The Deceleration Deficit: A Novel Field-Based Method to Quantify Deceleration During Change of Direction Performance

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ABSTRACT

The study investigated the relationship between linear and change of direction (COD) speed performance components and the individual differences between deceleration deficit (DD) and COD deficit (CODD). Thirty-six subjects (mean ±SD: age = 20.3 ± 2.9 years; stature = 175.2 ± 7.7 cm; body mass = 78.0 ± 16.7 kg) completed three trials of a 505 test in both turning directions (dominant (D); non-dominant (ND)) and three 15m linear sprints. DD was calculated via the 15m approach in the 505 test, minus the athlete's linear 15m sprint time. To compare individuals CODD and DD, z-scores were calculated, and moderate worthwhile changes (MWC) were identified between these deficit z-scores. Significant correlations were identified between linear sprints and 505 time (D: $r = 0.71, 0.74$; $P < 0.01$. ND: $r = 0.76, 0.75$; $P < 0.01$) for 10m and 15m sprint respectively, and between 505 performance and CODD (D: $r = 0.74$; $P < 0.01$. ND: $r = 0.77$; $P < 0.01$) and DD (D: $r = 0.41$, $P < 0.05$. ND: $r = 0.44$, $P < 0.01$). DD was significantly related to CODD (D: $r = 0.59$; $P < 0.01$. ND: $r = 0.62$; $P < 0.01$); however, 78% of subjects demonstrated differences between these deficit measures greater than an MWC. In conclusion, linear speed has the strongest significant relationship with 505 performance. DD could provide a more isolated construct than CODD which may be related to an athlete's deceleration capabilities.

Key Words: Agility; Deceleration; Velocity; Braking; Multi-Directional

INTRODUCTION

Change of direction (COD) speed is a key physical quality for success in a range of sports (25). Assessment of COD speed often includes the 505 test (1, 9, 27, 29) or various cutting manoeuvres (3, 4, 18, 19), with performance quantified via the total time taken to complete a pre-determined course. However, COD speed is comprised of many constituent parts, including linear speed, deceleration and re-acceleration (25). Specifically, the 505 test involves a 15m approach sprint, a 180° turn, and a 5m exit; or more simply, a maximal acceleration, a deceleration to a complete stop (16) and a re-acceleration into the new direction. Despite the test already being relatively short in duration (~2.3 seconds) (1, 9), it is reported that on average only approximately 31% of the time is spent changing direction (23).

Total time in a COD speed test is still a useful measure as the transfer of performance may primarily relate to the time taken to get from one point to another. However, an athlete may have varying capabilities in the different components that make up the test (acceleration, deceleration etc.). Providing greater insights into how the performance task is executed will enhance our ability to identify the main limiting factor(s); linear speed, deceleration or re-acceleration (22). The COD deficit (CODD) was designed to assess COD ability whilst controlling for linear speed, as COD abilities can be over or underestimated by total time measures due to an athlete's linear speed capabilities (5, 22). The CODD is a useful tool to help understand if an athlete should focus on their linear speed capabilities or ability to decelerate, change direction and re-accelerate during the training process. However, the CODD is still a single variable which represents a range of qualities, such as deceleration, acceleration and technique factors. Therefore, delineating the primary limitations in performance remains challenging.

The 505 test provides an opportunity to assess an athlete's ability to decelerate, as momentary zero velocity must be attained following a 15m approach, prior to the change of direction. Graham-Smith et al., (11) reported that after approximately an 8.5m maximal sprint, it takes athletes approximately 6.5m to decelerate and come to a complete stop. Therefore, the approach period of the 505 test may be viewed as an 8.5m initial sprint followed by a 6.5m deceleration period (entry into the turn). By recording, 1) the amount of time taken to maximally accelerate and come to a complete stop within the 505 test (in this case 15m); and 2) the amount of time required to cover the same distance but with no forced deceleration. Performance in these separate tasks could be compared and quantified as the 'deceleration deficit' (DD). This method could represent an athlete's deceleration ability relative to their linear sprinting speed. Isolating this time required to come to a stop via the DD measure could provide important information for coaches due to the high eccentric demand experienced during deceleration not found in acceleration (10, 13).

Deceleration is a key factor in COD speed performance, with the importance of braking impulse during the penultimate foot contact on COD performance previously reported (7, 8). However, our understanding of deceleration during COD speed is yet to be expanded past the penultimate step. The use of the DD in the 505 provides an opportunity for coaches to isolate the deceleration component of the task, providing unique insights into an individual's limiting factor(s) when performing the test. However, there are inherent deceleration components in both 505 total time and the CODD. Therefore, the relationship between these measures should also be investigated to identify if the DD provides different and meaningful information for coaches.

The aims of the current study were to; a) determine the relationship between linear sprint speed, 505 performance, CODD and DD, and b) investigate the individual differences between DD and CODD. It was hypothesized that linear speed would demonstrate a strong relationship with 505 time but not the CODD and DD. In addition, it was hypothesized that these two deficit measures would not be significantly correlated.

METHODS

Experimental Approach to the Problem

The study utilised a cross-sectional design where subjects completed a 505 COD test in both turning directions and a 15m linear sprint. All experimental data for subjects was collected in a single testing session. Pearson's correlation were used to determine the relationship between COD, linear speed and deceleration performance. Individual differences between DD and CODD times were compared via standardized metrics (z-scores).

Subjects

Thirty-six (nineteen female and seventeen male) recreationally active subjects (20.3 ± 2.9 years; stature = 175.2 ± 7.7 cm; body mass = 78.0 ± 16.7 kg) volunteered and provided informed consent. Subjects were required to be competing in an invasion sport (either netball, hockey, rugby or football) and taking part in coached strength training at least once per week with experience of COD speed testing protocols. All subjects were also required to be currently free from injury and illness. This study was approved by the University of Gloucestershire institutional review board and procedures were performed in accordance with the declaration of Helsinki.

Procedures

Subjects first attended a familiarisation session to practice the 505 test and to collect anthropometric data. This was followed by formalized data collection 48 hours later, with three trials completed of the 505 in each turning direction in a randomised order, and finally three 15m linear sprints. A two-minute rest period was provided between each recorded attempt. All testing was conducted on a Pulastic indoor sports floor and all subjects were instructed to wear clean indoor sports trainers. The testing session was preceded by a standardised warm up consisting of 5-min of various pulse-raising activities, including linear and multi-directional movements which mimicked the 505 test, and 5-min of dynamic muscle activation exercises such as body weight lunges and squats and dynamic stretches. Subjects were asked to refrain from alcohol 24 hours prior to testing and avoid caffeine ingestion the morning of testing procedures.

Performance Measures

180° COD Test

The COD speed test contained the same running pattern as the 505 test commonly utilised in other studies (1, 9, 22). Time was recorded using a smart speed timing gate system with gates placed at 0 and 10m and a smart jump contact mat (Smartspeed, Fusion Sport, Sumner, Australia) positioned at the 15m turning point (which was temporarily fixed to the floor to avoid slipping). The contact mat was used to record commencement and duration of plant step ground contact (Figure 1). For a 505 trial to be considered successful, subjects needed to ensure that their final plant step occurred on the contact mat and over the marked turn line, any trials where subjects missed the contact or turning line were discounted and repeated. In order to independently analyse performance of each task component, timing splits were utilised to measure 0-10m, 10-15m (repeated for the returning 5m acceleration) and the GCT of the plant step (Table 2). Subjects began each sprint 50cm behind the first gate, in a staggered, three-point stance and were instructed to run as fast as possible to the contact mat, turn on the marked point with either their left or right leg and the return as fast as possible back through the 10m gate. The turning leg used for the first trial was randomly allocated and then alternated between trials. Any trials where the marked turning line was not met were repeated. All timing variables were reported to the nearest 0.01 seconds. The three trials turning left or right were averaged and used for analysis. The dominant direction (D) was identified as the turning direction with the fastest 505 performance and the opposite direction was classified as non-dominant (ND) (2).

*** Insert Figure 1 here ***

15m Linear Sprint Test

The linear 15m sprint test was utilised in order to assess maximal acceleration capability with gates placed at 0, 10 and 15m. Subjects were instructed to start 50cm behind the first gate, in a staggered, three-point stance and sprint all the way through the 15m gate as fast as possible. Three trials were completed with at least a 2 minutes rest between each. Time for each distance and all variables were recorded to the nearest 0.01 seconds with the average of three trials being included for analysis.

COD and Deceleration Deficit Calculations

CODD was calculated to represent the individual's ability to change direction while controlling for their linear speed capabilities using the equation proposed by Nimphius et al. (22). The DD was calculated in order to quantify the time an individual needed to come to a stop relative to their own sprinting speed. The full approach time was used in order to represent the time required to approach the turn line as fast as possible while decelerating into a position to facilitate exit speed and overall 505 performance. Commonly braking force is still being applied through the first half of plant step ground contact, with the remainder of the step used for the application of propulsive forces (12). A force plate would be the optimum criterion measure to determine the relative contribution of these braking forces but is not practically viable in field-based testing. Therefore, the full approach includeed the time taken over the first half of ground contact in an attempt to capture the complete braking phase of the approach (12). This time was compared against the time the athlete needs to cover the same distance in a linear sprint. Equations to calculate the deficit measures are shown in Table 1.

*** Insert Table 1 here ***

Statistical Analysis

Statistical analysis was conducted using SPSS (PASW statistics, Version 19, IBM Corporation, New York, U.S.A) and Microsoft Excel (version 14.6.4, Microsoft, Redmond, DC, USA). Descriptive statistics (mean ± SD) were calculated for all variables. Normality was assessed and confirmed for all variables using a Kolmogorov–Smirnov test. Relationships between performance measures, were assessed using Pearson's product-moment correlation (2-way). The correlations were interpreted as follows: < 0.1 trivial, 0.1-0.3 = small, 0.3 – 0.5 = Moderate, 0.5 – 0.7 large, 0.7 – 0.9 = very large, 0.9-1.0 = nearly perfect, 1.0 = perfect (14). Statistical significance was set as $p < 0.05$. In addition, further analysis examined whether the DD was able to identify athletes whose deceleration ability limits their COD performance to a greater extent than CODD. These were calculated within individuals using z-scores though the formula:

z-score = (subject's test score – group mean score)/SD.

Worthwhile differences in z-score between DD and CODD were determined and compared to identify those with a moderate worthwhile change (Cohens d) between the two deficit scores (between subject SD multiplied by 0.5). A *moderate* worthwhile change was used in order to consider the potentially lower sensitivity of the deficit measures in a population with less multi-direction movement expertise (28). Subsequently, subjects that had a moderate worthwhile positive z-score difference indicated that the use of CODD alone may result in the overestimation of deceleration ability and a negative moderate worthwhile difference indicated an underestimation of deceleration ability if CODD is used in isolation.

RESULTS

Descriptive statistics for all variables are reported in Table 2. Relationships between performance and turning directions are displayed in Tables 3 and 4 respectively. Significant correlations were shown between linear sprint speeds, full approach and 505 time. No significant relationships were reported between linear sprint speeds and CODD or DD. 505 performance was significantly related to full approach speed, CODD and DD. Full approach was significantly related to CODD and DD showed a significant relationship with CODD.

The difference in z-scores between DD and COD deficit are presented in Figure 2. 78% of subjects show a divergence between the two deficit measures greater than a MWC in one of the two turning directions (MWC = D: > 0.45. ND: > 0.44) between the CODD and DD z-scores on their D and ND turning directions respectively. Analysis of the effects of turning direction identified that 12 subjects show a MWC between deficit scores in both directions with the MWC consistently positive or negative, 15 subjects have a MWC in just one of the two turning directions and one participant has a MWC on both turning directions with the difference on either side changing from positive or negative.

*** Insert Table 2, 3 and 4 here ***

*** Insert Figure 2 here ***

DISCUSSION

The aims of the current study were to examine the relationships between linear sprint, 505 total time, CODD and DD; and investigate whether DD provides additional information to these previously reported variables in competitive university level athletes. The primary findings indicate that linear speed was related to 505 time but not CODD or DD. 505 time was significantly correlated to both DD and CODD and these deficit variables were significantly related to one another but with large individual variance.

The results of the present study support previous research showing moderate to large correlations between 505 performance and linear speed (17, 22). In the current study, linear speed showed no significant relationship with CODD or DD. Although no previous research has compared DD and linear speed, relationships between these variables appear equivocal. Lockie et al. (17) reported a significant negative relationship between a linear 10m sprint and CODD ($r = -0.77$-82). Conversely, Nimphius et al. (22) did not find a significant relationship. Reasoning to elucidate these differences remain unclear and requires further investigation, however it may be that differences in technical proficiency were a contributing factor as the technical ability to apply force has been shown to be a key requirement for performance in linear and multi-directional tasks (7, 20). Therefore, the present results indicate that the athlete's linear speed capabilities did not clearly influence either of the deficit variables. However, these conclusions should be considered within the performance level and technical proficiency of the subjects used. The subjects in this study were faster over 10m than division I and II womens soccer athletes (17) and were similar to experienced male cricketers (22). 505 times were slightly slower than experienced male cricketers (22) but similar to Div II female soccer athletes (17). Furthermore, a moderate to large significant relationship between full approach and DD and large significant relationship between CODD and 505 time have been reported. These indicate that the inter-group performance variation was more likely due to each athlete's ability to execute the COD (CODD) or deceleration (DD) components of the test. Therefore, DD or CODD may provide an independent measure of deceleration or COD speed ability respectively. These results suggest the importance of investigating both an athlete's propulsive (linear sprint speed) and braking (DD or CODD) capabilities independently. This supports the conclusions of previous jumping tasks where concentric and eccentric impulse were unrelated (10, 15). This should be further investigated by assessing the DD with the addition of ground reaction force kinetics to explore the influence of braking and propulsive forces. This may be further warranted in subjects with higher levels of linear speed and acceleration as they may be required to decelerate from greater velocities and potentially higher levels of momentum (13). Caution is therefore required when applying the reported correlations to different populations with differing performance levels and further research is warranted.

Our results suggest that while linear speed still appears to be the primary factor influencing 505 total time, moderate significant relationships were also observed between DD and 505 performance. Therefore, deceleration ability could also be considered an important component of effective COD speed performance. The importance of the penultimate foot contact braking impulse on COD performance has been reported previously (7, 8). However, it is likely that the deceleration in the 505 test was distributed over multiple steps prior to the penultimate foot contact as it has been reported that athletes take an average of 6.61m when accelerating and coming to a stop within 15m (11). The results of the present study indicate an average 0.56 ± 0.13 seconds of additional time was required to come to a stop compared to continuing to accelerate over the same distance. The moderate nature of the relationship between 505 and DD may be due to the DD measure being relative to an individual's linear speed capabilities. For example, if an athlete does not require excessive time to come to a stop, a positive factor for COD speed performance, they still require effective linear speed in order to complete the COD task quickly. Therefore, to understand the role of deceleration on COD speed in greater depth, future research should investigate the deceleration phase over multiple steps and DD should be interpreted in conjunction with linear speed.

Only a moderate amount of shared variance was shown between the CODD and DD, which was likely due to deceleration time contributing to the CODD outcome (21). However, it is unclear from the CODD how much deceleration was contributing to the time required to complete the COD compared to the re-acceleration phase. The difference between CODD and DD z-scores shows that 78% of subjects showed a divergence between the two deficit measures greater than a MWC in one of the two turning directions. This suggests 78% of athletes would either over or underestimate their deceleration ability in one of the two turning directions if only the CODD was used. In 22% of the subjects, CODD provides a fair representation of their deceleration performance and the DD does not contribute to their performance profile in either turning direction.

During COD performance assessment it is important to consider directional dominance, which can be accurately identified utilising the CODD (5). Addition of the DD from this study may provide greater insights into the contributing factors of these directional differences. A larger correlation was identified between DD and full approach in the ND turning direction, indicating that the braking phase during the full approach on the ND direction had a greater influence on DD outcome than on the D turning direction (D: $r = 0.43$; $P < 0.01$. ND: $r = 0.54$; $P < 0.01$). This may be due to the ND turning direction braking phase being slower for some athletes and subsequently having a greater contribution to DD. However, this was not identified from the group mean times and requires further investigation. Independent analysis for each turning direction revealed that 58% and 55% of subjects (D and ND performance respectively) had a divergence between the two deficit measures greater than a MWC. Further analysis identifies 12 subjects, where the over, or under-estimation of deceleration from CODD was consistent on both turning directions. 15 subjects have an over, or under-estimation of deceleration from CODD in just one of the two turning directions. Finally, one subject had a MWC on both turning directions that changes from positive or negative, indicating that CODD underestimates deceleration ability on the D turning direction, but overestimates deceleration on the ND direction. CODD was reported to be a suitable representation of deceleration ability for both turning directions for 8 subjects. It is subsequently unclear from this analysis if there was a trend for the turning direction dominance to influence an over or underestimation of deceleration ability by CODD and further investigation is warranted.

While the current results suggest that DD provides unique information for the majority of athletes which may help coaches individualise training programs, it is important that this metric is further investigated with validity and reliability analysis to enhance our understanding. Furthermore, the reported correlations between DD and the other measures variables were all less than $r = 0.5$, meaning there was only approximately a 20% contribution of these variables to DD. Therefore, the factors which contribute to DD are currently unknown and warrant exploration. The DD itself may also be contributed to by a self-paced approach speed prior to the deceleration phase (24) where the athlete is reducing the load exposed to their non-dominant limb (26) or from a lack of deceleration ability requiring the braking phase to be spread over a greater number of steps and more time (7, 8). At present it is not possible to distinguish between contributing factors such as these and future research should look to investigate this further utilising a multiple regression analysis and including a broad range of physical measures such as eccentric strength (10, 13).

The results of the current study suggest that DD could provide a unique insight to deceleration capabilities which was not captured in CODD for the majority of athletes. In addition, both the CODD and DD were not influenced by an athlete's linear speed capabilities supporting the need for independent analysis of propulsive (linear speed), braking (DD) and multi-direction application (CODD) qualities during COD speed testing. Further research should be conducted to improve our understanding of the DD and how an individual's deceleration ability impacts COD speed performance, turning direction dominance, speed control and mechanics.

PRACTICAL APPLICATIONS

The current study indicated that the use of the DD helps identify athletes whose COD speed performance may be limited by deceleration ability, assisting coaches in individualising training interventions. The protocols used provided an opportunity to measure propulsive (linear speed), braking (DD) and multi-direction application (CODD) qualities during COD while also obtaining a general COD speed performance measure (505 time) from just two easy to administer field-based tests, maximising efficiency in testing.

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Figure 1: A Visual representation of the 505 COD test

Figure 2: The difference between z-scores for COD Deficit and Deceleration Deficit with a moderate worthwhile change threshold.

Table 1: A description of performance measures collected during the study

Table 2: Descriptive statistics for linear speed and best trial COD performance measures. Mean ± SD

Table 3: Pearson's correlation coefficient between performance measures in the dominant turning direction

Table 4: Pearson's correlation coefficient between performance measures in the non-dominant turning direction

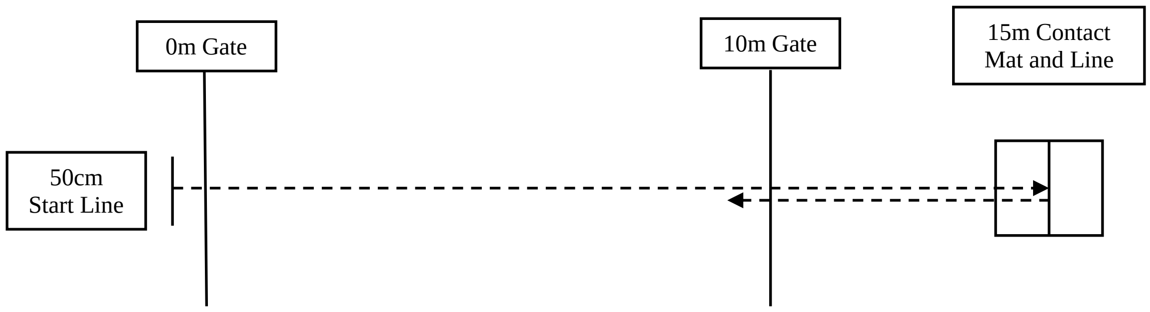

Figure 1: A Visual representation of the 505 COD test

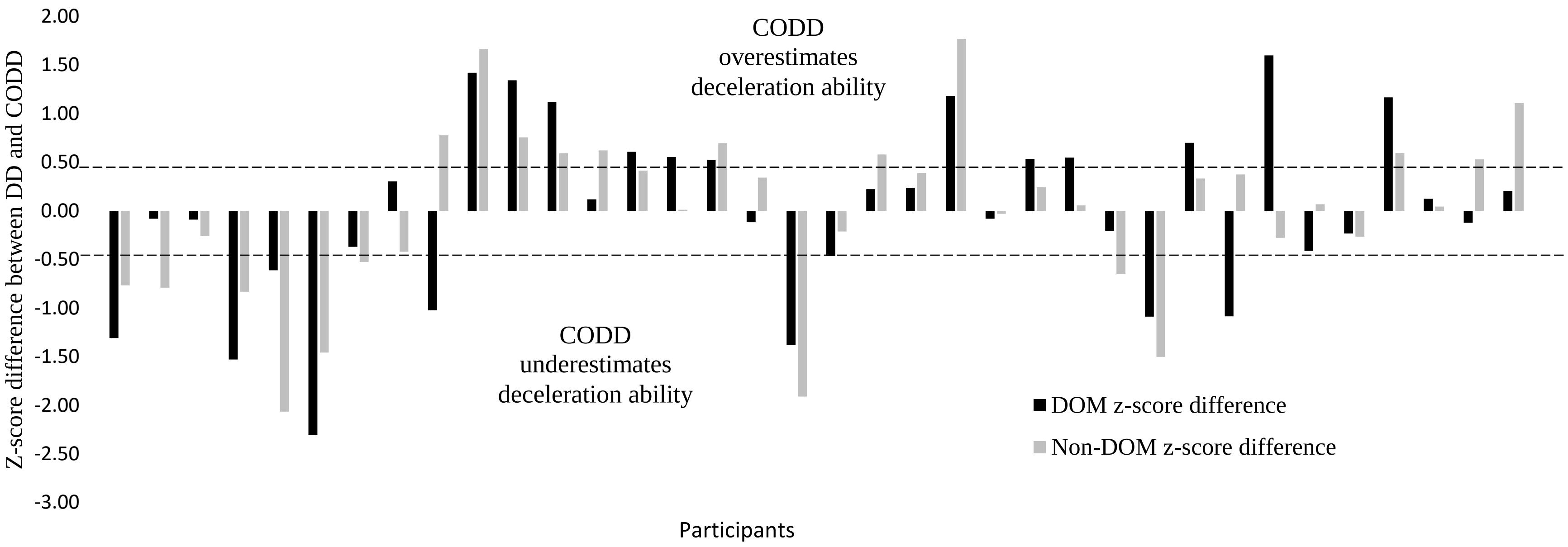

Figure 2: The difference between z-scores for COD Deficit and Deceleration Deficit with a moderate worthwhile change threshold.

Table 1: A description of performance measures collected during the study

Performance Measures	Description/Equation
Linear 10m Sprint (s)	Time from 0m to 10m when sprinting in a straight line, taken as a split time from a 15m sprint.
Linear 15m Sprint (s)	Time from 0m to 15m when sprinting in a straight line.
505 Time (s)	Total time taken to complete the 505 test as calculated in previous research (1).
Full Approach (s)	The time from the 0m gate to 50% of GCT of the plant step during the 505 test.
DD (s)	Full approach during the 505 test – 15m time during linear sprint.
CODD (s)	505 time – 10m time taken during 15m linear sprint (22).

Table 2: Descriptive statistics for linear speed and best trial COD performance measures. Mean ± SD

	10m Sprint (s)	15m Sprint (s)	505 (s)	Full Approach (s)	CODD (s)	DD (s)
DOM	1.85 ± 0.14	2.59 ± 0.21	2.54 ± 0.22	3.15 ± 0.26	0.69 ± 0.16	0.56 ± 0.12
Non-DOM			2.63 ± 0.23	3.15 ± 0.28	0.78 ± 0.15	0.56 ± 0.15

Table 3: Pearson's correlation coefficient between performance measures in the dominant turning direction

	10m Sprint	15m Sprint	505	Full Approach	CODD	DD
10m Sprint	1	0.98**	0.71**	0.87**	0.06	-0.02
15m Sprint		1	0.74**	0.88**	0.12	-0.06
505			1	0.86**	0.74**	0.41*
Full Approach				1	0.40*	0.43**
CODD					1	0.59**
DD						1

* P<0.05; **P<0.01

Table 4: Pearson's correlation coefficient between performance measures in the non-dominant turning direction

	10m Sprint	15m Sprint	505	Full Approach	CODD	DD
10m Sprint	1	0.98**	0.76**	0.85**	0.16	0.05
15m Sprint		1	0.75**	0.85**	0.17	0.01
505			1	0.87**	0.77**	0.44**
Full Approach				1	0.48**	0.54**
CODD					1	0.62**
DD						1

* $P<0.05$; ** $P<0.01$