Agility and Change-of-Direction Speed are Independent Skills: Implications for Training for Agility in Invasion Sports

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ABSTRACT

This review explores the differences between agility in invasion sports (defined as including reactive decision-making) and change-of-direction speed (CODS), and highlights the implications for training. Correlations between agility tests and CODS tests indicate that they represent independent skills. Agility tests discriminate higher- from lower-standard athletes better than CODS tests, indicating that the cognitive element of agility is important to performance. Training studies have shown that the development of strength qualities can transfer to gains in CODS, but this has never been shown for agility. There is some evidence that the importance of physical qualities is greater for CODS than for agility. It was concluded that the reactive element should be included in agility training, testing and research. While there appears to be no research evidence for the benefits of strength and power training, there is some support for the use of small-sided games for improving agility.

Key words: Agility Tests, Decision Making, Perceptions, Reactive Strength, Small-Sided Games, Sprint Training

INTRODUCTION

Agility is important for combat sports such as boxing, court sports such as tennis and team sports such as volleyball or baseball. However this review will be limited to a category of sports described as "invasion" or "territorial" sports, which have common characteristics. These sports involve opposing teams attempting to invade their opponent's territory to enhance scoring opportunities [1]. Gaining and maintaining possession of the ball is crucial for attack, and defending is important to prevent the opposition from scoring [1]. Invasion sports include all football codes, basketball, netball, European handball, lacrosse and field-hockey. Although sports played in an aquatic environment such as water polo or sports played on ice such as ice-hockey are also examples of invasion sports, only agility relating

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to land-based sports involving locomotion by walking or running will be discussed in this review. In invasion sports, agility skill is beneficial to attackers to evade their opponent's pressure or tackles, and for defenders to reduce space on the field or court to limit attacking movements, or potentially achieve a turnover.

Unfortunately there is no universally accepted definition of agility [2]. While earlier definitions referred exclusively to a change-of-direction element [3, 4], agility has more recently been defined as "a rapid whole-body movement with change of velocity or direction in response to a stimulus" [2], and this definition has been adopted by several authors [5-8]. A change of direction task that is pre-planned has been described as "change-of-direction" speed [2], and this phrase has become increasingly common to distinguish this closed skill from agility involving a reaction [9-12]. Apart from the change of direction, it is important to acknowledge two other elements in the above agility definition. First, "change in velocity" indicates that an agility game-scenario could include deceleration only, where an attacking player decides to suddenly reduce speed to create space between him or herself and the opponent. The second important element of this definition is that a change in velocity or direction is in response to an external stimulus provided by an opponent's actions. This recognises that players do not randomly change velocity or direction; rather they typically do so in response to external stimuli to either evade a defender or place pressure on an attacker. There are also situations in many sports where players need to change velocity or direction to get into the desired position on the field or court, but if they are not performed at maximum effort, they are not usually considered as agility manoeuvres [13]. Therefore, the stimulus to change velocity or direction is typically the actions of opponents. However, one rather unique invasion-sport example where a change-of-direction movement is pre-planned rather than a response to a stimulus is in American football, where an eligible receiver sprints forward and attempts to cut laterally after a pre-determined distance. There are many situations in invasion sports that involve set-plays, such as a free kick just outside the penalty box in soccer. In these cases, the pre-planned team strategy may be to advance the ball to a particular location, but typically the player in possession of the ball is still required to perform unpredictable evasive agility manoeuvres in response to a defender's actions. For example, if a basketball attacker notices that a defender is moving to the left to block forward progression, the player with the ball might cut to the right. Similarly, a defender will watch the attacker's movements carefully in order to quickly react to any evasive action.

In 2002, a model was published [14] indicating that agility was comprised of two main components; perceptual and decision-making factors and change-of-direction speed (CODS). CODS was in-turn determined by technical factors such as stride adjustments, physical elements such as straight sprinting speed and leg muscle qualities, which include strength, power and reactive strength. CODS activities are closed skills that involve pre-planned movements. An example of a CODS activity in sport is base-running in baseball or softball, where the batter runs a pre-determined distance before changing direction at an angle governed by the diamond. It is important to recognise that apart from the American football example mentioned above, CODS is very rare in invasion sports [5]. For the purposes of this review, the term "agility" will always refer to changes of velocity or direction in response to a stimulus provided by an opposition player's actions. The phrase "reactive agility" has previously been used in the literature [11,15-17] to acknowledge that agility is reactive in nature, but this will not be used here because, according to the definition of agility, the word "reactive" is redundant. The purpose of this review is to explore the factors that determine CODS and agility in invasion sports and provide practical applications for training and testing athletes to improve sports performance. While the review will provide insights into the role of strength and power training as well as cognitive factors for CODS and agility, it is beyond the scope of the review to discuss the technical factors relating to agility.

DIFFERENCE BETWEEN AGILITY AND CODS AND THE IMPORTANCE OF EACH

The different definitions for CODS and agility are not just semantic, as there is evidence to support the distinction. There is limited research that has used tests of agility in invasion sports, and even less that has compared *both* agility and CODS tests with the same athletes. To the authors knowledge, there are only five studies that have assessed athletes with an agility test as well as a comparable planned CODS test involving the same movement pattern [6,15,16,18,19]. Two of the studies were conducted with male Australian Rules footballers [15,16], one with rugby league [19], one with basketball [6] and one with female netballers [18]. To provide the necessary stimulus when assessing agility, three of these studies used a video-based display of an attacker [15, 18, 19] and the others used a live tester who performed side-steps as if evading a defender [6,16]. In all of these studies, the correlation between the agility and CODS test yielded Pearson coefficient's of r=0.68 [15], r=0.321 [16], r=0.434 [6], r=0.70 [18], and a Spearman correlation of -0.08 [19]. The common variance (r^2 x 100) from the first four studies varied from 10-49% (mean=29%), and since this value is clearly below 50%, indicates that agility and CODS are independent skills [20]. In agreement with this conclusion, the Spearman's correlation was very low [19]. Therefore, since the main difference between the agility and CODS tests in these studies was the cognitive component involving a reaction to an "opponent", this appears to dramatically change the character of the agility tests, a concept that will be discussed in more detail later.

Having established that agility and CODS are specific skills, the critical question that follows is which of these skills is more important for performance? This issue can be addressed by comparing higher- and lower-standard groups of athletes. If a superior-skilled group is better on a particular test, the quality assessed by that test can be said to be important for performance in the sport [21]. Conversely, if a higher-level group is not better on a test, the quality assessed by that test would appear to have little relevance to superior sports performance. Using such a research-design, several studies have shown the higher-skilled group to be superior ($p<0.05$) in an agility test but *not* ($p>0.05$) in a CODS test in Australian football [15, 16, 22] and rugby league [11, 19]. These results clearly indicate that agility is more related to performance in these invasion sports than CODS tests, and provides evidence for the importance of the perceptual and decision-making element of agility.

PERCEPTUAL AND DECISION-MAKING IN AGILITY

Whether attacking or defending, agility skill requires the ability to perceive relevant information about opponent's movements and react quickly and accurately. Some agility tests have been able to isolate the decision-making time from the total agility action. This is typically done by using high-speed video to determine the time from the stimulus (attacker's initial change of direction movement) to the tested athlete's first response [6, 11, 15, 17, 18, 19, 23]. In one study [17], the decision time only represented 3.6% of the total agility time, but the correlation between decision time and total agility time was r=0.77. The correlation coefficient between the responding movement time and total agility time was r=0.59, indicating that the decision-making time was even more influential to agility performance than the movement that followed. More recently, Scanlon et al. [6] reported that decision time was significantly correlated (r=0.577, $p<0.05$) with an agility test in basketball players, and concluded that cognitive qualities are important to develop agility in basketball.

Some studies that have reported decision-making time have also compared a higher- and lower-standard group of athletes. The higher-standard group was typically found to produce faster decisions ($p<0.05$) than the lower-standard group in netball [18] and rugby league [24, 25], although the difference between the groups is not always statistically significant [11,15]. One study measured decision-making time only by requiring participants to react to video footage of an attacker changing direction by pressing a switch in the hand to indicate as quickly and accurately as possible whether the movement was to the left or right [26]. It was found that professional Australian Rules football players were slightly faster ($p>0.05$, effect size=0.26) than elite junior players, but were significantly more accurate ($p=0.034$, effect size=0.60) in their decisions, indicating better overall decision-making skill. Further, it has been found that higher-standard players are less susceptible to deceptive actions of attackers, such as a fake pass in rugby union [27] and a fake side-step in Australian football [28].

A study with rugby league [29] required a group of sub-elite players to perform six sessions of agility training by viewing and reacting to 10 video-clips of an attacker changing direction in each session. After the brief training period, the training group reduced their decision time from 340 to 40 ms ($p<0.05$), whereas a control group from the same squad showed no meaningful change ($p>0.05$). In addition, a recent study on elite junior Australian football players [8] showed that decision-making time in an agility test improved by 31% ($p<0.001$) following 11 sessions of small-sided games designed to overload agility skill. Accordingly, these studies indicate that cognitive skill relating to agility is highly trainable, even in experienced athletes.

Research on cognitive skill in soccer has focussed on the defender observing video-footage of an attacker dribbling, or a goalkeeper reacting to a penalty kick. For example, Williams and Davids [30] compared elite and recreational soccer players and found the more skilled players were faster and more accurate ($p<0.05$) in anticipating the pass direction in a one-on-one situation. Based on eye-tracking analysis, the better players were shown to fixate longer on the hip region of the attacker, indicating that this provided an important cue about the pass direction. A later study [31] showed that elite junior soccer players were 6% more accurate ($p>0.05$) in anticipating pass direction than a sub-elite group in a one-on-one scenario, but 12% more accurate ($p<0.05$) in a 11 v 11 situation, indicating the anticipatory skill was more pronounced in the elite players when the task was complex with more possible passing options. Furthermore, studies of goalkeepers viewing a penalty shot have shown that more experienced or higher-standard players are superior to lower-standard players in predicting the correct direction of the kick [32-34]. Results from one of these studies showed that the more successful goalkeepers employed a different visual search strategy [33], indicating that the ability to extract and interpret relevant visual information is important for fast and accurate responses.

The above soccer research shows that better performers can identify important postural cues which serve as the visual stimulus to make their decisions about opponent's actions. It has also been shown that elite soccer players were *not* superior ($p>0.05$) to inexperienced players in a reaction time test using a flashing circle as a stimulus [30]. This finding highlights the point that the cognitive skill required to react quickly and accurately is based on a sport-specific stimulus rather than a generic one. This conclusion is supported by two studies indicating that while higher-standard Australian football players were better ($p<0.05$) than their lower-standard counterparts when reacting to a video-display of an attacker changing direction, they were *not* better ($p>0.05$) reacting to a generic stimulus of a flashing arrow [22] or light [15].

USE OF STRENGTH AND CONDITIONING TO TRAIN CODS AND AGILITY

Determining the relative importance of a trainable quality to either CODS or agility is necessary for a coach to know how much training time and effort to devote to development of that quality. The following section will discuss the importance of strength qualities and sprinting speed for the development of CODS and agility. There is a plethora of research that has reported the correlations between physical qualities and CODS [9,10,14,35,36], and while a strong relationship between two qualities indicates they possess common characteristics, it does not prove a cause-and-effect relationship. Ultimately, the issue that coaches are interested in is the effectiveness of a particular training approach for enhancing performance, and therefore more convincing evidence comes from training studies, which will be discussed below.

CODS RESEARCH

When evaluating the evidence relating to the importance of physical factors for CODS, a major difficulty is the huge variety of CODS tests used to assess this quality. This is expected because different invasion sports require a range of movement patterns and footwork. For example, some sports involve lateral shuffling such as basketball, while other sports such as rugby union or league commonly require side-stepping or cutting movements. One element that is common to all of these tests is that the athlete is required to complete a pre-planned course defined by obstacles such as cones in the shortest possible time, usually assessed with an electronic timing system.

CODS tests also vary greatly due to differences in the angle of directional change and the number of changes of direction, which may be as little as one [16] to as many as eleven [37]. One study that compared six different CODS tests used for assessing soccer players reported low to moderate inter-correlations ranging from -0.028 to 0.554, indicating a common variance of no more than 31% [38]. The authors concluded that the CODS tests were all specific due to their complexity and the different agility movement patterns. Therefore, there is no "gold-standard" generic CODS test that can be used for all invasion sports.

STRENGTH TRAINING

A study involving eight weeks of jump squat training with a heavy load (80% 1 repetition maximum - RM) produced a 10.2 % gain in 1RM squat strength ($p<0.05$), and this was accompanied by a 2.4% ($p<0.05$) improvement in T-test CODS [39]. In contrast, when three sets of three repetitions of heavy squats with 90 % 1 RM were performed five times per week for 3 weeks in addition to CODS training by professional soccer players, no benefits in a CODS test were realized [40]. The authors concluded that the added strength training did not offer a greater advantage over change-of-direction and coordination training. One explanation for the lack of benefit to CODS in this study could be the short three-week training period, which may have resulted in modest strength gains (not reported). A recent study [41] investigated the effects of two years of strength training with parallel squats in addition to normal soccer training in elite-junior soccer players. The supplementary strength training produced large gains in leg strength and this transferred to significant ($p<0.05$) improvements in a CODS test. However, two years of strength training in developing athletes is likely to result in meaningful gains in *any* physical quality utilising the leg muscles [42], and therefore the relevance of general strength training for enhancing CODS remains unclear.

POWER AND REACTIVE STRENGTH TRAINING

Jump squat training for eight weeks with an additional load of 30% of 1 RM has been found to produce a 10% greater peak power ($p<0.05$) in a jump squat with that load [39] and a 1.7% improvement ($p<0.05$) in the T-test of CODS, indicating that power development can transfer to enhanced CODS. When a drop jump (DJ) is performed with the intention of maximising rebound height and minimising ground contact time, it imposes high eccentric loads and can be described as a test of reactive strength [43]. Since the correlation between this type of DJ and a countermovement jump (CMJ) was only $r=0.37$, representing only 14% common variance [44], reactive strength is considered an independent form of power [43]. Reactive strength may be expected to correlate highly with CODS because changing direction (such as during a side-step) involves a relatively small knee flexion with a short ground contact time, and high eccentric loads during the leg extensor muscle stretch-shortening cycle [14]. This idea was supported by an investigation that showed that pure concentric leg power produced relatively low correlations with CODS, but a DJ test of reactive strength correlated more highly [14]. Since plyometric exercise can specifically target reactive strength, it is useful to determine the potential benefits of training with this exercise modality on CODS.

Two studies [45,46] have demonstrated that 6 weeks of plyometric training was effective for improving CODS. For example, training with the drop jump exercise induced significant improvements ($p<0.05$) in the 505 CODS test [46], and a range of multi-directional plyometric exercises produced improvements ($p<0.05$) in both the T-test and Illinois CODS tests [45]. Another study [37] required a group of 12 physical education students to perform a training program combining half squats (4 sets of 6 repetitions) with bilateral and unilateral plyometric exercises for eight weeks. In contrast to the previous two studies, while the training induced a significant gain ($p<0.05$) in both strength (1 RM squat) and power (CMJ), no significant improvement ($p>0.05$) in a CODS test involving three sharp changes of direction was observed. It was concluded that the CODS task was relatively complex, and may have been more influenced by motor control factors than strength qualities.

SPRINT TRAINING

Although there is a large body of work correlating straight sprint performance over various distances with CODS, there are few training studies relating to the possible benefits of straight sprint training to CODS or agility. In one of those, when linear sprint training was performed over six weeks, significant mean improvements in sprint time ($p<0.05$) of 2.9% were reported [47]. This was accompanied by an improvement of 2.3% ($p<0.05$) in a test that involved two slight changes of direction. However, when the COD tests became more complex by increasing the angle and number of changes of direction, the transfer was diminished. Indeed, in the most complex test involving five relatively sharp changes of direction, the straight speed gains had no transfer at all [47]. These findings indicate that the benefit of straight sprinting speed to CODS decreases as the CODS task becomes more complex. Therefore, since CODS activities involve decelerations, re-accelerations and constant adjustments of steps and body posture, the potential to improve CODS speed by linear sprint training is limited [47].

AGILITY RESEARCH

The above discussion is based on considerable research using various CODS tests to measure performance. Unfortunately, evidence for the importance of physical qualities for agility development is extremely rare, with some correlational research [6,11,16]. These studies reported correlations between sprint tests with *both* COD and agility tests, and are shown in Table 1. These data indicate that while sprint speed and CODS can share some common characteristics (19-55% common variance), the shared variance drops considerably for agility (11-17%). This is likely explained by the inclusion of the cognitive component of agility, which has been found to possess 59% common variance with agility performance [17]. The relatively low correlations between speed and agility suggest sprint training would be unlikely to transfer well to agility performance. Unfortunately, there is minimal research indicating the relationships between strength, power and reactive strength to agility. One study [48] correlated vertical, forward and lateral jump tests with an agility task requiring Australian football players to pursue a video-projected attacker from a rear view. The negative correlations ranged between -0.12 to -0.28 ($p>0.05$), and the authors suggested that agility performance was more likely to be influenced by cognitive rather than strength factors. Likewise, there is no research evidence for the specific effects of *training* sprint, strength, power and reactive strength on agility performance.

Table 1. Correlations between 10 m sprint performance with CODS and agility. the common variance (r^2 x 100) is in brackets

Authors	**CODS**		**Agility**
Gabbett et al [11]	"505" test	0.57 (32)	0.41 (17)
	"L Run" test	0.64 (41)	
Sheppard et al [16]	0.74 (55)		0.33 (11)
Scanlon et al [6]	0.439 (19)		0.406 (16)

SMALL-SIDED GAMES

Small-sided games (SSG) have become a popular training method for invasion sports because they have the potential to develop multiple fitness components together with sport-specific skills and tactics [49]. Two studies have specifically examined the value of SSG in improving CODS and agility performance. One of these compared six weeks of training with either CODS drills or soccer SSG in untrained men and women [50]. The CODS training was effective (5.9%) for improving performance on the CODS T-test, whereas the SSG had little effect (2.1%, $p>0.05$). Another recent study on elite junior Australian football players also compared CODS training with SSG designed to overload agility skill [8]. However, this study also assessed players on both a CODS test ("Planned Australian Football League agility test") *and* a video-based agility test, which was previously validated for Australian football [22]. After 11 sessions of training over a seven-week period, the CODS group experienced no significant changes ($p>0.05$) in either CODS or agility. The SSG group also achieved a trivial change in CODS ($p>0.05$), but agility performance improved by approximately 4% ($P=0.008$). This gain was accompanied by a 31% improvement ($p<0.001$) in the time taken to react to the attacker's change of direction movement (decision time), and a 1% change ($p>0.05$) in movement time. Therefore, these results indicate that SSG designed to encourage agility skill may provide a powerful agility training stimulus due to improvements in decision-making speed.

A case study of four rugby union players [51] involved testing agility before and after 18 training sessions which included SSG and other reactive drills. Each player demonstrated some improvement in agility performance, with a mean gain of 3%. Although other forms of training were performed such as speed and strength training which may have influenced agility performance, the authors recommended the use of open-skill training modalities such as SSG and reactive drills.

CONCLUSION

Invasion sports require offensive and defensive agility, but rarely CODS. Agility and CODS are different tasks due to the unpredictability and cognitive elements of agility, which are absent in CODS tasks. Evidence exists that agility tests are better able to discriminate higher-standard from lower-standard athletes than CODS tests, and therefore training and assessment of athletes should focus on agility. However, the majority of past research that has recommended physical training and testing, has been restricted to CODS tasks, and therefore may have limited application to agility in invasion sports. Accordingly, coaches and sport scientists are advised to develop training programs and tests that target the multi-dimensional nature of agility as required in sport, which includes a reactive element. In relation to testing, the challenge is to develop reliable tests that use sport-specific agility scenarios that capture the complexity of movement and decision-making aspects of on-field agility. This requires the inclusion of a ball or other sport-specific equipment, a variety of views (not just front-on), multiple players, different movements and some deceptive actions. Current agility tests have been restricted to the defensive role, and it is not known whether offensive agility is unique.

In relation to training, there is evidence that a carefully designed strength and conditioning program can enhance CODS, but there is no evidence that such programs are also beneficial for agility. Plyometric training using multi-directional exercises can potentially be specific to the change-of-direction movements used in agility tasks, but it is still not known whether it transfers to agility performance. It is possible that the importance of training various strength qualities for agility is diminished due to the relative importance of the cognitive component of agility. Accordingly, it could be speculated that athletes are not able to express their athleticism on the field or court because the decision-making requirement of agility dominates, but this needs to be examined further.

There is good evidence that the perceptual and decision-making element is important to agility performance and as such, training should be prescribed to include this component. One option is to use one-on-one activities where one player is designated an attacker, and the other player takes on the defensive role. The attacker should be encouraged to use evasive skill (sometimes including deception), while the defender should try to pick up cues from the attacker's movements to react as quickly and accurately as possible. Another training method that has some research support [8] is the use of sport-specific SSG, and coaches are encouraged to be creative with game design (e.g., field dimensions, rules, number of players) to maximise agility-skill demands. If the games can duplicate the skills of competition and also overload agility, change-of-direction technique and cognitive demands should be enhanced. Since the perceptual and decision-making component of agility is highly trainable [8,29], another option is to perform video-based cognitive training involving decision-making alone, without the subsequent sprint. Such a program has been shown to be effective for developing anticipation skill in softball fielders [52]. A potential advantage of this is the possibility of enhancing agility without applying a physical load, which could be especially valuable for injured players who are not able to participate in intense physical activity.

Based on the discussion above, a new model of agility of invasion sports is proposed (Figure 1). This is intended to show the main factors that contribute to agility performance. A significant difference between this model and a previously reported model [14] is that the proposed version excludes CODS, which is not a component of agility, but a different skill. It is important to acknowledge that the relative importance or contribution to performance from these factors is variable, with some exerting a large influence (e.g., cognitive factors), some having a minor influence (e.g., straight speed), and many others exerting an unknown influence. Therefore, to prescribe a holistic training program for the development of agility, the coach can use the model to check that all the contributing elements are targeted. However, future research is needed to provide evidence to coaches about the most important factors and the training methods that are most effective for enhancing agility performance.

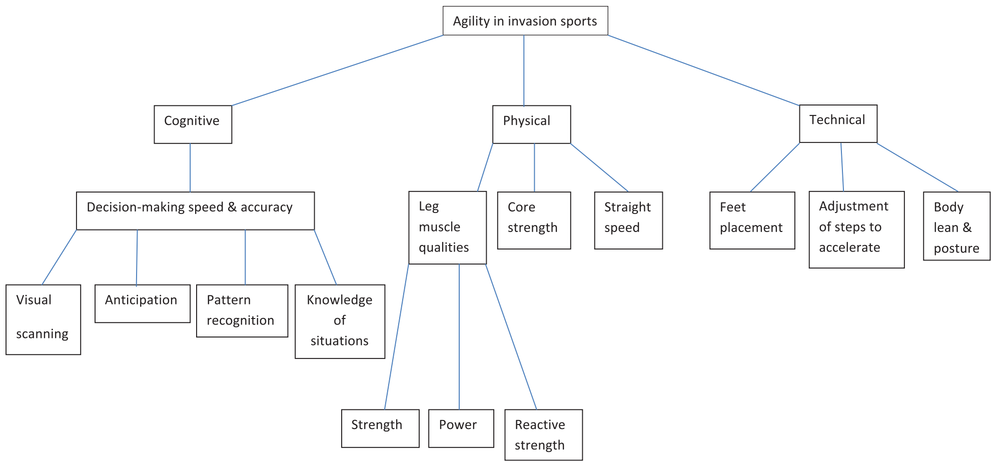

Figure 1. Model of main factors that determine agility in invasion sports, modified from Young et al. [14]

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