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Title: Physical qualities predict change-of-direction speed but not defensive agility in Australian Rules football.

Running head: Agility, change-of-direction speed and physical qualities.

Authors:

Warren B Young (Corresponding author)¹ w.young@federation.edu.au Phone 03 5327 9685

Fax 03 5327 9478

Ian Miller¹ ianmiller@students.ballarat.edu.au

Phone 0430 599105

Scott Talpey¹ s.talpey@federation.edu.au

Phone 03 5327 6363

¹ Faculty of Health, Federation University Australia, PO Box 663, Ballarat, Victoria, Australia. 3353.

Abstract

The purpose of this study was to determine the relationships between selected physical qualities, change-of-direction speed and defensive agility performance in Australian Rules football players. Twenty-four male community-level players were assessed on sprint acceleration (10-m time), maximum strength (3 repetition-maximum half squat), leg power (countermovement jump), reactive strength (drop jump), as well as a single change-of-direction speed test and a defensive agility test. Change-of-direction speed was correlated with reactive strength ($r = -0.645$, $p = 0.001$) and sprint acceleration ($r = 0.510$, $p = 0.011$). Multiple regression indicated the combined physical qualities explained 56.7% of the variance associated with change-of-direction speed (adjusted $R^2 = 0.567$, $p < 0.05$). Participants were median-split into faster and slower change-of-direction speed groups, and these were compared by independent t-tests. The faster group was significantly better ($p < 0.05$) on the sprint acceleration and reactive strength tests (large effect size). The correlations between physical qualities and agility were trivial to small ($r = -0.101$ to 0.123 , $p > 0.05$) and collectively explained only 14.2% of the variance associated with agility performance (adjusted $R^2 = -0.142$, $p > 0.05$). When faster and slower agility groups were compared, there were trivial to moderate differences ($p > 0.05$) in all physical qualities. It was concluded that reactive strength and sprint acceleration are important for change-of-direction speed but the physical qualities assessed are not associated with defensive agility performance. For agility tasks similar to this study, sprint and resistance training should not be emphasized, and training other factors such as the development of sport-specific **technique and** cognitive skill is recommended.

Key words: evasion sports, side-step, sprint acceleration, decision making

INTRODUCTION

In many invasion sports such as the various codes of football, agility is an important quality. If an attacking player can evade defenders, the ball can be moved forward to provide scoring opportunities. Conversely, defensive agility is required to block attacking movements, and to increase pressure on the attacker with the objective of causing a turnover. Agility has been defined as a change in speed or direction in response to a stimulus (23). For example in football codes, defensive agility involves a change in speed and/or direction that is always in reaction to the attacker's movements. Despite this, most training, testing of athletes, and research concerned with agility involves pre-planned change-of-direction movements around obstacles such as poles and cones (1, 11, 12). Such activities can be described as change-of-direction speed rather than agility (3, 33), and generally do not occur during competition.

Considerable research has been conducted to determine the relative importance of fitness components such as speed, strength and power to change-of-direction speed. For example, various measures of explosive leg muscle function have been reported to have statistically significant ($p < 0.05$) correlations with different tests of change-of-direction speed (16, 17, 28, 33). A drop jump (DJ) test proposed to assess explosive leg extensor function in a fast stretch-shortening cycle (reactive strength) correlated more strongly with change-of-direction speed than a test of concentric-only leg power (33). The authors suggested the stronger correlation was due to the similarity in the leg push-off mechanism in the drop jump and change-of-direction tests. Further, training that causes gains in leg power has been shown to transfer to improved change-of-direction speed (13, 15), although this has not always been found (27).

Unfortunately there is a paucity of research examining the relationship between physical qualities and agility performance. Henry et al. (8) recently reported correlation coefficients less than 0.3 ($p > 0.05$) between an agility test (with reaction) and unilateral jump tests in the vertical, horizontal and lateral directions. The authors concluded that agility performance is more likely to be influenced by

non-strength factors (skill, balance) rather than reactive strength. Further insights into the importance of physical qualities can be determined by evaluating research that assesses both agility and change-of-direction speed in the same athletes. This has been done only for sprint acceleration performance (10-m time) in Australian Rules footballers (24) and rugby league players (5). In both studies, the correlation between sprint performance was stronger with change-of-direction speed than agility. For example, Sheppard et al. (24) reported a correlation of $r = 0.738$ between 10-m time and a test involving a single pre-planned change of direction. However, when sprint performance was correlated with an agility test involving a reaction and a similar movement, the correlation coefficient was only 0.333. These results suggest that acceleration performance has less association and potentially less influence on agility compared to change-of-direction speed, and this is likely to be a result of the cognitive component associated with reacting in the agility task. It is possible that other physical qualities such as strength and power may also have a diminished influence on agility due to the presence of the decision-making element. Therefore the purpose of this study was to determine the relationships between sprint acceleration, leg extensor strength, power and reactive strength with both agility and change-of-direction speed. **Since our study required athletes to respond to an attacker carrying a football, the focus was on defensive agility and our findings are expected to provide insights into the relative importance of the selected physical qualities to defensive agility performance.**

METHODS

Experimental approach to the problem

The study was designed to determine the relationships between agility, change-of-direction speed and four physical qualities; sprint acceleration, leg strength, power and reactive strength. The change-of-direction speed test was designed to replicate the movement of the agility test, but was a pre-planned movement with a single change of direction around a pole. The similarity of the two tests meant that the primary difference was expected to be the cognitive component of the agility

test. The physical qualities were chosen because they have been identified as the key physical fitness factors determining agility performance (33).

Subjects

Twenty-four ($n = 24$) males aged between 18 and 24 years with a mean $\pm$ standard deviation stature and body mass of 180.4 ± 7.2 cm and 78.5 ± 9.2 kg respectively, volunteered to participate in the study. All participants played Australian Rules football at the community-level with at least two year's experience. At the time of the study, players participated in 2-3 training sessions per week, and were free of injury and illness. The study was approved by the University's Human Research Ethics Committee and all participants provided written consent.

Procedures

Each participant attended three sessions on different days. The first session involved explanations, demonstrations and practice of the test skills and procedures. The next two sessions involved testing, and were conducted two to four days apart. The first of these sessions included a 10-m sprint test, an agility test and a change-of-direction test in that order. The second testing session included an assessment of leg extensor power with a countermovement jump, a test of reactive strength with a drop jump, and a test of leg strength with a 3 repetition maximum half-squat, in that order. Although all of these tests were brief in duration, a 3-5 minute rest between tests was provided to prevent any cumulative fatigue.

All testing was conducted in a temperature-controlled laboratory ($18-20^{\circ}$ C) on an all-purpose surface. Participants were instructed to wear suitable clothing (shorts, T-shirt, non-slip running shoes) and be adequately hydrated. Both testing sessions began with a standardised warm-up of approximately 15-min, and consisted of jogging, running drills emphasising knee lift and knee flexion, forward and lateral leg swings, walking lunges and 10-m runs at gradually increasing speeds from 65-95% of maximum perceived effort.

Agility and COD speed tests

The agility test has been described in detail (36), and involved reacting and moving as if pursuing an attacker who performed a change-of-direction movement which was displayed from a video on a 3 x 3-m screen. A similar test has been shown to possess adequate test and retest reliability using the mean of six trials (32). Since we used eight trials and practised the test within a familiarization session, it may be expected that the reliability was improved. Eight different video-clips were played which depicted different attacking agility scenarios. The attacker was an Australian Rules football player of a similar standard to the participants, and he was viewed changing direction to the left or right following a sport-specific situation such as picking up or bouncing the ball. The participant began the test from a stationary position with the toe of the front foot directly under a light gate beam. The initial forward movement triggered the playing of the video of the attacker, and the participant was instructed to follow the attacker to the left or right as if attempting to tackle. Agility performance was recorded by an electronic dual-beam infra-red timing light system (Swift Performance Equipment, Brisbane, Australia) from the first forward movement to the instant of passing through a finish gate to the left or right. The total time was comprised of approximately 3.5 m of forward movement, a 45° change-of-direction movement with a short sprint for approximately 3.5 m. The exact angle of the change of direction could not be controlled because of the open-skill nature of the agility test, however observation revealed this was achieved within $\pm 5^\circ$. If an athlete turned to the wrong side, he was required to correct this error and recover by running to the correct side as quickly as possible. **When this occurred (less than 5% of the trials), the participant appeared to anticipate the stimulus and once the error was recognized, he quickly initiated a change of direction to the correct side within one to two steps.** Since the eight video clips were the same for all subjects, each participant was not permitted to watch others or discuss the test until all testing

was complete. A 30 s rest was provided between trials and the mean of the eight trials was considered to represent agility performance and was used for analysis.

For the change-of-direction speed test, the same start and finish gates were used so that the distance and direction of movement was similar to the agility test. A 1.4 m-high pole was placed 3.5 m forward of the start line and was positioned 0.4 m to the side so that the participant could follow a straight-ahead path before “cutting” to the left or right. This meant that the pole was offset to the left for a left turn or to the right for a right turn. If the pole was touched but didn’t fall, the trial was continued. However, if it was knocked over, the test was stopped and another trial was allowed. Two trials turning to the left and two trials turning to the right were performed, with half of the participants starting with left turns and half with right turns. A 30 s rest between trials was provided and the mean of the best left and best right trial was retained to represent change-of-direction speed.

Tests of physical qualities

A 10-m sprint was chosen to represent acceleration performance (36), and this test has previously been shown to possess good test and retest reliability (24). Timing was conducted using the same light-gate system as used for the agility and change-of-direction speed tests. The participant adopted a standing start with the toe of the front foot on the line directly under the start beams so that the first forward movement triggered the timing. Participants were instructed to sprint when they were ready, and to only move forward with no preliminary backward movement. Three trials were conducted with a 2-minute rest between trials, and the best trial was retained for analysis.

Maximum strength of the leg extensor muscles was estimated with a 3-repetition maximum (3-RM) half-squat exercise performed in a Smith machine. The procedures described by Stapff (25) were adapted so that the bottom position of the squat produced a 90 degree knee angle, as measured by a goniometer. This was controlled by lowering the bar to lightly touch some rubber tubing attached

to the rack which was positioned to yield the target knee angle. The test began with a warm-up consisting of a 4-min jog, 10 half squat repetitions with 50% of the estimated 3-RM, 5 repetitions with 75% and 3 repetitions with 90% of the estimated 3-RM. After a successful 3-repetition trial, the weight was increased so that the maximum weight that could be lifted only three times was recorded to the nearest 5 kg. The 3-RM was divided by body mass to obtain the participant's relative strength.

Leg power was assessed with a countermovement jump, as described by Young et al (31). Participants were instructed to use a self-selected countermovement (dip) immediately before extending the legs as fast as possible to jump for maximum height. An aluminium pole of 0.4 kg mass was held across the shoulders and had a position transducer attached at one side (PT5A, Fitness Technology, Australia). Vertical ground reaction forces during leg extension were recorded by a force platform (400 Series Performance Force Plate, Fitness Technology, Australia), and power was calculated from the computer software (Ballistic Measurement System, Fitness Technology, Australia). Power was divided by body mass to obtain relative power ($W \cdot kg^{-1}$), as this variable has been found to correlate more strongly to sprint and jump performance than absolute power (31). The best of six jumps was retained for analysis, with 1-min recovery between each trial.

Reactive strength is considered as a specific form of explosive leg muscle function (21) and was measured by a drop jump (DJ) test (35). The participant stepped off a 30-cm high box and was instructed to jump for maximum height and minimum ground contact time with the objective of maximizing the height divided by contact time score. The hands were held on the hips and participants were instructed to land from the rebound jump with the legs fully extended before flexing at the hips, knees and ankles to "soften" the landing. Jump height and ground contact time were measured by a contact mat system (Swift Performance Equipment, Queensland, Australia) (30). Three trials were allowed with one minute recoveries, and the best height divided by contact time

score was used for analysis. This score, considered to represent reactive strength, was determined with customised software (30).

Statistical analyses

To determine the relationships between agility, change-of-direction speed and the physical qualities tested, Pearson Product Moment correlations were performed. The magnitude of the correlation coefficients was described according to the following thresholds: 0 - 0.09 = trivial, 0.10 - 0.29 = small, 0.30 - 0.49 = moderate, 0.50 - 0.69 = large, 0.70 - 0.89 = very large (9). To determine the capacity of the physical qualities to predict performance, multiple regressions using the enter approach were performed for both agility and change-of-direction speed tests. To further establish the association between the physical qualities and the outcome measures, the participants were median-split to generate two sub-groups; “faster” ($n = 12$) and “slower” ($n = 12$) performers in both agility and change-of-direction speed. The statistical power was 0.90 and 0.97 and the minimum sample size was seven and nine for agility and change-of-direction speed, respectively. The groups were then compared with independent t-tests to determine if any of the physical qualities were different between the groups. The magnitude of the differences between the means was described with effect sizes with the corresponding descriptors: 0 - 0.19 = trivial, 0.20 - 0.59 = small, 0.60 - 1.19 = moderate, 1.20 - 1.99 = large, 2.00 - 3.99 = very large (9). The Statistical Package for the Social Sciences (Version 19) was used to perform all inferential statistical tests using a significance level of $p < 0.05$.

RESULTS

The mean and standard deviation results of 24 male Australian football players are shown in Table 1, and the correlations between the 10-m time, 3-RM, CMJ, DJ and the agility and change-of-direction speed measures are shown in Table 2. The correlation between the agility and change-of-direction

speed test was $r = 0.157$ ($p = 0.465$), indicating a percent common variance ($r^2 \times 100$) of 2.5%. Sprint acceleration and reactive strength produced large correlations ($p < 0.05$) with change-of-direction speed (0.510 and - 0.645 respectively). However, the relationships between the tests of physical qualities and agility were trivial to small ($p > 0.05$). The multiple regression for change-of-direction speed produced an adjusted $R^2 = 0.567$ ($p < 0.05$), whereas the prediction of agility performance from the physical tests was much weaker (adjusted $R^2 = - 0.142$, $p > 0.05$).

Tables 1 & 2 about here

The descriptive data and the comparison of the faster and slower groups are shown in Tables 3 and 4 for change-of-direction speed and agility tests, respectively. For both tests, the separation of the participants into two groups created very large differences ($p < 0.01$) between the groups. For change-of-direction speed, the faster group displayed significantly faster sprint acceleration (effect size = 1.46, $p = 0.003$) and greater reactive strength (effect size = 1.63, $p = 0.001$), compared to the slower group. For agility, the faster group demonstrated no significant differences in the physical performance tests, and an 8.2% lower reactive strength compared to the slower group, however these differences were trivial to moderate ($p > 0.05$).

Tables 3 & 4 about here

DISCUSSION

This was the first study to report relationships of multiple physical qualities to *both* change-of-direction speed and agility, involving tests with similar movement patterns. The very low commonality between the agility and change-of-direction speed tests (2.5%) indicates they represent independent skills, which is in agreement with previous research (6, 20, 24). The main difference between the tests was that the agility test involved a perceptual and decision-making element requiring a reaction to a stimulus before the following change of direction movement, whereas the change-of-direction speed test was a pre-planned activity. The dissimilarity suggests

that the influence of the cognitive component of agility is profound, and will be discussed later. Although both tests involved similar movements in relation to distance and direction, it was observed that in the agility task, participants typically approached the attacker displayed on the screen tentatively. The final forward steps appeared to be shorter and sometimes involved a split-step (2). This approach may be advantageous for a defender because once a decision is made to turn to the left or right, the athlete is in a position to turn equally as well in either direction. In contrast, during the forward path of the change-of-direction speed test, participants appeared to use a typical running gait and then performed a side-step to achieve the new running direction. This may be expected since the change-of-direction movement was pre-planned. Therefore the very low common variance between the agility and change-of-direction tests may be due to a combination of the cognitive component and different footwork/movement strategies employed during the two tasks.

The large negative correlation between performance in the drop jump and the change-of-direction speed test ($r = -0.645$, $p < 0.05$) suggests that the reactive strength of the leg extensors is important for change-of-direction speed performance. This finding is supported by previous research using a bilateral drop jump test (33) and other plyometric tests (14). The importance of reactive strength is further supported by the finding that the better change-of-direction speed group displayed significantly greater reactive strength (26.1%, $p < 0.05$) than the slower group (Table 3). The relevance of reactive strength can likely be explained by physical demands of the side-stepping technique used to change direction in the change-of-direction speed test, since the push-off involves a fast stretch-shortening cycle muscle action of the hip, knee and ankle extensors (33).

When all the tests of physical qualities were entered into a multiple regression, the combined relationship of these variables to change-of-direction speed was large ($p < 0.05$), and explained 56.7% of the variance associated with this outcome measure. This finding indicates that sprint acceleration and strength qualities are important for change-of-direction speed performance, at

least when there is a single directional change. It is possible that physical qualities contribute less to more complex change-of-direction tasks, since sprint-training gains have been found to transfer less to change-of-direction when the task had a greater number and sharper turns (34). Another factor besides physical qualities that is likely to contribute to change-of-direction performance is technique, which includes the adjustment of steps to accelerate and decelerate, body lean and foot placement for the push-off (33).

There were trivial to small relationships ($p > 0.05$) between the physical qualities and agility performance (Table 2). Further, the combined physical qualities explained only 14.2 % of the variance associated with agility performance ($p > 0.05$), indicating that the physical qualities assessed in the present study had little contribution to agility performance. This conclusion was supported by the finding that the faster agility group was no better than the slower group in any of the physical fitness tests; indeed the faster group was slightly worse ($p > 0.05$) in all of the fitness components (Table 4). These findings are consistent with Sheppard et al. (24) who reported a very large correlation between 10-m sprint performance and a change-of-direction speed test ($r = 0.738$), but the relationship was only moderate ($r = 0.333$) when sprint performance was correlated with agility.

The results of this study suggest that while physical qualities contribute to change-of-direction speed, they have minimal influence on agility performance. This may be partly explained by the contribution of the cognitive component of agility, where the performer must react to the attacker's movements before executing a change-of direction and short sprint. Using high-speed video to isolate the decision-making time, large to very large correlations with total agility time ($p < 0.05$) have been reported in Australian football (38) and basketball players (20). Further, decision-making time in an agility test has been shown to be less ($p < 0.05$) in higher-standard compared to lower-standard athletes in rugby league (22) and netball (4). Higher-standard players have also been shown to be less susceptible to fake passes or movements in Australian football (7) and rugby union (10). It

is thought that the superior speed and/or accuracy of decision-making during defensive agility found in higher-standard soccer players emanates from more effective visual search strategies that allow them to extract the most relevant information such as postural cues from their opponents actions (18, 19, 29). While speculative, it is possible that the trivial to moderately inferior physical qualities of the faster agility group may have occurred because individuals with less “athleticism” may compensate by relying on faster and more accurate decision-making.

Another reason for the weak association between the physical qualities and agility performance may be related to the technique used to change direction. As noted earlier, it was observed that players tended to approach the screen that displayed the attacker with caution and with small steps, which may be an effective strategy to prepare for the uncertainty of the stimulus and requirement to turn to either side. These movements may not have allowed the participants to use their speed and strength qualities to generate fast movements. In contrast, the change-of-direction speed test involved faster pre-planned movements, and therefore speed and leg muscle function could be expected to be more influential to performance. It is acknowledged that the defensive movement-strategy used in the agility test may be different to the movement approach used for attacking in many sports. It is possible that once a player in possession of the ball decides which direction to turn, he or she may perform a more aggressive side-stepping movement which could exploit the strength qualities of the leg muscles. Therefore the results of this study may not apply to agility when attacking. Given that the movements discussed were subjectively observed, future research should address the techniques used and the potential contributions from physical qualities to both defensive and offensive agility.

PRACTICAL APPLICATIONS

Sprint acceleration and reactive strength were strongly associated with performance in a single change-of-direction test, suggesting that these physical qualities may be important for change-of-direction speed. Although correlations do not indicate causality, the findings suggest that training

designed to improve acceleration and reactive strength may transfer to enhanced change-of-direction speed performance. In sports that contain skills requiring change-of-direction speed such as running between bases in baseball or running between wickets in cricket, physical conditioning to develop the relevant fitness qualities is recommended. This advice is supported by previous research indicating that plyometric training can enhance various change-of-direction speed performances (15, 26).

There was very little association between any of the physical qualities and agility performance, and it was suggested that agility was more influenced by important contributions from cognitive processes and the use of a movement strategy that diminished the exploitation of physical qualities. Therefore when training for defensive agility with a similar movement strategy used in this study, physical conditioning is unlikely to be an effective approach to improving performance. Although not directly studied in this research, training to develop the speed and accuracy of decision-making in agility activities is recommended. One example is small-sided games designed to overload agility, which have been shown to be effective for Australian football players (36).

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Table 1. Mean $\pm$ standard deviation descriptive results for all tests.

	Mean $\pm$ SD
Change-of-direction speed (s)	1.77 $\pm$ 0.07
Agility (s)	2.66 $\pm$ 0.09
10 m time (s)	1.92 $\pm$ 0.05
Relative strength (bodyweight)	1.94 $\pm$ 0.18
Relative power (W.kg ⁻¹)	55.2 $\pm$ 6.88
Reactive strength (cm.s ⁻¹)	176.3 $\pm$ 32.1

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Table 2. Relationships between change-of-direction speed, agility and the physical qualities.

	COD Speed Correlation coefficient	p value	Common Variance	Correlation magnitude descriptor	Agility Correlation coefficient	p value	Common Variance	Correlation magnitude descriptor
10-m time	0.510	0.011	26	Large	-0.003	0.989	0.001	Trivial
Relative Strength	-0.204	0.340	4.2	Moderate	0.119	0.579	1.4	Small
Relative Power	-0.209	0.326	4.4	Small	0.123	0.568	1.5	Small
Reactive Strength	-0.645	0.001	41.6	Large	-0.101	0.640	1.0	Small

Table 3. Comparison of faster and slower groups for change-of-direction speed.

	Slow	Fast	Percent difference from slow	P Value	Effect Size and descriptor
Body mass (kg)	78.8 ± 11.8	78.1 ± 6.1	-0.9	0.865	0.07 (trivial)
Height (cm)	180.2 ± 8.5	180.6 ± 6.1	0.2	0.891	0.05 (trivial)
Change-of-direction speed (s)	1.83 ± 0.03	1.72 ± 0.04	-6.0	<0.001	3.11 (very large)
Agility (s)	2.67 ± 0.10	2.65 ± 0.08	-0.7	0.714	0.22 (small)
10-m time (s)	1.96 ± 0.05	1.90 ± 0.03	-3.1	0.003	1.46 (large)
Relative Strength (bodyweight)	1.88 ± 0.19	2.00 ± 0.15	6.4	0.116	0.68 (moderate)
Relative Power (W.kg ⁻¹)	53.1 ± 6.01	57.2 ± 7.30	7.3	0.144	0.61 (moderate)
Reactive Strength (cm.s ⁻¹)	156.0 ± 20.5	196.7 ± 28.8	26.1	0.001	1.63 (large)

Table 4. Comparison of faster and slower groups for agility.

	Slow	Fast	Percent difference from slow	P value	Effect Size and descriptor
Body mass (kg)	79.4 ± 8.3	77.6 ± 10.4	-2.3	0.645	0.19 (trivial)
Height (cm)	178.7 ± 6.9	182.1 ± 7.4	1.9	0.255	0.48 (small)
Agility (s)	2.72 ± 0.06	2.60 ± 0.06	-4.4	<0.001	2.0 (very large)
Change-of-direction speed (s)	1.76 ± 0.06	1.78 ± 0.07	1.1	0.378	0.31 (small)
10-m time (s)	1.91 ± 0.05	1.94 ± 0.05	1.6	0.256	0.60 (moderate)
Relative Strength (bodyweight)	1.95 ± 0.21	1.94 ± 0.17	-0.5	0.932	0.05 (trivial)
Relative power (W.kg ⁻¹)	57.22 ± 7.40	53.13 ± 5.91	-7.2	0.149	0.61 (moderate)
Reactive strength (cm.s ⁻¹)	183.8 ± 34.8	168.8 ± 28.6	-8.2	0.261	0.47 (small)