

Research article

## Reliability and Validity of a New Test of Change-of-Direction Speed for Field-Based Sports: the Change-of-Direction and Acceleration Test (CODAT)

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### Abstract

Field sport coaches must use reliable and valid tests to assess change-of-direction speed in their athletes. Few tests feature linear sprinting with acute change-of-direction maneuvers. The Change-of-Direction and Acceleration Test (CODAT) was designed to assess field sport change-of-direction speed, and includes a linear 5-meter (m) sprint, 45° and 90° cuts, 3-m sprints to the left and right, and a linear 10-m sprint. This study analyzed the reliability and validity of this test, through comparisons to 20-m sprint (0-5, 0-10, 0-20 m intervals) and Illinois agility run (IAR) performance. Eighteen Australian footballers (age = 23.83 ± 7.04 yrs; height = 1.79 ± 0.06 m; mass = 85.36 ± 13.21 kg) were recruited. Following familiarization, subjects completed the 20-m sprint, CODAT, and IAR in 2 sessions, 48 hours apart. Intra-class correlation coefficients (ICC) assessed relative reliability. Absolute reliability was analyzed through paired samples t-tests ( $p \leq 0.05$ ) determining between-session differences. Typical error (TE), coefficient of variation (CV), and differences between the TE and smallest worthwhile change (SWC), also assessed absolute reliability and test usefulness. For the validity analysis, Pearson's correlations ( $p \leq 0.05$ ) analyzed between-test relationships. Results showed no between-session differences for any test ( $p = 0.19-0.86$ ). CODAT time averaged ~6 s, and the ICC and CV equaled 0.84 and 3.0%, respectively. The homogeneous sample of Australian footballers meant that the CODAT's TE (0.19 s) exceeded the usual 0.2 x standard deviation (SD) SWC (0.10 s). However, the CODAT is capable of detecting moderate performance changes (SWC calculated as 0.5 x SD = 0.25 s). There was a near perfect correlation between the CODAT and IAR ( $r = 0.92$ ), and very large correlations with the 20-m sprint ( $r = 0.75-0.76$ ), suggesting that the CODAT was a valid change-of-direction speed test. Due to movement specificity, the CODAT has value for field sport assessment.

**Key words:** Lateral cutting, field testing, Illinois agility run, linear speed, team sports.

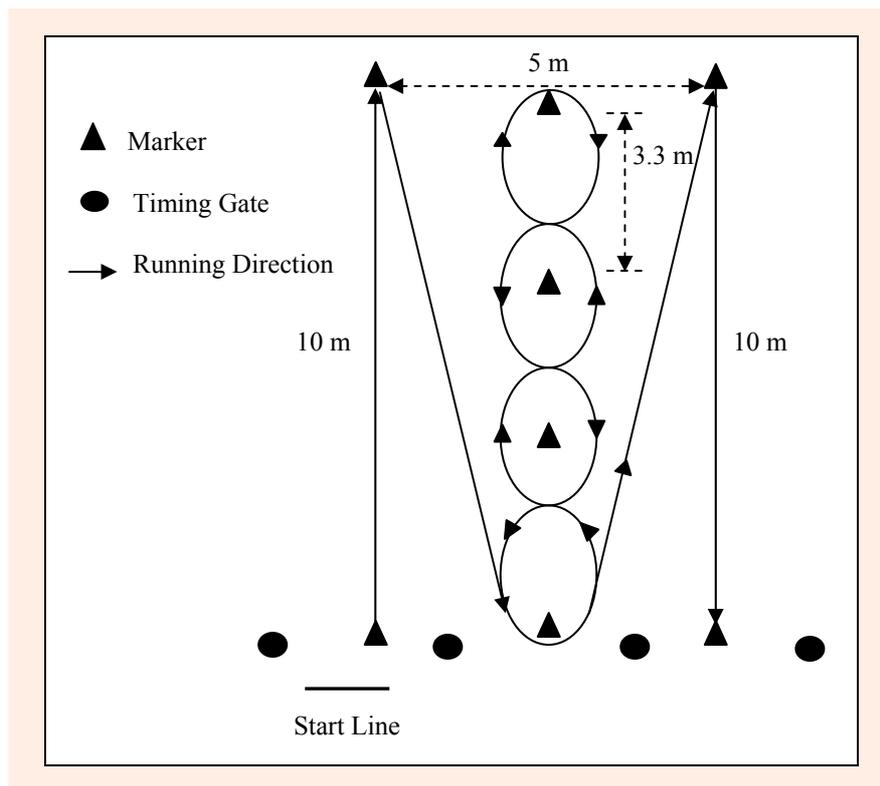
### Introduction

Linear and change-of-direction speeds are essential qualities for athletes who play field sports, such as soccer, rugby union, rugby league, American football, and field hockey (Lockie et al., 2003; Dawson et al., 2004; Spencer et al., 2005). For example, Bloomfield et al. (2007) reported that soccer players, on average, perform over 700 turns and swerves at different angles throughout a game. Linear speed is as the name suggests, speed over a straight-line distance. Agility is a multi-faceted skill (Metikos et al., 2003; Young and Farrow, 2006), but Young and Farrow (2006) have defined it as a rapid

whole body movement with change of velocity or direction in response to a stimulus. There is no doubt that the cognitive component of agility is very important (Gabbett et al., 2008; Sheppard et al., 2006). However, the mechanics associated with agility are also essential for skill execution. Change-of-direction speed helps describe these mechanics, in that it incorporates the ability to accelerate and decelerate rapidly, in addition to changing direction (Young and Farrow, 2006). In view of the importance of both linear speed and change-of-direction speed for field sport athletes, it is imperative that the assessment protocols adopted by field sport coaches and strength and conditioning professionals are found to be valid and reliable.

However, the movements that are used within particular change-of-direction speed tests are wide and varied. As a result, numerous tests have been developed to assess change-of-direction speed in athletes from field-based sports. Some examples include the: 505 for rugby league (Gabbett et al., 2008) and soccer (Maio Alves et al., 2010) players; Illinois agility run (IAR, Figure 1) for rugby union (Jarvis et al., 2009) and soccer (Vescovi et al., 2006) players; T-test for soccer players (Sporis et al., 2010); pro-agility shuttle for American football (Sierer et al., 2008) and soccer (Vescovi et al., 2006) players; and 3-cone drill for American football (Sierer et al., 2008) and rugby league (Gabbett et al., 2008) players. While the value of these tests is widely acknowledged, there are some limitations. For instance, the 505 only features one simple cut, and may not be representative of the complex change-of-direction movement demands of many sports (Gabbett and Benton, 2009). In addition, while the pro-agility shuttle is specific to American football through the use of a 3-point stance starting position and lateral running (Sierer et al., 2008), the starting position adopted, and movement patterns required for this test may not make it relevant for many other field sports. There are also few change-of-direction speed tests that assess the ability to sharply change direction while running forwards (i.e. completing diagonal or zig-zag style cuts). This is pertinent, as the space used for movements within a change-of-direction speed assessment are important considerations for correctly administering a test (Metikos et al., 2003). A test that assesses linear acceleration, in addition to the ability to make several sharp cuts while continuing to sprint forwards over specific distances, has value for field sports.

The assessment that most likely tests this capacity is the IAR, as it involves acceleration, as well as directional changes when sprinting in a linear fashion (Figure



**Figure 1.** Illinois agility run dimensions and completion route. m = meters.

1). However, the IAR can last for approximately 14-18 s (Jarvis et al., 2009; Wilkinson et al., 2009; Vescovi and McGuigan, 2008). Potentially, this could result in metabolic limitations in the performance of a field sport athlete within this test (Vescovi and McGuigan, 2008). To a certain extent, the distances used during the IAR also seem to have been selected arbitrarily, without necessarily considering actual sprint distances covered during traditional field sport match-play, or the step kinematics produced by field sport athletes. Indeed, maximal sprint efforts during field sports tend to be short (i.e. 10 m or less) (Bangsbo et al., 1991; Dawson et al., 2004; Duthie et al., 2006), and rapid sprint acceleration efforts may not be sufficiently assessed within the IAR. Therefore, there is value in constructing a test of change-of-direction speed that incorporates field sport-specific distances, as well as demanding changes of direction.

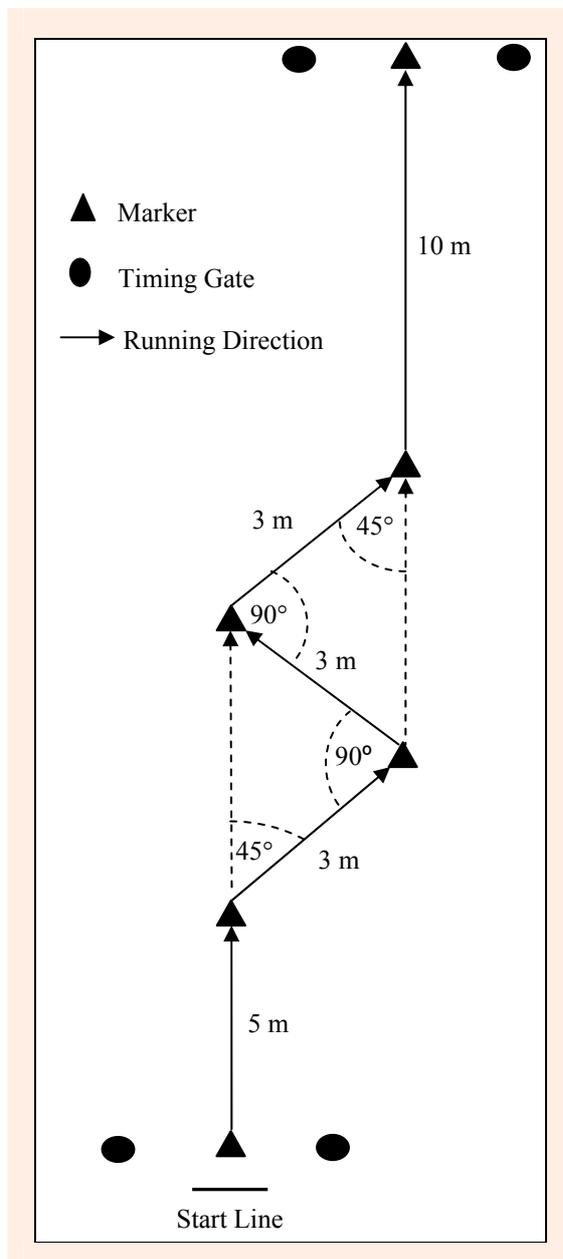
The Change-of-Direction and Acceleration Test (CODAT) was designed to assess change-of-direction abilities while sprinting forwards, using data derived from research analyzing the time-motion of field sports. The structure of the test can be seen in Figure 2. The CODAT involves a straight 5-m sprint, followed by three 3-m sprints. These 3-m sprints are made at angles of 45° and 90°. Following the third 3-m sprint, there is a straight 10-m sprint to the finish line. The 5-m and 10-m linear sprints were included as speed over these distances have been found to delineate between faster and slower field sport athletes (Lockie et al., 2011), as well as being important for overall linear acceleration (Spinks et al., 2007; Sporis et al., 2009). Furthermore, the inclusion of the 10-m sprint is based on research from the sports of rugby union (Docherty et al., 1988; Duthie et al., 2006), Australia-

lian football (Dawson et al., 2004; Gray and Jenkins, 2010), and soccer (Bangsbo et al., 1991), that state that the approximate duration of sprints in these games is 2 s. Depending on the speed of the athlete, a 2-s sprint would equate to an approximate distance of 10 m (Duthie et al., 2006; Lockie et al., 2011).

Additionally, linear sprints in field sports often contain at least one direction change (Dawson et al., 2004). To stress this capability, the CODAT features 4 diagonal direction changes, intermixed with short 3-m sprints, in a zig-zag pattern. These cuts are similar to that used in research assessing field sport-specific running demands (Jennings et al., 2010). The 3-m sprints place a great emphasis on effective step length and foot positioning that is often emphasized in change-of-direction speed training (Young and Farrow, 2006). An effective step pattern should involve the athlete shortening their step lengths prior to making a direction change (Sayers, 2000; Sheppard and Young, 2006; Young and Farrow, 2006). Given that a field sport athlete's step length during the initial stages of acceleration is approximately 1.2 m (Lockie et al., 2011), a 3-m sprint will stress an athlete's ability to develop an effective step pattern prior to a cut. Furthermore, as the total distance from the start to the finish of the CODAT equates to approximately 24 m, this test should not have the same metabolic limitations that could be evident in the IAR.

Analysis of linear and change-of-direction speed generally involves recording data across a number of trials. Accurate data collection requires a consistency across these trials. The validity of a field test can be ascertained by comparing it with an established test, and determining whether it assesses components of fitness

known to be important for performance (Wilkinson et al., 2009). Although there is no single, gold standard change-of-direction speed test, establishing a relationship between the CODAT and a recognized assessment will provide the new test with a point of context. Despite the potential metabolic limitations as a result of the extended test duration, the IAR has been previously shown to be a reliable assessment of change-of-direction speed, with a typical error of 1.8% (Wilkinson et al., 2009). However, due to the length of the test, the IAR may not sufficiently assess the shorter, change-of-direction speed demands that are emphasized in many field sports. The CODAT may be able to stress aspects of linear acceleration and change-of-direction speed specific to field sports, as well as highlighting the ability to sprint forwards while making sharp cuts that are often required during the match-play of field sports.



**Figure 2.** Change-of-direction and acceleration test dimensions and completion route. m = meters.

The aim of this study was to investigate the relative and absolute reliability, and the usefulness, of the CODAT, while also comparing it to standards for linear speed (20-m sprint) and change-of-direction speed (IAR). In support of these aims, we hypothesized that the CODAT would correlate with both the 20-m sprint and IAR time due to the inclusion of short linear accelerations, and change-of-direction movements, within the CODAT. This would indicate the validity of the test as an assessment of change-of-direction speed and acceleration. Furthermore, it was also hypothesized that the CODAT will be found to be reliable and useful. This research has value for field sport and strength and conditioning coaches. A test that incorporates sport-specific changes of direction could prove advantageous in the accurate assessment of a player's abilities for purposes such as performance monitoring or team selection.

## Methods

### Subjects

Eighteen experienced first grade Australian football players (age =  $23.83 \pm 7.04$  yr; height =  $1.79 \pm 0.06$  m; mass =  $85.36 \pm 13.21$  kg) from an amateur regional competition were recruited for this study. This subject number is similar to that used previously in studies analyzing the reliability of sprint (Wilkinson et al., 2009; Veale et al., 2010), and sport-specific (Spencer et al., 2006; Buchheit et al., 2011) tests. Subjects were recruited if they: were currently active in Australian football competition; had a general field sport training history ( $\geq 2$  times-week<sup>-1</sup>) extending over the previous 12 months; did not have any existing medical conditions that would compromise participation in the study; and were available for all testing occasions. The methodology and procedures used in this study were approved by the institutional ethics committee, and conformed to the policy statement with respect to the Declaration of Helsinki. All participants received a clear explanation of the study, including the risks and benefits of participation, and written informed consent was obtained prior to testing.

### Testing procedures

A familiarization session was conducted 48 hours prior to the first testing session (Sheppard et al., 2006; Young and Willey, 2010). Two testing sessions were then completed by all subjects, also separated by 48 hours (Beekhuizen et al., 2009; Sheppard et al., 2006). Prior to data collection in the first testing session, each subject's age, height, and mass were recorded. Subjects completed 3 different tests within a session: the 20-m sprint, IAR and CODAT. All tests were conducted on a natural grass surface in dry, consistent weather conditions. Subjects wore their own football boots during the test. The order of the tests completed by the subjects was randomized across the group. The same order for each subject was kept constant across the two testing occasions.

Three successful trials were used per test for each subject, and the average was taken for each session. Rest periods of 3 minutes were allocated between all trials. Time was measured through the use of timing gates

(Smartspeed, Fusion Sport, Australia), which consisted of reactive data units coupled with reflector units affixed on top of tripods. The reactive data units were synchronized with a handheld computer (iPAQ, Hewlett-Packard, USA) which included customized software to record sprint time. Gates were placed at a height of 1.2 m for all tests, and subjects began each sprint 30 cm behind the start line, in order to trigger the first gate (Oliver and Meyers, 2009). The equipment used in the current study has been found to be reliable and valid when recording linear and change-of-direction speed in athletic populations (Green et al., 2010). Subjects used a standing start for all speed tests, placing their preferred foot in the forward position. If subjects rocked backwards, hesitated, or slipped prior to starting in any of the speed tests, the trial was disregarded and another attempt was allowed after the recovery period. Time for each distance was recorded to the nearest 0.01 s.

### 20-meter sprint

Gates were positioned at 0 m, 5 m, 10 m, and 20 m. Sprints over 5 m (Lockie et al., 2011; Spinks et al., 2007), 10 m (Jarvis et al., 2009; Lockie et al., 2011), and 20 m (Gabbett et al., 2008; Sporis et al., 2009) have been used in the assessment of field sport athletes. Once ready, subjects were allowed to start in their own time, and were instructed to run maximally once they initiated their sprint.

### Illinois Agility Run (IAR)

The dimensions and route direction for the IAR are shown in Figure 1, and was conducted in accordance with established methods (Jarvis et al., 2009; Roozen, 2004; Wilkinson et al., 2009). The IAR involves four markers being placed to indicate an area that is 10-m long and 5-m wide. In the centre of the area, 4 markers are placed 3.3 m apart. Two timing gates were used; one at the start line and one at the finish. No technical advice was given as to the most effective movement technique. Subjects were only instructed to complete the test as quickly as possible. Subjects were instructed not to cut over the markers; they were to run around them. If a subject failed to do this, the trial was stopped and re-attempted after the requisite recovery period, so that 3 successful trials were completed.

### Change-of-Direction and Acceleration Test (CODAT)

The dimensions and movement direction for the CODAT is shown in Figure 2. As previously stated, this test was designed on the basis of sprint distances important for field sport athletes (Bangsbo et al., 1991; Dawson et al., 2004; Docherty et al., 1988; Duthie et al., 2006; Gray and Jenkins, 2010; Lockie et al., 2011; Sporis et al., 2009), and direction changes and footwork that are demanded of field sport athletes during a game (Dawson et al., 2004; Jennings et al., 2010; Lockie et al., 2011; Young and ). A timing gate was positioned at the start and at the finish of the test. As per the IAR, no instructions were given as to the most effective movement technique, and subjects were instructed to complete the test as quickly as possible. Subjects were also to ensure they cut around markers, and

did not run over them. Trials were stopped and re-attempted after the rest period if the subject did cut over the top of a marker, so that 3 successful trials were completed.

### Statistical analyses

Statistical analyses were processed using the Statistics Package for Social Sciences (Version 20.0; IBM Corporation, New York, USA). Means and standard deviations (SD) were calculated for each test, in addition to 90% confidence limits (90% CL). The normality of the data distribution was checked using the Kolmogorov-Smirnov test, while homogeneity of variance was assessed by Levene's test. For the relative reliability analysis, intra-class correlation coefficients (ICC) were used. An ICC equal to or above 0.70 was considered acceptable (Baumgartner and Chung, 2001, Hori et al., 2009).

Absolute reliability was assessed by paired samples t-tests ( $p \leq 0.05$ ), which were used to assess any significant differences between the sessions for each speed test (Sheppard et al., 2006, Beekhuizen et al., 2009), and typical error (TE) (Hopkins, 2000). The spreadsheet of Hopkins (2009) was used to determine the TE (s), expressed as a coefficient of variation (CV, %). A CV of less than 5% was set as the criterion for reliability. The usefulness of the test was determined by comparing the TE to the smallest worthwhile change (SWC) in time for each test (Hopkins, 2004). The SWC was determined by multiplying the between-subject SD by either 0.2 ( $SWC_{0.2}$ ) (Hopkins, 2004), which is the typical small effect, or 0.5 ( $SWC_{0.5}$ ) (Cohen, 1988), which is an alternate moderate effect. If the TE was below the SWC, the test was rated as 'good'; if the TE was similar to the SWC, the test was rated as 'OK'; and if the TE was higher than the SWC, the test was rated as 'marginal' (Hopkins, 2004). For the validity analysis, Pearson product-moment correlations ( $p \leq 0.05$ ) were used to define relationships between the 20-m sprint, IAR and CODAT (Oliver and Meyers, 2009; Sassi et al., 2009; Sheppard et al., 2006; Wilkinson et al., 2009). The strength of the correlation coefficient ( $r$ ) was designated a descriptor as per Hopkins (2002). For this study, an  $r$  value less than 0.3 was considered small; 0.31 to 0.49 moderate; 0.5 to 0.69 large; 0.7 to 0.89 very large; and 0.9 and higher near perfect for predicting relationships.

### Results

Table 1 displays the mean times, and 90% CL, for each of the speed tests for both testing sessions. In regards to the relative reliability of the speed tests, there were no significant differences between the testing occasions. The ICCs for each of the tests was in excess of 0.70, with the CODAT ICC equaling 0.84. The measures of absolute reliability (TE and CV) are also shown in Table 1, along with the  $SWC_{0.2}$ ,  $SWC_{0.5}$ , and ratings of usefulness. The CV was less than 5% for each test. For each test, the TE was either similar to, or exceeded, the  $SWC_{0.2}$ . The TE was below the  $SWC_{0.5}$  for each test.

The correlations, and corresponding 90% CL, between each of the speed tests are shown in Table 2.

**Table 1.** Descriptive data for testing sessions 1 and 2, p value for differences between the sessions, mean and 90% confidence limits (90% CL) and reliability statistics (intra-class correlation coefficient [ICC], typical error [TE], coefficient of variations [CV], smallest worthwhile change [ $0.2 \times$  standard deviation =  $SWC_{0.2}$ ;  $0.5 \times$  standard deviation =  $SWC_{0.5}$ ], and ratings of usefulness) for the 20-m sprint (0-5 m, 0-10 m, and 0-20 m intervals), change-of-direction and acceleration test (CODAT), and Illinois agility run (IAR) in Australian football players (n = 18).

	Session 1 (s)	Session 2 (s)	Mean and 90% CL (s)	p value	ICC	TE (s)	CV (%)	$SWC_{0.2}$ (s)	Rating	$SWC_{0.5}$ (s)	Rating
0-5 m	1.09 (.07)	1.06 (.09)	1.06 (1.03-1.09)	.31	.76	.04	5.1	.02	OK	.05	Good
0-10 m	1.87 (.11)	1.84 (.10)	1.84 (1.80-1.88)	.25	.85	.04	3.5	.02	OK	.06	Good
0-20 m	3.26 (.17)	3.23 (.18)	3.24 (3.17-3.30)	.25	.96	.06	1.9	.04	OK	.09	Good
CODAT	6.22 (.35)	6.07 (.53)	6.10 (5.95-6.26)	.26	.84	.19	3.0	.10	Marginal	.25	Good
IAR	14.19 (.76)	14.02 (.90)	14.08 (13.79-14.36)	.17	.91	.29	2.5	.17	Marginal	.42	Good

Significant, positive relationships were demonstrated for time in each of the linear sprint intervals, and the 2 change-of-direction speed tests. This indicated that subjects faster in linear sprinting also tended to be faster in the change-of-direction sprints as well. Correlations ranged from large to near perfect. The strongest relationships were between the 0-5 m and 0-10 m intervals ( $r = 0.95$ ;  $p < 0.01$ ), the 0-10 m and 0-20 m intervals ( $r = 0.95$ ;  $p < 0.01$ ), and the CODAT and IAR ( $r = 0.92$ ;  $p < 0.01$ ).

## Discussion

There are few validated change-of-direction speed tests that assess an athlete's ability to sprint linearly, while also performing direction changes (i.e. following a zig-zag style of running). The purpose of this study was to analyze a specifically designed speed test, titled the Change-of-Direction and Acceleration Test (CODAT). This test was designed for use in field sport athletes. The CODAT was compared to the IAR to provide some measure of validity. Although there is no single standard for a change-of-direction speed test, the IAR was chosen as it involves linear sprinting and diagonal cuts, and has been used to test athletes from a range of field sports, including soccer (Vescovi et al., 2006; Vescovi and McGuigan, 2008), rugby league (Gabbett, 2002), rugby union (Jarvis et al., 2009), Australian football (Draper and Lancaster, 1985), and field hockey (Draper and Lancaster, 1985; Keogh et al., 2003). The results from this study demonstrated that although there were some limitations, the CODAT displayed acceptable reliability and validity for field sport testing. The CODAT can detect moderate per-

formance changes (SWC calculated as  $0.5 \times$  SD) in change-of-direction speed in field sport athletes.

There were no significant differences in the mean CODAT times recorded from testing sessions 1 and 2, nor were there between-session differences for the other speed test times (Table 1). Previous research has found good reliability for measures of linear sprint performance (Cronin et al., 2007; Green et al., 2010; Oliver and Meyers, 2009), and measures of change-of-direction speed, including the IAR (Wilkinson et al., 2009). In keeping with these findings, acceptable ICCs ( $>0.70$ ) and CVs ( $<5\%$ ), were also found for the CODAT. The ICC for the CODAT was 0.84, indicating a high level of relative reliability. This was further supported by a CV of 3.0%. The CV attained for the CODAT was similar to other change-of-direction speed tests that were determined to be reliable. This includes several soccer-specific tests with a duration of approximately 6-8 s, inclusive of and  $90^\circ$  and  $180^\circ$  cuts (CV = 2.9-5.6%) (Sporis et al., 2010), and a shortened version of the T-test that had a duration of approximately 6 s (CV = 2.7%) (Sassi et al., 2009). Additionally, although the sample size for this study is relatively small (Hopkins et al., 2001; Buchheit et al., 2011), finding good relative reliability suggests that changing the sample size may not greatly affect the results (Buchheit et al., 2011), and thus was appropriate for this study. However, as will be discussed, absolute reliability may have benefited from a larger sample.

Indeed, despite the acceptable levels of relative reliability, the degree of the test usefulness must be discussed. This was evidenced by the differences between the TE and  $SWC_{0.2}$  (Table 1). For the 20-m sprint, the TE

**Table 2.** Correlations (with 90% confidence limits [90% CL]) between the 0-5 meter (m), 0-10 m, and 0-20 m intervals of a 20-m sprint, the change-of-direction and acceleration test (CODAT), and Illinois agility run (IAR), in Australian football players (Pearson's correlation coefficient =  $r$ ; significance =  $p$ ; n = 18).

		0-5 m	0-10 m	0-20 m	CODAT
0-10 m	r	.95			
	90% CL	.92 - .98			
	p	.00 *			
0-20 m	r	.86	.95		
	90% CL	.79 - .93	.92 - .98		
	p	.00 *	.00 *		
CODAT	r	.76	.76	.75	
	90% CL	.65 - .87	.65 - .87	.64 - .86	
	p	.00 *	.00 *	.00 *	
IAR	r	.68	.71	.75	.92
	90% CL	.54 - .82	.58 - .84	.64 - .86	.88 - .96
	p	.00 *	.00 *	.00 *	.00 *

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

was almost similar to the  $SWC_{0.2}$ , indicating that the usefulness of these tests was rated as 'OK' (Hopkins, 2004). However, the TE being much greater than the  $SWC_{0.2}$  for the IAR, and in particular the CODAT, means the usefulness of these particular tests for the current study population was rated as 'marginal' (Hopkins, 2004). It is worth noting that the sample used for this study (experienced Australian football players from the same amateur club) was relatively homogeneous. The homogeneity of the group would contribute to the low  $SWC_{0.2}$  recorded in this study (Table 1). A larger, more heterogeneous sample of field sport athletes completing would likely result in a greater SD for the CODAT, and by extension the SWC would increase. This could then increase the usefulness of the CODAT to assess small changes to 'good'.

Nevertheless, moderate changes that exceed 0.5 times the CODAT's SD would be detected by this test in the present population. As can be seen in Table 1, the TE for the CODAT was below the  $SWC_{0.5}$ , which provides a usefulness rating of 'good'. This is pertinent, as within the context of this study, the results did indicate that the CODAT was a valid assessment of change-of-direction speed in field sport athletes. CODAT time demonstrated significant, large-to-near perfect relationships with all intervals of the 20-m sprint, as well as the IAR (Table 2). The relationships indicated subjects who were faster in the CODAT were also faster in the 20-m sprint and IAR. Notably, one of the strongest correlations occurred between the IAR and CODAT ( $r = 0.92$ ). The near perfect correlation between the CODAT and IAR demonstrates that they are assessing similar physical capacities (i.e. change-of-direction speed) in the subjects from the current study. In line with the studies hypothesis, these results provide a measure of the CODAT's validity in measuring change-of-direction speed in field sport athletes. Although these results may imply that the IAR is sufficient for assessing change-of-direction speed, there are other benefits provided by the CODAT. As will be discussed, the assessment of linear acceleration, and the field sport-specific duration of this test, demonstrates the potentially greater value of the CODAT for field sport and strength and conditioning coaches.

Previous research has acknowledged the specificity of linear sprinting when compared to change-of-direction speed (Little and Williams, 2005; Young et al., 2001). Indeed, Little and Williams (2005) found particularly low correlations ( $r = 0.35$ ) between a 10-m sprint test, and a zig-zag test which utilized 3 turns at  $100^\circ$ . However, the design of the CODAT includes linear 5-m and 10-m sprints in order to stress acceleration capacities. The inclusion of these straight sprints and how they assess linear acceleration can be viewed through the very large correlations between the CODAT and the 0-5 m ( $r = 0.76$ ) and 0-10 m ( $r = 0.76$ ) intervals of the 20-m sprint. Speed over a short distances (i.e. 5 m or less) are essential for effective acceleration, whether it is for a linear sprint (Cronin and Hansen, 2005; Lockie et al., 2011), or following a change of direction (Wheeler and Sayers, 2010). The relationships established between the CODAT, and the IAR and short sprint intervals, specifies that this test does indeed assess both linear acceleration and change-of-

direction capabilities. To further document whether both the ability to accelerate, and the ability to change direction whilst sprinting, are both appropriately assessed within the CODAT, it would be pertinent to measure split times within the CODAT, as well as time to make the direction changes and cuts. In addition, as has been conducted for linear acceleration (Lockie et al., 2011), it would be of benefit to detail the stance kinetics associated the direction changes in the CODAT.

The times recorded for the CODAT also provide a measure of the test's validity for field sport athletes. The CODAT took approximately 6 s to complete, which has been proposed as an acceptable duration for a maximal test of change-of-direction speed (Meir et al., 2001). In a review of field sport literature, Glaister (2005) states that high-intensity work periods in sports such as rugby union, soccer, and field hockey tend to last for between 4-7 s. As an example, fast running and sprint efforts in Australian football often last for 6 s or less (Dawson et al., 2004). Furthermore, 6-s sprint efforts are often used in repeat-sprint training and testing protocols for field sport athletes (Sirotic and Coutts, 2007, Sirotic and Coutts, 2008). The CODAT was also completed in less than half the time than that recorded for the IAR (Table 1). Therefore, given the potential metabolic limitations that could be associated with the IAR because of its extended duration (Vescovi and McGuigan, 2008), the CODAT could provide a valid, alternate assessment for change-of-direction speed in field sport athletes.

A limitation of the CODAT is that it may not be applicable for athletes who complete movements in restricted spaces, or over shorter distances (e.g. court sport athletes such as squash or tennis players). This is because the latent dimensions of change-of-direction speed movements incorporate specific actions, with the CODAT emphasizing frontal and lateral movements with changes of direction of up to  $90^\circ$  (Metikos et al., 2003). Nonetheless, for field sport athletes, the CODAT has practical relevance. The sprint distances covered and direction changes performed are applicable to a range of field sports, in particular the different football codes. Athletes of different ages and ability levels could benefit from use of the CODAT, as it is a relatively short, easily administered, field sport-specific test. Additionally, there is also scope for incorporating specific skills within the CODAT. This could involve carrying a football, dribbling a soccer ball, or dribbling a ball using a hockey stick. This would be particularly pertinent for field sport and strength and conditioning coaches who would want to assess their athletes in diagonal, zig-zag style sprinting patterns, specific to their sport.

## Conclusion

The results from this study indicate that the CODAT is a valid assessment of change-of-direction speed in field sport athletes, and reliable when considering ICC and CV. Although the usefulness of the CODAT is questioned to detect small performance changes in the present population, the CODAT can detect moderate changes in change-of-direction speed. This is pertinent, as the CODAT will

stress a field sport athlete's capacity to accelerate and change direction while sprinting. The findings from this study also provide avenues for future research. Comparisons between higher and lower level athletes could be conducted to document whether the CODAT can discriminate between playing standards, as well as research analyzing whether CODAT performance changes with specific change-of-direction speed training. While acknowledging the need be careful when interpreting the results drawn from the CODAT in a homogenous sample of Australian footballers, field sport coaches and strength and conditioning professionals could use this test with the understanding that it is a valid change-of-direction speed assessment for their athletes.

### Acknowledgements

The authors would like to thank the Gosford Wildcats Australian Football Club for providing subjects to this study. This research project received no external financial assistance. None of the authors have any conflict of interest.

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## Key points

- The change-of-direction and acceleration test (CODAT) was designed specifically for field sport athletes from specific speed research, and data derived from time-motion analyses of sports such as rugby union, soccer, and Australian football. The CODAT features a linear 5-meter (m) sprint, 45° and 90° cuts and 3-m sprints to the left and right, and a linear 10-m sprint.
- The CODAT was found to be a reliable change-of-direction speed assessment when considering intra-class correlations between two testing sessions, and the coefficient of variation between trials. A homogeneous sample of Australian footballers resulted in absolute reliability limitations when considering differences between the typical error and smallest worthwhile change. However, the CODAT will detect moderate (0.5 times the test's standard deviation) changes in performance.
- The CODAT correlated with the Illinois agility run, highlighting that it does assess change-of-direction speed. There were also significant relationships with short sprint performance (i.e. 0-5 m and 0-10 m), demonstrating that linear acceleration is assessed within the CODAT, without the extended duration and therefore metabolic limitations of the IAR. Indeed, the average duration of the test (~6 seconds) is field sport-specific. Therefore, the CODAT could be used as an assessment of change-of-direction speed in field sport athletes.

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