Journal of Strength and Conditioning Research Publish Ahead of Print
DOI: 10.1519/JSC.0000000000001045

The influence of test distance on change of direction speed test results

Running Header: Change of direction speed testing

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This project received no external funding

ABSTRACT

This study assessed the relationships between linear running velocity and change of direction (CoD) ability, and how assessing CoD ability over distances ≤ 5 m influences test reliability. Participants (n=15) from amateur rugby league teams performed three trials of a 20 m sprint test (light gates at 5 m, 10 m and 20 m) and six trials of the 5-0-5 agility test. Twelve participants repeated the 5-0-5 test several weeks later. A three-dimensional motion capture system (250 Hz) was used to track the centre of mass at 0.3 m, 0.5 m and 1.0 m either side of the turn and identify specific CoD phase times. Pearson's correlations showed strong, significant relationships between the 5-0-5 time and 5 m (r=0.89, P<0.001); 10 m (r=0.91, P<0.001) and 20 m sprint times (r=0.93, P<0.001). However, the strength of these relationships decreased (r<0.65, P>0.05) when CoD ability was measured over distances less than 0.5 m. Analysis of coefficient of variation (CV%) data indicated that the 5-0-5 test had high intra (CV% = 2.8) and inter-test reliability(CV% = 1.3), with these data decreasing for distances less than 1 m (CV% = 3.5-6.9). Specific movement phase times were the least reliable measures of CoD ability (CV% 4.7-53.6). Results suggest a bias between high speed linear running ability and 5-0-5 time. However, an effective compromise can be found between test reliability and the external validity by assessing CoD ability over 1 m. Findings indicate that the current practice of assessing CoD ability over large distances in questionable.

Key Words: Change of direction speed; agility; repeatability; acceleration ability

INTRODUCTION

The ability to change directions rapidly is a key determinant of performance in many sports (13). Change of direction (CoD) ability has been linked traditionally with the term agility, although it is apparent that the latter is a complex skill involving numerous cognitive and physical capacities and can not be defined based purely on physical ability (5, 13, 19). Additionally, researchers have suggested that the presence of decision-making elements separates agility movements from the physical capacity of CoD ability. Regardless, CoD speed is a key aspect of agility performance (12, 13, 15, 22), with other factors such as the ability to accelerate and decelerate rapidly also having been acknowledged as key aspects of agility movements (3, 12, 21).

The 5-0-5 agility test is a relatively simple test that is based on measuring the time taken to complete a single 180 deg direction change over a 15 m up-and-back course (3). The result for the 5-0-5 test is the return time recorded via timing gates positioned 5 m before the turn. The simplicity of the test and minimal equipment required has meant that it has been adopted by numerous sports (4, 6). The creators of the 5-0-5 test suggested that it isolated the ability to change directions independent of running speed capacity and as a result represented a valid measure of agility performance for many sports (3). However, despite these claims, limited literature has reported the validity or reliability of this test. Gabbett, Kelly, and Sheppard (6) reported high levels of test-retest reliability for the 5-0-5 test (Intraclass Correlation Coefficients [ICC]=0.9 and typical error 1.9%) and moderate correlations with linear running ability (r=0.58) in rugby league players. In addition, limited published data exists on the relationships between 5-0-5 times and linear running ability in amateur level participants – the groups who typically use this type of test.

Typically researchers validate CoD tests by correlating performance scores against high speed linear running ability (e.g. maximal velocity or performance time over distances ≥ 20 m). As CoD ability and high speed linear running ability are considered different capacities (9, 17, 21), they should exhibit weak correlation coefficients. Although some CoD tests are highly correlated with high speed linear running ability (11), protocols that have reported weak relationships with linear running performance typically have involved multiple direction changes (9, 10, 20). For example, Young, Hawken and McDonald (20) found that the strength of the relationships between maximal linear running speed and CoD performance decreased when the number of in test direction changes during the test increased from two to three (r = 0.27 and r = 0.19). However, some controversy remains as study on rugby league players (6) reported stronger correlation coefficients between 20 m sprint time and tests involving three direction changes (r=0.73) compared to a single direction change 5-0-5 test (r=0.58). Stronger correlations have been reported between performance in CoD tasks and acceleration speed than those observed with maximum running speed (9, 10, 20). Reported correlations between performance CoD test times and 0-10 m sprint times range typically from r = 0.50 (10) to as low as r = 0.35 (9). In spite of these data CoD tests that record moderate to high correlations with linear running ability are still promoted as valid measures of sports specific agility performance (2, 4).

Regardless of the testing protocol, a fundamental issue with most CoD testing is that performance is based on time to complete a predetermined task. Such a simple measure has the potential to skew the data towards factors such as running velocity, or the capacity to accelerate or decelerate rapidly and not on CoD ability per se. In addition, typically the shortest distance over which CoD performance is assessed is 5 m (3, 6, 14, 18), a factor that may bias test results towards high speed linear running ability. Accordingly, it is somewhat surprising that limited research has reported the reliability of CoD tests over distances less than 5 m, or compared performance in these tests with linear running ability. Therefore the aim of this study was to (i) examine the relationships between linear running velocity and CoD ability when the latter is assessed over distances less than or equal to 5 m, and (ii) to assess the impact of assessing CoD ability over distances less than or equal to 5 m on test reliability.

METHODS

Experimental Approach to the Problem

This study compared performance in a standard CoD test (5-0-5 agility test (3) with measures of high speed linear running ability among a group of semi-professional rugby league players. The external validity of the various CoD measures obtained from the 5-0-5 test were assessed by correlating these data against measures of high speed linear running ability. Intra and inter-test reliability was assessed using standard procedures (8). It was hypothesized that the strength of the relationships between linear running ability and CoD ability would decrease as the distance over which CoD ability was measured decreased. In addition, it was also hypothesized that as the distance over which CoD ability was measured decreased, the relative reliability of these measures would also decrease.

Subjects

Fifteen amateur level rugby league players volunteered to participate in this project (mean ± SD, age 24.6 ± 4.7 years, mass 85.24 ± 10.07 kg, height 1.807 ± 0.070 m). Prior to testing, participants were informed of the potential injury risks associated as a part of the required agility and sprint tests before being asked to complete relevant consent forms. The current study had full ethics approval from the institutional Human Research Ethics Committee.

Procedures

Linear running ability was determined via a 20 m maximal sprint test on an indoor running track. Electronic timing gates (Smart Speed, Fusion Sport, Brisbane, Australia) were used to record times at 5 m intervals along the 20 m. Three trials were completed with at least 4 mins between each repetition. Standard protocols were observed for the 5-0-5 testing (4), with a total of six trials (three trials turning towards both the right and left side). Participants were allowed at least 3 mins rest between each trial, with the turning direction (i.e. to the right or the left) randomized between participants. To quantify test re-test reliability 12 of the subjects repeated the 5-0-5 protocol 4 weeks after the initial testing. All sprint and agility times were recorded to the nearest 0.001 s.

A unique aspect of this study was the use of an eight camera (250 Hz) three-dimensional (3D) motion capture system (Qualisys AB, Gothenburg, Sweden) to monitor movements during the 5-0-5 direction change. This system tracked the position of 14 mm retro-reflective markers that were located over key pelvis and lower limb landmarks. Markers were attached adjacent to the 2nd sacral vertebrae and bilaterally over the anterior superior iliac spines, greater trochanters, medial and lateral condyles, medial and lateral malleoli and on the participant's shoes adjacent to the distal lateral edge of the 5th metatarsal and the superior surfaces of the 1st metatarsal. Four marker clusters were positioned laterally mid segment on both upper and lower legs. Standard biomechanical modeling software (Visual3D, C-Motion, Inc. Maryland, USA) was then used to construct a 7 segment model of the pelvis and lower body. Marker trajectories were modelled in 3D using standard biomechanical software (Visual3D, C-Motion, Inc. Maryland, USA) then filtered using a 9 Hz 2nd order low pass filter prior to the construction of a 7 segment rigid body model of the pelvis and lower limbs (Figure 1). The position of the whole body centre of mass (CoM) was approximated by the location of the sacral marker. A global reference system was established using standard procedures so that movements towards the turning line were represented as negative movements in the y-axis, while movements away from the turning line were positive. Although not used in this project the x-axis was established as being perpendicular to the main running direction (positive direction to the right), with the positive z-axis pointing vertically.

Three events were used to divide the 180 deg direction change into two phases. The *Pivot* (when the 1st Metatarsal of the non-turning foot first made contact with the ground prior to making the 0 m line) and the *Turn* (the point where whole body CoM has travelled its furthest forward) defined the Deceleration Phase (Figure 1a to 1b). The Acceleration Phase (Figure 1b to 1c) was defined as occurring from the *Turn* until *Acceleration Plant* (the point when 1st Metatarsal of the turning foot first made contact with the ground again after making the direction change).

**** Insert Figure 1 here ****

In addition to 5-0-5 performance time ($Time_{505}$), five additional agility times were recorded from the 3D kinematic data. Three of these were specific CoD values and were based on the movements of the CoM along the global y-axis (CoM_y) during the direction change. These were calculated from the time for CoM_y to move 0.3 m, 0.5 m and 1.0 m either side of Turn ($Time_{0.3}$, $Time_{0.5}$ and $Time_{1.0}$ respectively). The other two times recorded were the duration of the Deceleration ($Time_{decel}$) and Acceleration Phases ($Time_{accel}$).

Statistical Analyses

Following data collection, all data recorded was coded into an SPSS file for statistical analysis (Version 21.0 for Windows, SPSS Inc., USA). Reliability testing involved standard repeat trial testing to develop Typical Error of Measurement (TEM), ICC and Coefficient of Variation (CV%) values. The relative validity of each of the CoD measures was examined using Pearson Product Moment correlation coefficients to assess their relationships with the various measures of high speed linear running ability with the strength of the relationship being reported as: small 0.2–0.4; moderate 0.5–0.7; large > 0.7 (1). The repeat nature of the testing means that a significance level of $P<0.01$ *was* used for all correlation analyses, with data presented as means (±1 SD).

RESULTS

All three sprint measures had TEM scores less than 0.04 s and relatively low CV% values (Table 1). The intra-test and test re-test reliability data for each of the temporal agility variables indicated that intra-test reliability improved when agility was measured over longer distances. Test re-test reliability data for each of these variables showed improved TEM and CV% scores, but otherwise followed a similar trend. $Time_{accel}$ had a relatively high intra-test CV% (9.6%), suggesting that caution be taken when analyzing these data, although this improved during the second test session. The $Time_{decel}$ was shown to be an unreliable measurement during both intra-test and test re-test sessions and was subsequently removed from further analysis.

**** Insert Table 1 here ****

Results indicated that each of the linear sprint tests were highly interrelated with correlation coefficients between 0.97 and 0.99 (Table 2). Similarly, each of the agility measures showed moderate to high interrelationships (r=0.74 to r=0.98). $Time_{accel}$ recorded moderate significant relationships with $Time_{0.5}$ and $Time_{0.3}$, but was not correlated significantly with either $Time_{505}$ or $Time_{0.1}$. Analyses also showed strong significant relationships between $Time_{505}$ and 5 m (*P*<0.001), 10 m (*P*<0.001) and 20 m sprint times (*P*=0.001), with the latter accounting for more than 80% of the variance in predicting $Time_{505}$. Conversely, correlations there were moderate linear relationships between $Time_{1.0}$ and 5 m (*P*=0.012), 10 m (*P*=0.013) and 20 m sprint times (*P*=0.008). This trend continued with the strength of the correlations between each of the agility performance times and linear running ability decreasing as the distance over which agility was measured decreased. $Time_{accel}$ did not correlate significantly with any of the linear running speed times.

**** Insert Table 2 here ****

DISCUSSION

This study showed that the $Time_{505}$ was a reliable performance measure, as characterized by low intra-test and test re-test TEM and CV% values. These result are consistent with previous research conducted on elite rugby league players (6) and physical education students (17). However, strong correlations between the $Time_{505}$ and the 20 m sprint test indicated that the 5-0-5 test is biased towards both high speed linear running speed. In order to address this issue this study used 3D motion analysis techniques to record CoD performance times over distances considerably less than those reported previously in the literature (≤ 1.0 m). Results confirmed the hypothesis that the strength of the relationships between high speed linear running ability and CoD ability decrease when the latter is measured over shorter distances. Additionally, it was confirmed that the assessment of CoD speed over these short distances results in a concurrent reduction in both intra-test and test re-test reliability.

This research indicated that 5-0-5 time and high speed linear running ability are highly interrelated in a heterogeneous population of lower level athletes (i.e. relatively large spread in performance times). Although the strength of this relationship was higher than had been reported previously for elite level rugby league players (6), this study confirmed that performance in the 5-0-5 test is biased towards linear running ability the test population. The proportionally weaker correlations between high speed linear running ability and CoD speed measures for distances ≤ 1 m suggest that the distances over which CoD speed are measured currently may be too long. However, from a practical perspective it is not realistic to assess CoD ability over distances less than or equal to 0.5 m as this requires expensive equipment (timing gates do not work effectively over these distances). Accordingly, when these data are considered in conjunction to the reliability data it would appear that measuring CoD speed over a distance of 1 m provides an effective compromise between test reliability and the need to discriminate CoD ability from high speed linear running ability.

A novel aspect of this research was the assessment of movement phase times of the last deceleration step and first acceleration step. Unfortunately, the extremely poor reliability of $Time_{decel}$ meant that further analysis using this variable would be inappropriate at this stage, but it is likely that the ability to decelerate the CoM rapidly is also a key component of CoD ability. These data also show that when undertaking a 180 deg CoD test, deceleration movement times are extremely variable within and between individuals, particularly when compared to acceleration movement times. Correlations between $Time_{accel}$ and both $Time_{0.5}$ and $Time_{0.3}$. indicate that the relative speed of this first acceleration step appears to be an important component in determining CoD ability over small distances. Although these data have not been reported for the 5-0-5 test previously, this finding is consistent with previous literature that has reported acceleration as an important aspect in agility and CoD movements (7, 12, 13, 16, 21).

The primary tools used to assess reliability in this study were TEM and CV%, both of which have been shown to be ideal measures for assessing within subject error (8). Previous studies have also used ICC as a measure of reliability for agility testing (6, 14). However, within-subject error measurements have been identified as being better for testing reliability than retest correlations, as ICC is sensitive to both the heterogeneity of values between participants as well as the within subject variance (8). The hetrogeneous population of athletes tested in this study are no doubt responsible for the poor test re-test ICC, but low CV% values recorded for $Time_{1.0}$, $Time_{0.5}$ and $Time_{0.3}$.

This study assessed reliability and validity of the 5-0-5 test as a test of CoD ability. Despite findings indicating that the 5-0-5 test is reliable, its validity as a measure of CoD ability is questionable. To prevent CoD performance time being influenced by the participant's high speed linear running ability CoD ability needs to be assessed over distances ≤ 1 m. However, practitioners should exercise care when interpreting data collected over such short distances as test-retest reliability is influenced by the distance over which CoD is assessed.

PRACTICAL IMPLICATIONS

The relative absence of data on test-retest reliability, coupled with questions on the ability of this test to differentiate between high speed linear running speed and CoD ability, meant that the efficacy of this test as a functional CoD assessment tool is questionable. Results from this research indicate that practitioners who currently use the 5-0-5 test should start assessing times over the last meter, essentially creating a 1-0-1 test. It is acknowledged that taller athletes might create false triggers on the timing gate within this range and so it is possible that gates would need to be moved out to 1.5-2.0 m. Regardless, the current practice of assessing CoD distance over large distances is now questionable.

ACKNOWLEDGEMENTS

No financial assistance was awarded for this project.

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FIGURE LEGENDS

Figure 1. Diagram showing the seven segment lower limb model at the *Pivot* (a) *Turn* (b) and *Acceleration Plant* (c) positions.

Table 1: Descriptive statistics and intra and test re-test reliability data for the linear running and CoD performance times

		Intra-test reliability testing				Test re-test reliability testing		
Variable*	Mean (s)	SD (s)	TEM (s)	ICC	CV (%)	TEM (s)	ICC	CV (%)
5 m sprint	1.116	0.093	0.034	0.88	3.0			
10 m sprint	1.910	0.157	0.032	0.96	1.6			
20 m sprint	3.276	0.294	0.037	0.99	1.1			
$Time_{505}$	2.602	0.158	0.072	0.81	2.8	0.032	0.97	1.3
$Time_{1.0}$	1.072	0.058	0.039	0.57	3.7	0.024	0.82	2.4
$Time_{0.5}$	0.741	0.050	0.040	0.39	5.6	0.024	0.72	3.5
$Time_{0.3}$	0.575	0.045	0.039	0.27	6.9	0.024	0.65	4.5

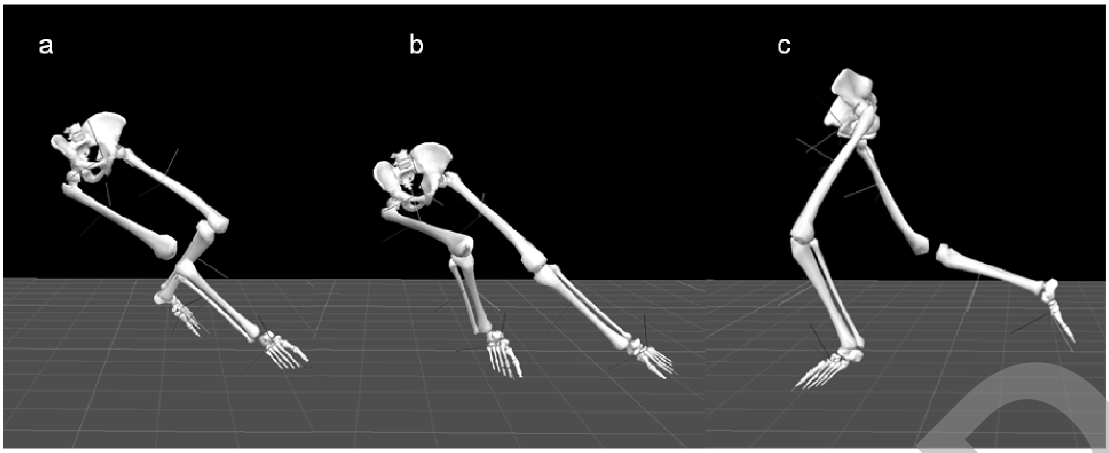
$Time_{decel}$	0.185	0.082	0.080	0.05	39.5	0.031	0.81	53.6
$Time_{accel}$	0.740	0.109	0.070	0.62	9.6	0.032	0.91	4.7

* 5-0-5 time ($Time_{505}$) recorded via timing gates while the time for the CoM_{horiz} to move 0.3 m ($Time_{0.3}$), 0.5 m ($Time_{0.5}$) and 1.0 m $Time_{1.0}$) either side of the Turn and duration of the Deceleration ($Time_{decel}$) and Acceleration phases ($Time_{accel}$) were recorded using a 3D motion analysis system.

Table 2: Correlation coefficients between sprint and CoD ability measures

	5 m sprint	10 m sprint	20 m sprint	$Time_{505}$	$Time_{1.0}$	$Time_{0.5}$	$Time_{0.3}$
5 m sprint time (s)							
10 m sprint time (s)	0.99*						
20 m sprint time (s)	0.97*	0.99*					
$Time_{505}$ (s)	0.89*	0.91*	0.93*				
$Time_{1.0}$ (s)	0.66*	0.65*	0.72*	0.87*			
$Time_{0.5}$ (s)	0.53	0.56	0.64	0.77*	0.81*		
$Time_{0.3}$ (s)	0.50	0.52	0.58	0.74*	0.84*	0.98*	
$Time_{accel}$ (s)	0.02	0.10	0.16	0.35	0.36	0.69	0.70

* Correlation is significant at the 0.01 level (2-tailed)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