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Advancing the pro-agility test to provide better change of direction speed diagnostics

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A B S T R A C T

The pro-agility shuttle is commonly used by practitioners to assess change of direction (COD) performance in athletes. Total time for the test is the metric of interest; however, it provides very little insight into the accelerative, decelerative and COD ability of athletes. The aim of this study was to determine whether the utilisation of three timing lights could reliably measure different components of COD performance. The traditional pro-agility test was adapted, and additional timing lights were placed 1 m from each COD line, enabling linear acceleration, deceleration and COD performance to be isolated. Twenty-five participants (age: 18.1 ± 0.51 y, height: 177.0 ± 2.80 cm, body mass: 86.7 ± 5.45 kg) completed three sessions, consisting of three trials, separated by one week. Absolute and relative consistency was assessed using coefficients of variation (CV) and intraclass correlation coefficient (ICC), respectively. Results showed significant difference ($p < 0.05$) in the second COD between sessions two and three. Absolute consistency was considered acceptable (< 10%) for nearly all variables except Acceleration 2 and Acceleration 4 between days 2-3. Relative consistency was 'poor' to 'good' for all variables from day 1-2 (ICC = 0.13 to 0.79) and 'poor' to 'good' for days 2-3 (ICC = -0.15 to 0.86). These findings suggest that using an advanced protocol enables the distinction between different performance components of the pro-agility shuttle to be assessed with reasonable reliability.

1. Introduction

An athlete's ability to change direction is an important physical quality required in many sports. Change of direction (COD) speed tests such as the pro-agility shuttle, a foundation assessment for sports such as American football (Sierer, Battaglini, Mihalik, Shields, & Tomasini, 2008), are frequently used for both talent development and identification (Sierer et al., 2008; Vescovi & McGuigan, 2008), whereby performance can mean the difference between being selected for a team, or not (McGee & Burkett, 2003; Sierer et al., 2008). The pro-agility test, which features a total of 18.3 m (20 yards) of linear sprinting and two 180° direction changes, is commonly used due to the ease of data collection. In research and applied practice, the total time taken to complete the pro-agility shuttle has been overwhelmingly used to quantify performance (Nimphius, Geib, Spiteri, & Carlisle, 2013). However, researchers have suggested that the use of "total time" from COD and agility tests may be confounded because total time is biased to linear sprint ability (Nimphius, Callaghan, Spiteri, & Lockie, 2016). Linear sprinting and COD are considered independent athletic qualities and should be measured as such (Nimphius et al., 2013; Salaj & Markovic, 2011; Vescovi & McGuigan, 2008). Research on the pro-agility shuttle reported only 29% of total time was spent changing direction, with the rest of the time being explained by athlete linear sprint ability and physical attributes (Nimphius et al., 2013).

To provide better information to sports scientists and applied practitioners, it would be more suitable to have measures that elucidate the contribution of different performance components (i.e. acceleration, deceleration and COD), which make up total test duration, in the pro-agility shuttle. Though total time may determine selection and give a macro-appreciation of COD performance, it fails to provide an isolated measure of constituent components of acceleration, deceleration and COD ability. Therefore, knowing the contribution of constituent components will provide higher level diagnostics to better inform COD speed

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development and programming. Therefore, the aim of this study was to establish whether an advanced diagnostic protocol, with additional timing lights place 1m before each COD can be used to identify different performance components which comprise the 18.6 m of linear sprinting and two 180° COD and determine the reliability of constituent components (acceleration, deceleration and COD) within the pro-agility shuttle. We hypothesized that all constituent components would be reliable, with the linear sprinting components having the highest consistency.

2. Methods

2.1. Experimental Approach to the Problem

Twenty-five male team sport athletes performed three maximal effort attempts of the pro-agility shuttle over three testing occasions separated by seven days. In addition to timing lights at the start finish line, two additional timing gates were placed 1 m (1.1 yards) prior to each COD line. A repeated measures analysis was conducted on the raw data to determine whether between-day performance differed in terms of mean percent change, absolute consistency (CV) and relative consistency (ICC).

2.2. Participants

Twenty-five male team sport athletes (age: 18.1 ± 0.51, height: 177.0 ± 2.80 cm, body mass: 86.7 ± 5.45 kg) participated in this study. Athletes competed in various team sports, such as rugby, field hockey and soccer at high school or regional levels, had 2-3 years of strength and conditioning, and speed training experience. Participants were required to be healthy and free of injury at the time of testing. After being orally briefed on the methods and reading the information sheet, participants provided their written informed consent, or assent, prior to participating in this study and where appropriate, subjects' guardians provided written consent. Participants were notified that they were free to withdraw from the study at any point. This research was approved by the Auckland University of Technology Ethics Committee and conformed to the Declaration of Helsinki.

2.3. Procedures

Testing was conducted on an indoor rubber floor. Wearing the same clothing and footwear, athletes were required to attend four sessions: one familiarisation session where the athletes practiced performing the pro-agility shuttle and three testing sessions. Testing sessions were conducted seven days apart, at the same time of the day, under the same experimental conditions. Each testing sessions lasted approximately one hour. During each testing session, athletes performed a standardised warm up consisting of progressive sprint and COD drills interspersed with dynamic lower body stretching, followed by three pro-agility trials.

For the pro-agility run, the participants started on a centreline facing the researcher. The participants sprinted 4.57 m (5 yards) to the left, then 9.14 m (10 yards) to the right, and 4.57 m (5 yards) back to finish the test as they crossed the centreline. Three trials within each testing session were used to gather averaged performance data. Three minutes of passive rest was provided between trials to limit performance fluctuations resultant from fatigue and decrease risk of injury. The instructions provided were to, stand in a 3-point stance with their left foot 30 cm behind the start/finish line. Once the participant was stable a "go" command was given. Timing started when the turned 90 degrees to the left and ran through timing gate 1. Touched the COD line with their left hand, the participant then turned and ran to the other side and touched the COD line with their right hand, the test was then finished by turning and running back through the middle line. To ensure the athletes touched the line, the researchers observed each trial. In the case the athlete did not touch the line, slipped or had a mistrial, they were given a retrial after three minutes of passive rest.

2.4. Equipment

To quantify COD performance, timing gates (Swift Duo^{tm} timing gates, Smartspeed lite, www.fusionsport.com) were set at the start/finish line and 3.55 m (3.88 yards) either side of the start line (i.e. 1 m before each COD line) to isolate components of the COD (see Figure 1) (Sayers, 2014, 2015). Timing gate height was set at 1 m for the start/finish to correspond with approximate centre of mass and gates one meter from each COD were set at 0.75 m to account for participants lower centre of mass during the COD (Morrison, Albert, & Kuruganti, 2015; Çınarlı, Kafkas, & Kafkas, 2018). This set-up enabled total time (i.e. 18.2 m) and associated constituent components to be quantified.

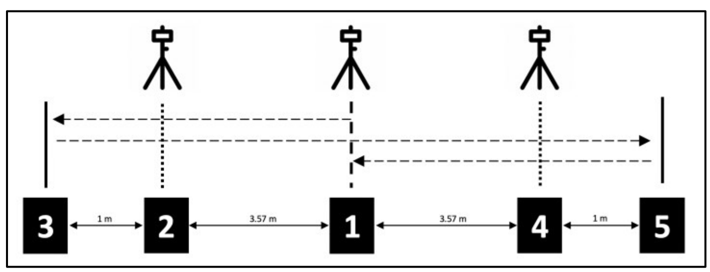

Figure 1: Advanced pro-agility diagnostic protocol

2.5. Data Analysis

Table 1 provides a description of all the variables of interest within this study. As can be observed from the table, the pro-agility test was broken into four linear accelerations and two COD components. Each of these components assessed different neuromuscular stresses often dependent on the entry velocity and therefore the decelerative-accelerative capability of the subjects.

2.6. Statistical Analysis

The two fastest trials from each session were averaged for all the variables of interest and used for subsequent analysis. Assumptions of normality and descriptive variables were tested using IBM SPSS statistical software package (version 25.0; IBM Corporation, New York, USA). Data was reported using 95% confidence limits (CL) and means. Reliability was established using pairwise analysis of averaged data of the two fastest trials. Each dependent variable was investigated between the first and second sessions and between the second and third sessions. A one-way analysis of variance (ANOVA) using repeated measures was used to determine whether between-day performance differed for total time and each of the sub-tests. To determine if systematic differences were present between testing sessions one to two and two to three, dependent *t*-tests were used. Significance was set at $p < 0.05$. Using a specifically designed spreadsheet, absolute consistency between sessions was assessed by calculating CV and mean percentage change (Hopkins, 2015). Relative consistency using test-retest correlations was measured via ICC using a two-way random model and average measures (Koo & Li, 2016). CVs of less than 10% were deemed acceptable as a percent of typical error (Uthoff, Oliver, Cronin, Winwood, & Harrison, 2018). Classification of ICC was deemed as follows: 'very poor' (< 0.20), 'poor' (0.20 - 0.49), 'moderate (0.50 – 0.74), 'good' (0.75 – 0.90) or 'excellent' (> 0.90) (Buchheit & Mendez-Villanueva, 2013). Magnitudes of change between pairwise trials were determined using Cohens *d* effect size. Effect size threshold of < 0.2, 0.2-0.6, 0.6-1.2, 1.2-2.0, and > 2.0 were determined as trivial, small, moderate, large, and extremely large (respectfully) (Cohen, 1988).

3. Results

The mean and standard deviation for each sessions' splits results are displayed in Table 2. No systematic change was observed in any measure between sessions. Mean change for all acceleration measures ranged from -2.41% to 1.90% between session 1-2 and -4.16% to 1.46% between session 2-3. Acceleration 1 showed the smallest change in mean between session 2-3 (0.02% [1.06 ± 0.09 to 1.04 ± 0.06], d = 0.26). Absolute consistency for accelerations

Table 1: Pro-agility diagnostic categorisation and physical assessment qualities measured

Split	Name	Explanation/Distance	Quality
1 → 2	Acceleration 1	Acceleration form the start line to first timing gate. Distance = 3.57 m (3.91 yd).	Concentric first-step quickness
2 → 3 → 2	COD 1 – lower speed entry	Timing 3.57 m (3.91 yd) entry and exit of the first COD. Distance 2.0 m (2.18 yd)	Lower intensity COD ability
2 → 1	Acceleration 2	Acceleration after the first COD from first timing gate to start/finish timing gate. Distance = 3.57 m.	Re-accelerative ability
1 → 4	Acceleration 3	Acceleration from start/finish line timing gate to entry of second COD timing gate. Distance = 3.57 m.	Re-De- accelerative ability
4 → 5 → 4	COD 2 – higher speed entry	Timing 3.57 m entry and exit of the second COD. Distance = 4.58 m.	High intensity COD ability
4 → 1	Acceleration 4	Acceleration from second timing gate to finish timing gate after the second COD. Distance = 3.57 m.	High reactive first-step quickness
1 → 3 → 5 → 1	Total time	Pro-agility total time. Distance = 18.28 m.	All the above

Note: m = metres, yd = yards, COD = change of direction measures ranged from 5.16% to 16.25% for all sessions, averaged CV for acceleration measures was 9.23% between sessions 1-2 and 10.33% between sessions 2-3. Only acceleration 1 and acceleration 3 were found to have CVs ≤ 10% between sessions 2-3. Relative consistency ranged from 'poor' to 'good' (ICC = -0.15 to 0.79) for all acceleration measures for all sessions. Only acceleration 1 and total time had an acceptable level of reliability (ICC = 0.71 [95% CL = 0.23 – 0.89], d = 0.26 and 0.86 [95% CL = 0.65 – 0.94], d = 0.09 (respectively)). Change in mean for COD measures ranged from -0.15 to 7.10% with no systematic changes observed. The smallest change in mean was observed in COD1 between session 2-3 (0.20% [0.59 ± 0.04 to 0.60 ± 0.10], d = 0.13). Absolute consistency for COD measures ranged from 5.20% to 12.77% between sessions 1-2 and 6.87% to 9.60% between session 2-3. The CVs of both COD1 and COD2 were < 10% between session 2-3. ICC ranged from 0.13 to 0.85, relative consistency much higher (> 0.60) between session 2-3. Only acceleration 1, COD 2 and total time met both reliability criteria.

Table 2: Pro-agility descriptive statistics

Split	**Mean (± SD)**			**% change of mean (95% CL)**		**CV (95% CL)**		**ICC (95% CL)**	
	Day 1	*Day2*	*Day3*	*Day1-2*	*Day2-3*	*Day1-2*	*Day2-3*	*Day1-2*	*Day2-3*
Accel 1	1.04 ± 0.06	1.06 ± 0.09	1.04 ± 0.06	0.81% (-1.67 – 3.35)	0.02% (2.74 – 2.86)	5.16% (4.15 – 6.89)	5.39% (4.28 – 7.39)	0.79 (0.49 – 0.91)	0.71 (0.23 – 0.89)
COD1	0.57 ± 0.04	0.59 ± 0.04	0.60 ± 0.10	1.40% (-1.50 – 4.34)	0.20% (-4.55 – 5.20)	5.20% (4.0 – 7.3)	9.60% (7.6 – 13.2)	0.13 (-1.1 – 0.63)	0.63 (0.06 – 0.85)
Accel 2	0.94 ± 0.10	0.93 ± 0.09	0.88 ± 0.13	-1.11% (-6.32 – 4.39)	-4.16% (-11.54 – 3.84)	11.56% 9.25 – 15.60	16.25% 12.77 – 22.69	0.41 (-0.34 – 0.74)	-0.15 (-2.19 – 0.56)
Accel 3	0.73 ± 0.06	0.71 ± 0.07	0.71 ± 0.05	-2.41% (-5.94 – 1.325)	1.46% (-2.65 – 5.74)	7.74% (6.21 – 10.38)	8.07% (6.39 – 11.12)	0.44 (-0.27 – 0.76)	0.51 (-0.15 – 0.79)
COD2	0.63 ± 0.09	0.63 ± 0.09	0.68 ± 0.11	-0.15% (-5.91 – 5.97)	7.10%* (3.38 – 10.96)	12.77% (10.21 – 17.27)	6.87% (5.45 – 9.44)	0.39 (-0.47 – 0.74)	0.85 (0.48 – 0.95)
Accel 4	0.94 ± 0.10	0.96 ± 0.12	0.91 ± 0.13	1.90% (-3.83 – 7.97)	-3.85% (-9.26 – 1.89)	12.40% (9.91 – 16.76)	11.50% (9.08 – 15.93)	0.41 (-0.44 – 0.76)	0.48 (-0.24 – 0.79)
Total Time	5.03 ± 0.28	5.04 ± 0.33	5.01 ± 0.28	-0.13% (-2.23 – 2.01)	0.63% (-0.86 – 2.15)	4.38% (3.53 – 5.85)	2.85% (2.27 – 3.89)	0.73 (0.37 – 0.89)	0.86 (0.65 – 0.94)

Note: Data are mean ± SD of each variable with the difference between sessions with the percent (%) difference given with the 95% confidence interval. * = significance level < 0.05, Accel = Acceleration, COD1 = first change of direction, COD2 = second change of direction.

4. Discussion

The pro-agility test provides a macro-understanding of change of direction ability by giving a total time. Of interest to these authors was whether the pro-agility test could be broken into sections to give a micro-understanding of the COD speed by breaking it down into smaller components provides practitioners with further insight into the COD speed strategy athletes adopt. In doing this, four acceleration measures and two CODs were identified as measures that could provide greater diagnostic information, rather than a single total time for the test. Each of these measures represented different components of COD speed as indicated in Table 1; however, prior to any use of these measures it was important to determine the reliability of the variables of interest. The main findings of this study were: 1) only acceleration 1, COD 2 and total time met the thresholds for acceptable reliability; 2) there appeared very little systematic bias between sessions 1-3, so it would seem that a familiarisation and a testing session is all that is needed to capture acceptable data.

The first measure of acceleration was the only variable that was found to have acceptable reliability. The reason for this being initiation of movement from a static position, where movement velocity would be lower than that of Acceleration 3, where assessment from a flying start may increase variability in sprint time, reducing the reliability of the measurement (Barber, Thomas, Jones, McMahon, & Comfort, 2016; Duthie, Pyne, Marsh, & Hooper, 2006; Hader, Palazzi, & Buchheit, 2015). Another reason for Acceleration 1 being the only reliable measurement of acceleration may be that acceleration was not influenced by COD, as seen in Acceleration 2 and Acceleration 4 (Barber et al., 2016; Duthie et al., 2006; Hader et al., 2015; Loturco et al., 2019) whereby, post-COD acceleration is influenced by body and force orientation (Dos'Santos, Thomas, Comfort, & Jones, 2018). These findings partially support our hypothesis that linear sprinting performance components would be reliable, yet CV > 10% for re-accelerative ability and high reactive first-step quickness indicate that the linear sprint components immediately following a COD were found to be less reliable in this study.

An interesting finding was that COD2 was the only COD measure to have acceptable reliability between sessions 2-3. This was an unexpected result because it would be assumed that the potentially higher entry velocity results in greater variability of movement, where it would be hypothesised that COD1 would have better reliability due to a lower entry velocity. It should be noted that when looking at average measures between session 2-3, COD2 took a significantly longer time to complete, than COD1 (0.65 ± 0.10 and 0.59 ± 0.06 [$p < 0.05$] (respectively)). This may be due to the increased entry velocity requiring greater braking forces during deceleration and longer ground contact time, thus impulse, when changing direction (Dos'Santos et al., 2018; Freitas et al., 2018). Similarly, (Loturco et al., 2019) further identified that those with higher acceleration had higher COD deficits, i.e. difference between linear sprint and COD. Supporting the finding by (Dos'Santos et al., 2018), that athlete ability to successfully change direction is resultant of the entry velocity and angle of directional change, where deceleration and longer ground contact times may explain the longer COD completion times when entry velocity is high. In view of this, COD measures showing acceptable CV values and 'moderate' to 'good' levels of ICC may still be used reliably (Atkinson & Nevill, 1998) for talent identification and monitoring of development. Along with this, significance reported for change of mean in the COD2 measure (7.10% [0.63 ± 0.09 to 0.68 ± 0.11]) between days 2 and 3 should be noted. The significance potentially indicates movement velocity influences COD and first-step quickness post-COD. It may be thought that reliability of the COD measures is a function of where the COD timing gates are placed, where if the gates are placed further away from the COD lines, placed equally between the start/finish and COD line, it may result in less variability. However, future research would need to be conducted to determine this. This study reported total time to be the most reliable and least variable measurement. This may be due to the amalgamation of the individual components to provide a single total time result. These findings highlight that athletes can achieve very similar total times, but the means in which they achieve these times in terms of the components of the pro-agility shuttle can differ. There was very little systematic bias between sessions 1-2, confirming there to be no predictable errors in measurement. With knowledge of this, it would seem appropriate for conduction of one testing session, with familiarisation prior, to gather acceptable performance data using this protocol.

4.1. Conclusion

To the best of the researchers' knowledge, this study is the first to advance the diagnostic value of the pro-agility test by splitting the test into a number of components. However, limitations of this study should be noted. Firstly, timing gate distance of 1 m may not be suitable when assessing taller athletes who may extend near or further than 1 m when changing direction. Additionally, timing gate height of 0.75 m may not be suitable for athletes who have an extremely low COD position. Therefore, future research is required to identify differences between timing gate set-up. Nevertheless, the results of the current research indicate that a diagnostic protocol which differentiates COD from linear sprinting and allows for assessment of performance within the pro-agility shuttle can be used to accurately identify strengths and weaknesses regarding COD and linear sprint performance.

4.2. Practical Applications

It appears that an advanced diagnostic protocol can be used to reliably distinguish between different performance components within a pro-agility shuttle. While we recommend that the linear sprinting component, high reactive COD ability, performance be interpreted with caution, the inclusion of additional timing splits provide unique information pertaining to independent physical performance capabilities. Sports scientists and strength and conditioning professionals may use this information to identify the specific performance components relevant to the sports they work with. It can be concluded the use of an advanced diagnostic testing protocol for the pro-agility shuttle, can be used to provide applied practitioners with a more isolated measure of COD ability, which is not confounded by linear sprinting, and provide specific information pertaining to areas of needed development and guide COD speed strategy.

Conflict of Interest

The authors declare no conflict of interests.

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