzitetske lige igraju ragbi.*

**Ključne reči:** 505 test, okretnost, brzina promene pravca, studentkinje, timski sport