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Agility in Invasion Sports: Position Stand of the IUSCA

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ABSTRACT

Agility is a complex skill that is influenced by several physical, technical and cognitive factors. In this position stand, we discuss agility as it relates to invasion sports such as the many football codes. An important concept when conceptualising agility is understanding how it is applied on the field or court. Agility is particularly important in contests between attackers and defenders. For example, an attacker needs to create space or separation from defenders, in order to evade or to maintain possession of the ball. Conversely, defenders may require agility to reduce time and space in relation to the attacker, thereby applying pressure with the intention of achieving a turnover of possession. The movements performed in an agility scenario are diverse, and may involve an isolated deceleration, or a range of actions to produce a lateral displacement of the body at various angles and speeds. To create novel insights into agility, the interactions between predators and prey are explored in the animal world and reveal that successful pursuit (like a defender) or escape (like an attacker) is influenced by the ability to accelerate and attain high speeds, decelerate, and manoeuvre with control at optimum speeds, as well as expressing perceptual and cognitive skills. A plethora of sports literature claiming to discuss agility actually refers to pre-planned change-of-direction (COD) movements, known as COD ability. There are several differences between agility and COD ability, which should be considered when testing and prescribing agility activities. The characteristics of different agility techniques are presented and discussed with consideration to performance and the risk of injury such as anterior cruciate ligament (ACL) rupture, with the aim of creating multiple movement solutions for the athlete. Due to the diversity of agility actions performed in invasion sports, physical development should include tissue strengthening as well as fast and slow stretch-shortening cycle exercises to cater for different speeds and angles of agility movements. The speed and accuracy of decision-making in agility contests (cognitive component) are determined by the athlete's ability to anticipate opponent's actions, visually scan the environment, recognise patterns of play, and predict movement strategies based on knowledge of situations. One versus one contests, small-sided games, and video perceptual training can enhance the cognitive component of agility. Finally, there is no single coaching strategy or method that should be used to develop agility. Instead, the appropriate methodology must fit the individual needs of athletes, and therefore a mixed multicomponent approach is needed as part of an agility framework. Training examples to develop agility are presented throughout this position statement.

INTRODUCTION

Invasion sports are team games in which the purpose is to invade the opponents' territory while trying to score points and minimise the opposition's scoring. These include some of the most popular spectator sports in the world such as all codes of football, field and ice hockey, and court sports such as basketball, netball, and handball. These "multidirectional sports" require a range of technical and tactical skills, as well as the development of various physical qualities for successful performance, with the ability to move effectively, a component that ties these components together. A parameter closely associated with

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effective movement is agility, and this is generally considered to be a key component of performance. An attacking player able to evade defenders and create scoring opportunities or a defender making a last-ditch movement to intercept a ball can be some of the most exciting aspects of invasion sports, and so developing agility becomes an essential component of any performance development program.

Before a coach can develop a training program, it is important to understand the demands of the sport and how any parameter relates to the tasks and actions an athlete will need to undertake. Therefore, it is useful to establish what agility is in the context of invasion sports. In the strength and conditioning (S&C) literature, a popular definition of agility is "a rapid whole-body movement with change of velocity or direction in response to a stimulus'' [1]. This definition acknowledges that agility can include a whole-body change of direction (COD) through various angles, as well as a deceleration to stop suddenly in response to a stimulus. The athlete must perceive a stimulus, react, and then perform a movement in response, a process that requires both perceptual skills, technical, and physical qualities. However, this definition may be considered somewhat narrow and may not fully reflect agility movement in sport, which can require players to make complex movement decisions based on a changing environment with consideration to their teammates and opponents' actions.

There are many scenarios in games where agility occurs. For example, when a team loses possession and must transition from attack to defence, where players may have to quickly change their running direction and/or movement type. Another example is an inaccurate pass from a teammate, requiring a player to suddenly react and change their running pattern and/or direction to receive the ball. While these are examples of quite common scenarios, arguably more critical moments in invasion sports occur in direct contests. A contest is a situation where possession is disputed or opposed. For example, an attacker in possession is moving forward and gets into close proximity to at least one defender. The attacker must assess the situation and make a decision whether to pass the ball or take on a defender and attempt to evade in order to progress down the field or court. If the attacker decides to evade, they might use a deceptive action such as a fake pass to distract the opponents and progress the forward advance (Figure 1 and Table 1).

Although attacking and defending agility have some common elements, research has shown that being good at attacking agility does not guarantee being good at defensive agility, and vice versa [2,3]. It was suggested that the statistical independence of attacking and defending agility in Australian football was likely related to differences in footwork and perceptual information [2,4]. This implies that coaches should evaluate both in their athletes, and train them accordingly. However, research concerning the important characteristics of attacking and defending agility in match play is currently lacking.

Figure 1. The actions of both attacking and defending rugby players provide a stimulus for the opponent to react to as quickly and accurately as possible. (David Ribeiro / Alamy Stock Photo)

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Table 1. Goals of agility in a contest. The technique used, movement speed and change of direction angle is dependent on the situation.

Attacking Agility	Defending Agility
• Movement to create time and space (separation) from opponents to maintain possession • May use a deceptive action such as a fake step or fake pass	• Movement to reduce time and space from the attacker to force a turnover of possession • May attempt to block attacker's progress, tackle or corral them to make them ineffective

Agility manoeuvres will ultimately be task specific and can vary hugely with the respect to multiple factors such as the approach speed, the entry and exit angles at which athletes travel, the movement patterns they deploy, their footwork patterns, deceptive patterns etc. [4]. In a task such as evading an opponent, some athletes may use a deceptive action in an attempt to add uncertainty to the defender, and this may involve a hard deceleration with or without a change in direction [4]. Where space permits, an attacking player with outstanding linear speed capacities may evade defenders simply by sprinting in a straight line to escape pursuers. Ultimately, the strategy used by both defenders and attackers is influenced by the interaction of the task at hand, the environmental factors pertaining at that instance and the capacities of all athletes [5]. Players make decisions, all of which will be shaped by their perceptions as they relate to the above interactions. As a result, there are unlikely to be universal strategies used by all athletes at all times, instead these will be shaped to the conditions that occur at any instance.

Importantly, whilst there will be a variance in strategies deployed, key capacities which underpin these strategies can be improved. Where athletes can improve their attacking agility through training, they have more movement solutions at their disposal. Likewise, training to improve defensive agility should enable players to equally increase their range of options, for example by applying greater pressure on attackers and being in a more optimum position to perform a tackle, where appropriate. Agility is a complex skill, especially for "360-degree sports" such as soccer, Australian, and Gaelic football where the ball movement and players can travel in any direction. Consequently, designing an effective training program to enhance agility performance in sport is complex and challenging.

A deterministic model of agility suggested that performance is determined by three main components; cognitive, physical, and technical, which are in turn influenced by many other factors[6]. Importantly, the relative contribution of these is likely to vary depending upon the previous interaction of task environment and athlete [5]. A full understanding of agility will only be forthcoming through referring to multiple disciplines, including motor learning, skill acquisition, physiology, and biomechanics, together with an understanding of the sport itself, all of which further highlights the complexity of agility.

Therefore, the purpose of this position stand is to review and discuss the many determinants of agility performance and provide evidence-based guidelines for training agility to enhance sports performance. It is hoped that this will inform training practice and stimulate further research. We have chosen to focus on invasion sports because of the common element of attacking and defending contests where agility is crucial. Further, the vast majority of research has been conducted in invasion sports such as the various football codes. Applications to other sports, such as net sports (e.g. volleyball, tennis, badminton), which also require agility, will need to be made with caution. Before examining agility in invasion sports in more detail, it can be useful to explore what can be learned by behavioural research in the animal kingdom, as information drawn from such fields can help people to reconsider any preconceived ideas of agility.

WHAT CAN PREDATOR-PREY INTERACTIONS IN ANIMALS TELL US ABOUT AGILITY IN SPORT?

In nature, predatorial animals hunt for prey to obtain food. Therefore, both predator and prey need movement skills (speed and agility) to improve their chances of surviving. In all invasion sports, defenders are permitted to approach the player in possession (attacker) and provide pressure within the rules of the game. Therefore, the defender can be viewed as the predator who seeks to pursue a player in possession of the ball to achieve a turnover. Conversely, the player in possession (attacker) may be considered the prey who may need to quickly evade to maintain possession. While wild animals cannot be compared to humans with regard to agility technique, exploration of the predator and prey movement strategies and interactions in their

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natural environmental habitats may provide useful insights for agility development.

A study of cheetahs hunting in the wild showed that in response to prey they take many sharp turns, while running at self-regulated sub-maximal speeds, thereby improving their ability to turn and successfully capture prey [7]. The cheetah will significantly decelerate prior to turning to facilitate a sharper turn. Furthermore, whilst cheetahs have been reported to have some of the highest stride-to-stride acceleration values, their deceleration values are even higher, enabling them to make significant speed reductions in just one stride [7]. Such high deceleration capacity, alongside their acceleration and top speed capacities, provide cheetahs with an amazing variability of movement options to select from, thereby increasing their likelihood of out manoeuvring the prey for capture. Accordingly, for team invasion sports developing a well-rounded high-intensity locomotor profile may help to navigate the evolutionary agility demands of invasion sports [8].

Using a mathematical modelling approach, Wheatley et al. [9] showed that there is a speed-accuracy trade-off, whereby animals running faster can result in more movement errors such as the misplacement of the feet. It was suggested that individual animals that run faster need greater coordination to avoid mistakes. Applying these findings to invasion sports, agility should not necessarily be seen as moving or changing direction at maximum speed. Instead, it is about optimal speed that improves the likelihood of movement accuracy and task success[5]. In fact, analysis of professional Australian football matches showed that about 80% of agility events occur at walking to striding speeds [4]. It is often desirable to make a measured response rather than charging at the opponent. Indeed, a defender with a high speed and momentum might be more vulnerable to being evaded, since it takes more impulse (force over time) to change momentum. Likewise, tests of agility that simply involve how fast an athlete can cover a pre-determined course do not reflect typical agility demands in sport. The results of Wheatley et al. [9] as well as Wynn et al. [10] also suggest that agility training should be directed at moving with control, so that movement success is not compromised at higher speeds.

According to Moore & Biewener [11], prey can increase their chance of survival by possessing both manoeuvrability (how quickly and sharply an animal can perform a turn) and movement variability (a high number of different directions for movement). Further, slow moving prey have a wider variety of escape options and are therefore less predictable [12]. In relation to invasion sports, it is advantageous for the attacking player to have the ability to move rapidly in multiple directions and to do so with a range of strategies to reduce the ability of an opponent to anticipate[5]. This ability could then improve the athlete's chances of finding space and time to avoid being dispossessed. This ability to move effectively in variable directions is especially important in "360 degree" sports such as soccer, where players and passes can be in any direction.

Predators have often been shown to have higher muscle power, are faster, and have a greater capacity to accelerate and decelerate than their prey [12]. It is possible for the prey to match their predator's locomotor capabilities through turning manoeuvrability, affording them a critical escape space [12].

Rattlesnakes preying on kangaroo rats have been studied using high speed video analysis [13], and it was found that the ability of the rat to avoid being bitten was associated with faster reaction times from the rats. The authors concluded that prey reaction time plays a central role in shaping the outcome.
If the collective findings of predator-prey interactions can be applied to sports, they suggest that athletes may achieve successful agility performance in contests by possessing a combination of athleticism (physical capacities) as well as the skill to decelerate and turn in a wide variety of directions and speeds to adapt to the sports situation. They should be prepared to regulate approach speed where appropriate to increase the COD angle, and to develop a range of strategies to facilitate success in a range of task scenarios. The ability to react quickly to opponents contributes to successful agility.

AGILITY AND CHANGE-OF-DIRECTION SPEED ARE NOT THE SAME

In the above sections, agility has been described as a skill that should be understood in the context of invasion sports; that is movement directed to evade or pursue opponents. Despite this, the vast majority of coaching and scientific literature has historically described agility and assessed it according to a pre-planned COD task [1]. When performing a COD task, the athlete is required to turn around various lines or obstacles such as cones or poles as fast as possible, with the outcome being the completion time. In testing COD ability, the number of changes

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IUSCA International Universities Strength and Conditioning Association of direction can vary from 1-15, and the turning angle may vary from 45-180 degrees [14]. It is suggested that COD ability can be better isolated by testing only one COD and by measuring entry and exit speeds [14]. Various footwork techniques are prescribed such as side-stepping, side-shuffling, or back pedalling. Collectively these tests have more recently been described as tests of COD ability rather than agility [14,15]. In relation to training, methods such as "speed-agility-quickness" (SAQ) or "fast feet" involve various COD drills and are quite popular in S&C training programs for invasion sports. Change of direction drills and activities are used by S&C coaches as they are thought to develop technical and physical attributes that underpin agility performance [15]. They are also prescribed in an effort to develop controlled actions before progressing to more intense and complex agility activities [14].

However, COD ability is different to agility because the former is a pre-planned task, whereby the athlete has prior knowledge of the new direction of travel and can adopt anticipatory postural adjustments in order to execute the actions. Further, there is no stimulus that the athlete must react to. Change of direction ability appears to have little in common with attacking or defending agility in invasion sports, and COD tests do not distinguish between attacking and defending footwork [16]. As mentioned earlier, effective agility often requires the athlete to move at sub-maximum speeds with control, rather than turning as fast as possible with little regard for the quality of movement, as in COD ability tests.

Invasion sports do not involve pre-planned COD manoeuvres because attackers and defenders always need to change direction in response to a stimulus, usually opponent's actions. There are occasions when an attacking team will use set plays, and players will plan to move to a certain location on the field or court. However, once a defender approaches the attacker, the attacking agility manoeuvre will need to be performed with an element of unpredictability, and the precise technique and new direction of travel cannot be entirely pre-determined [16]. Some research has compared a COD speed test with an agility test that both involve the same distance and angle of direction change. In four studies when the correlation between the tests was averaged, the statistical commonality was reported to be 29% [6]. As this is clearly below 50%, it was concluded that COD speed and agility are independent skills and should not be used interchangeably[6]. Differences between COD speed and agility are shown in Table 2.

The appeal and therefore the prevalence of COD testing in sport has been suggested to be because there are many available standardised protocols with normative data, tests are quick and easy to administer with a large group, they are reliable, and minimal equipment is required [16]. Likewise, COD training drills are also easy to control and to monitor the training load. As previously indicated,

Table 2. Proposed differences between change of direction speed and agility.

	COD	**Agility**	
		Attacking	**Defending**
Objective	Change Direction	Movement to evade opponents or create time and space	Movement to corral, block or tackle attack-er
Decision making	Pre-planned adjustment of body posture and steps	Reaction to defend-ers movement and game situation , use of deception, under time pressure	Reaction to attacker and game situation under time pressure
Skill classification	Closed & Predictable	Open and unpredictable	
Choice of technique/ footwork	Pre-Planned	Varies depending on game situation	
Speed and angle of direction change	Pre-planned	Varies depending on game situation	

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agility training (and testing) is far more complex and more challenging to design and administer. Although agility tests using one vs. one duels have been developed [2,3], methods for evaluating agility performance in a competition setting are lacking.

A key driver behind the use of COD drills for testing or training is that agility is thought to be underpinned by COD ability [17,18]. This infers that if an athlete improves performance in a COD drill or test, there will be a positive transfer to agility performance. Although there is very little research on this topic, the available evidence seems to question the notion of transfer or is unclear. The first study required elite junior Australian Rules football players to perform either COD drills or small-sided games (SSG) designed to challenge agility with 11 sessions over a 7-week period [19]. The COD training group experienced no improvement in a defensive agility test (effect size=0, trivial change, P>0.05). By contrast, the SSG group demonstrated a statistically significant (P<0.05) moderate gain of 4%. A similar finding was reported for junior soccer players, where adding COD drills to normal soccer training provided no additional benefit to agility performance, as tested by reacting to an opponent while dribbling a ball [20]. Another study of elite junior soccer players [21] found that a 6-week COD training program provided some benefit to agility performance, although it is not clear whether the gain was significantly greater than a control group because the group x time interaction was not reported. Also, the improvement completely disappeared when the task involved dribbling a ball. One study [22] reported that 12 weeks of SAQ training enhanced agility in preadolescent soccer players. However, the training actually contained a blend of COD drills and agility tasks involving reacting to opponents, which makes it impossible to attribute to the gains in agility performance to the COD drills. Further research involving sport-specific agility testing is therefore required.

Wheeler et al [23] examined the side-stepping technique of national and international rugby players while evading a defender and compared this to the technique of pre-planned side-steps without an opponent (COD task). They found several statistically significant differences in technique which led them to conclude that by only training pre-planned COD drills, incorrect movement patterns maybe learned. Therefore, rather than relying on the outcome of COD tests, it is important to discuss the role of *technique* that contributes to agility performance, which is discussed below.

THE ROLE OF TECHNIQUE IN AGILITY PERFORMANCE

What is agility technique?

Technique can be simply defined as “a specific sequence of movements” and “the way in which sports skills are performed” [24], with a more complex definition including “the motion activity specified by biomechanical principles of human motion which utilize motor features of movement and body structure to obtain the best sports result” [25]. Despite agility being influenced by perceptual-cognitive factors (e.g., fast thinker) and physical qualities such as strength and speed, agility movements are skills, and thus developing an athlete’s technical and mechanical abilities to perform the agility action (e.g., fast mover) in a rapid, controllable, and efficient manner, is integral for improving agility performance and mitigating injury risk [26-31].

Biomechanical considerations of agility technique

Irrespective of attacking or defensive agility actions highlighted previously, agility movements typically involve some form of directional displacement of the centre of mass (COM) relative to the base of support (BOS), and thus the fundamental mechanical characteristics are very similar (i.e., to manipulate changes in COM speed). A range of different agility techniques performed in invasion sports in both attacking and defensive scenarios [4,23,32,33] are illustrated in Table 3, containing the descriptions, applications, and advantages of these actions based on previous literature [30,34-38]. Most agility actions generally involve a COD which can be defined as a “reorientation and change in the path of travel of the whole-body COM towards a new intended direction” [39,40] with technique critical for facilitating effective application of the braking and propulsion impulses necessary to control and manipulate COM speed in accordance with the intended task’s goal [30,35]. Changing direction in an agility task is generally divided into four phases: [24,30,35]

1. Linear / curvilinear / lateral motion (Initiation)
2. Preliminary deceleration / preparatory postural adjustments (preparation)
3. Main COD plant phase (execution)
4. Reacceleration (follow-through)

These four phases of COD agility actions are influenced by the athlete’s approach speed, physical capacity, COD angle, and the contextual demands of any sport-specific scenario [4,30,36]. The COD

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biomechanical demands are angle- and velocity-dependent with an angle-velocity trade-off present [30,36]. Practitioners should be cognizant that as the intended COD angle increases, horizontal momentum must reduce to a greater extent (increased braking impulse), thus deceleration mechanics are integral in facilitating sharp agility actions [37-39]. Finally, COD agility actions should be coached as a multistep strategy. Foot contacts preceding the COD such as the penultimate step (second to last) and potentially earlier steps, play a critical role in braking, stride adjustments and preparing the plant foot contact for load acceptance and push-off in order to effectively redirect the COM in the desired direction [37,40-42]. An example of an undervalued and underreported COD agility technique is deceleration illustrated in Figure 2, where a wide receiver performs a rapid horizontal deceleration to create space separation prior to changing direction and re-accelerating in a new direction to create a scoring opportunity.

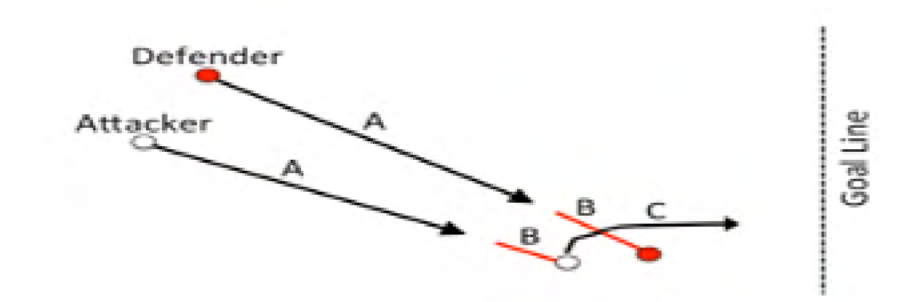

Figure 2. Illustration of an attacking deceleration action in American football. Scenario A, both attacker and defender are sprinting (black arrows). Scenario B, attacker rapidly decelerates over a short distance to create separation from defender to avoid tackle (red line with white circle). Defender decelerates late and over a greater distance (red line with red circle). Consequently, in scenario C, this results in greater space for the attacker to exploit towards the goal line and reaccelerate (black arrow).

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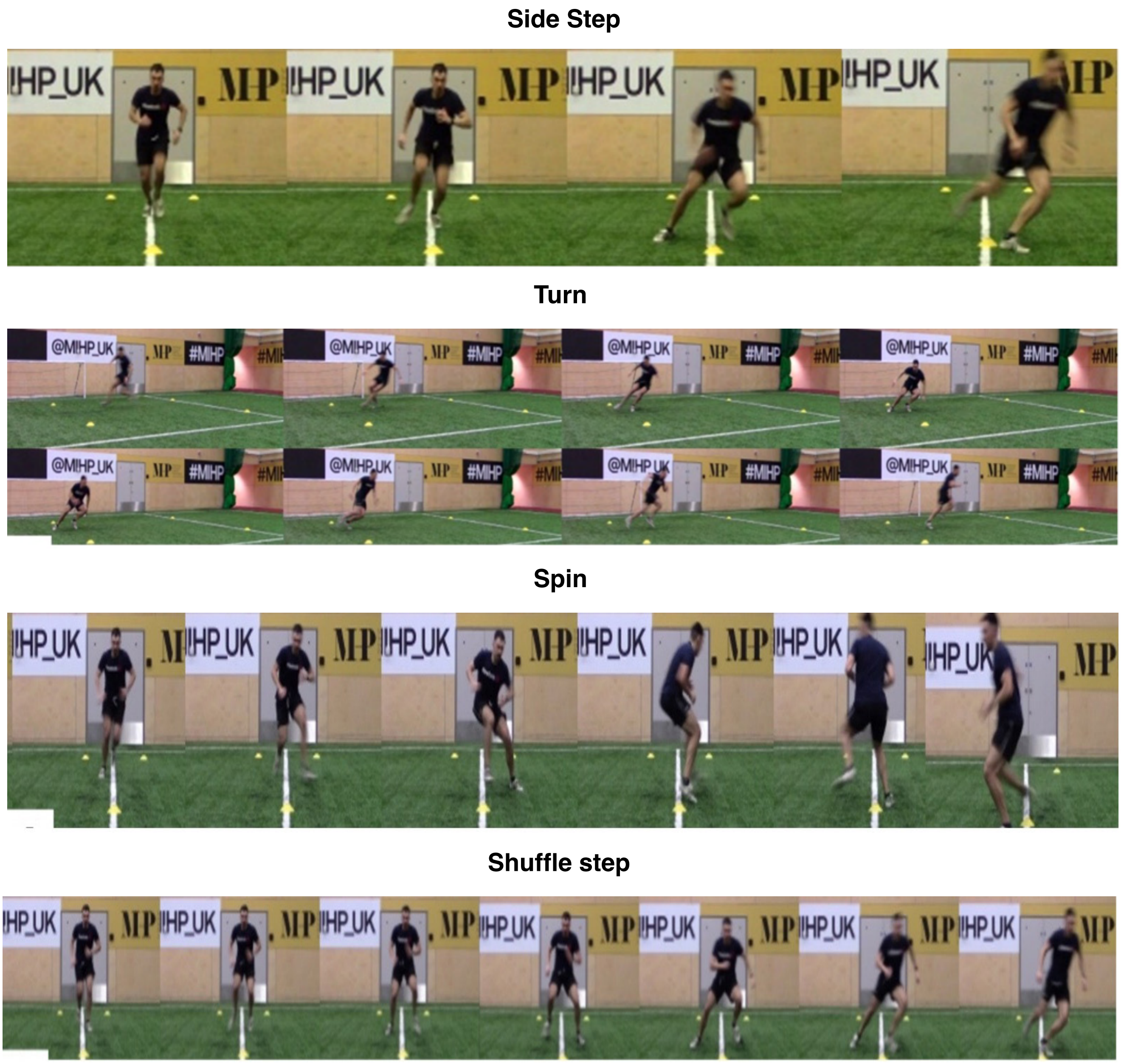

Figure 3. Photo-sequence of agility technique

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Table 3. Agility actions descriptions, advantages, applications and contextual considerations

	Description and application	Advantages	Contextual considerations
Side-step	Athlete planting their foot laterally opposite to the direction of travel to create a propulsive impulse into the new intended direction. Side-steps most frequent attacking agility action in netball[32], 1vs1 ARF (74%)[4], and successful for tackle break-success in rugby union (66-73%)23,33. Most frequent defensive agility action in ARF (~39%)[4]	• ↑ cutting angles, ↑ GCTs, ↑ braking and propulsive forces vs XOC • ↓ preparation time vs shuffle, split step • ↑ exit velocity vs split step, shuffle, spin • Successful action in penetrating defensive lines in evasion sports • ↓ deceptive action vs shuffle / split steps	• Generally, for cuts of 0-90° • Evasive action (separation from opponent) 1 vs 1 or multiple defenders, typically with moderate to high entry velocity • Sharp redirection – COD angle priority, with moderate to high approach velocity • Pressing actions as a defender • Interceptions / covering runs as a defender
Shuffle step	Athlete performs a series of lateral "side-steps" (often double / triple) with the final movement similar to the side-step action. Sometimes known as double / triple step / stutter step. Not as frequently performed as side-stepping in netball[32]. Under researched and examined action.	• ↓ preparation time vs split step • Distribution of mechanical loads across more foot contacts • ↑ deceptive action vs side-step but ↓ velocity maintenance vs XOC, side-step • Reduces momentum prior to main push-off • Offers two directional options	• Generally, for cuts of 0-90° • Evasive action (separation from opponent) 1 vs 1 or multiple defenders, low to moderate entry velocity • Evasive action initiated from static/stationary positions • Defensive action to permit athletic ready and reactive position from static or low intensity initiation / may be performed when attacker has performed a deceiving action and the defender must correct their position.

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Crossover cut (XOC)	Athlete positions the plant foot on the same side (ipsilateral) of the new direction (or sometimes medially across the pelvic midline) and then crossing the opposite leg (contralateral) in front of the body for the new step in the new direction, accelerating in the same direction of the push-off leg. Not as frequently performed as side-steps in rugby and limited tackle break success[22,33]. ~10 and 4% attacking and defensive frequency in ARF, respectively[4]. Key action part of multi-step side-step strategy.	• ↑ velocity maintenance, ↑ exit velocity, ↓ GCT • ↓ cutting angle vs side-step, shuffle • ↓ preparation times vs all other actions • Limited deceptive action	• Generally, for cuts of ≤45° • Key feature of curvilinear motion • Scenarios where velocity maintenance and momentum critical (i.e., collisions) • Tracking / covering runs as a defender • Interceptions as a defender
Split Step	Athlete performing a small jump (amplitude jump) prior to push-off, landing with both feet greater than or equal to shoulder width apart, and then, upon landing, the contralateral limb is used for push-off into the intended direction of travel. Not as frequently performed as side-stepping in netball[32]. Under researched and examined action.	• ↓ approach velocity and ↑ GCT vs side-step and XOC • ↓ knee joint loads vs side-step • Distribution of mechanical loads across two foot contacts • Offers two directional options • Potentially greater SSC utilisation (prestretch and load) with amplitude jump • ↑ preparation time vs side-step and shuffle • Slower decisions and greater decision errors vs. side-step and shuffle	• Generally, for cuts of 0-90° • Evasive action (separation from opponent) 1 vs 1 or multiple defenders, low to moderate entry velocity • Evasive action initiated from static/stationary positions • Accurate timing of jump integral • Defensive scenarios in 1 vs 1 scenarios to offer two options when attacking running directly at defender • Pressing scenarios as a defender
Spin	Athletes plants foot and pivots/ rotates foot and whole body using a "blind turn" / spinning movement, generally rotating whole-body ≥270°. Least occurring attacking agility action in netball[32] and ARF[4]. No occurrence by defenders in ARF[4]. Under researched and examined action.	• ↑ protection of implement (i.e., when ball carrying) • Potentially smaller target when opponent makes tackle attempt • Blind side spin likely deception / unexpected movement	• Evasive action (separation from opponent) 1 vs 1 or multiple defenders, low to moderate entry velocity • Effective when defender is reducing space / tackling from side

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Deceleration	Athlete reduces horizontal momentum (negative acceleration) across a series of foot contacts as an isolated agility action or prior to COD manoeuvre. Under researched and examined action in the context of agility. ~8% attacking agility and ~23% defensive agility frequency in ARF[4]. More intense decelerations occur more frequently than accelerations across as a plethora of multidirectional sports meta-analysis soccer, rugby codes, field-hockey[41].	• Deceptive action where short time and distance to stop can create separation from opponent and generates greatest change in momentum • Central to reduce horizontal momentum prior to COD actions, typically for directional changes ≥60° • Central for stride adjustment and slight reductions and increases in acceleration to square up and wrong foot opponent • Generally performed in sagittal plane which is safer strategy and can reduce mechanical loads during main execution foot contact	• Deceptive action where short time and distance to stop can create separation from opponent, typically to receive a pass. • Central to reduce horizontal momentum prior to COD actions, typically for directional changes ≥60° • Central for stride adjustment and slight reductions and increases in acceleration to square up and wrong foot opponent • Performed during linear tasks to avoid tackles / blocks from lateral direction (Figure 3). • Pressing scenarios as a defender • Tracking and following runs as a defender • Interceptions as a defender
Turn	Unilateral or bilateral turning strategy where one foot rotates and remains in contact with the ground and redirects COM (typically for directional changes ≥ 110˚). Large turns occur in typically 360° sports such as soccer[43] and ARF[4].	• ↑ GCT and ↑ braking force (impulse) and deceleration vs cutting actions • Necessary where sharper redirections and deflections are needed • Bilateral turning strategy may distribute loading across two limbs	• Deceptive and evasive action where sharp redirections and separations are required such as v-cuts • Evasive action (separation from opponent) 1 vs 1 or multiple defenders, low to high velocity moderate entry velocity • Necessary where sharper redirections and deflections are needed • Pressing actions as a defender • Following and covering runs as a defender • Interceptions as a defender

COD: Change of direction; XOC; Crossover cut; GCT: Ground contact time; SSC: Stretch shortening cycle; COM: Centre of mass; ARF: Australian rules football.

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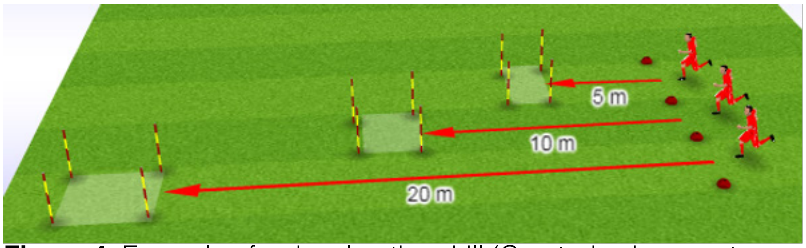

Figure 4. Example of a deceleration drill (Created using sportsessionplanner.com)

From a practical application perspective, coaches are encouraged to incorporate drills that target the capacity to decelerate, such as with “deceleration runways”, described above (Figure 4). In this activity the athlete’s deceleration capacity is developed by progressively increasing the approach velocities/ momentum (mass x velocity) via distance. In this activity multiple decelerations can be performed within the same runway to increase the density of actions, but it should be noted that this may decrease movement speeds and therefore deceleration intensities. Additionally, deceleration training may also be viewed as a high velocity eccentric strength training modality.

Agility technique: a performance-injury risk conflict?

Whilst the agility techniques presented in Table 3 and Figure 3 are associated with performance in invasion team-sports, they are also commonly associated with lower-limb injury (knee, ankle, groin, hamstring) during offensive (i.e., cutting / evasive) and defensive scenarios (i.e., pressing / chasing) [44-48]. Of concern, particularly in cutting dominant sports, are non-contact anterior cruciate ligament (ACL) injuries that are considered the most debilitating and severe lower-limb injury athletes can experience [35,49,50]. Injuries occur when a mechanical load exceeds the tissue’s tolerance capacity [51-53], and agility actions have the potential to generate potentially high uncontrollable mechanical loads that ultimately increase ACL strain [34,54,55]. These loads are amplified with sub-optimal technique, and neuromuscular and biomechanical control deficits, and thus modifying athletes’ agility technique is considered a modifiable risk factor to mitigate injury risk [26,50,56-59].

A performance-injury risk conflict is present during COD agility actions (such as side-step cutting), whereby technical and mechanical characteristics necessary for rapid propulsion, deflection, and deception (e.g., wide lateral foot plants, reduced hip and knee flexion, lateral trunk flexion, high impact GRF, faster approach velocities) are in conflict with safer performance (i.e., reduced knee joint loading). Readers are encouraged to view specific literature for further information regarding the performance-injury conflict [35,38,60-62] but briefly athletes are unlikely to sacrifice performance at the expense of safer, but less optimal agility performance. This creates a paradox for S&C practitioners whose aim is to improve on-field agility performance and mitigate injury risk. Consequently, agility tasks will inevitably have an inherent risk of injury, but practitioners must be mindful of the performance-injury risk conflict when coaching agility techniques. Practitioners should therefore focus on modifying “high-risk” postures which offer no associated performance benefits [35,61], such as knee valgus and lack of penultimate foot contact braking, developing athletes’ physical capacity and tissue robustness [50,57,60,63-67] through targeting physical qualities and strategies (outlined in the next section), and periodise and monitor high-intensity actions for tissue homeostasis regulation [51,56,54,68]. To achieve these aims, a periodised “mixed-method” training approach that can overload and develop specific tissue strength capacities (i.e., traditional resistance loading), combined with exercises that harness agility technique (i.e., coordinative overload) are likely necessary to increase individual affordances for enhanced agility performance [69].

Agility technical frameworks and philosophies

It is unlikely that a universal model exists for agility technique development, as technique will vary across individuals of different anthropometrics, physical capacity, perceptual-cognitive ability, skill level, and training history [31,41]. Indeed, a flexible coordinative strategy and movement variability is likely beneficial for injury mitigation and tissue homeostasis by distributing loading and stresses across different joints and tissues; therefore, potentially reducing the cumulative loading on tissue structures [70-72]. However, too much variability is likely detrimental, with an optimal zone (i.e., goldilocks effect - not too much or little) suggested to be effective for injury mitigation [68-71]. Additionally, movement and coordinative variability is suggested to be conducive for task performance and execution, allowing greater flexibility and adaptability to environmental constraints and perturbations [71,73]. Because of the unpredictable, chaotic, multidirectional movements possible

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in invasion sports, the overarching aim of the agility framework is to create athletes who possess adaptable movement strategies with multiple movement solutions to solve the problems encountered within the contextual demands of the sport [30,41,63,74]; features that have previously been highlighted to be important for agility performance [75]. In this sense, it would be advantageous for athletes to be able to execute agility movements proficiently and safely from both limbs, across a spectrum of angles and speeds, and under conditions of fatigue, to further improve on agility performance and mitigate injury risk [30,74].

It should be noted that the key difference between attacking and defensive agility are the intentions of the movement. For example, attacking scenarios may involve deceitful preparatory movements and postural adjustments to fool opponents and increase evasion success. Conversely, defensive agility movements may involve reacting to opponent(s) movements and trying to identify anticipatory postural and kinematics cues regarding the intended movement direction. Irrespective of the scenario, it cannot be disputed that fundamental technical characteristics and biomechanical movement principles exist (Table 3), which are necessary to facilitate changes in locomotor activity, direction, velocity and which should be adhered to when coaching agility movements (Figure 5).

In brief, the key technical characteristics and movement principles are outlined in Figure 5 for agility movements. Essentially, most agility movements will require velocity regulation and moderation prior to the preparatory and execution phase as part of a multi-step action. Preparatory postural adjustments are then central for reducing momentum (deceleration) where necessary, making appropriate stride adjustments, lowering the centre of mass for increased stability, and facilitating preparatory changes in posture to optimise braking and propulsion during the main execution foot contact (though influenced by angle, entry speed, physical capacity) (Figure 5). Next, during the execution phase, irrespective of agility action performed (Table 3), the agility action will require a change in base of support relative to their centre of mass, with simultaneous joint movements (triple flexion to extension) and a firm base of support to increase braking and propulsive impulse and orientating this in the optimal direction (particularly medio-lateral and Horizontal) (Figure 5). For all phases, it is central to maintain strong frontal plane knee alignment to reduce knee joint loading. Finally,

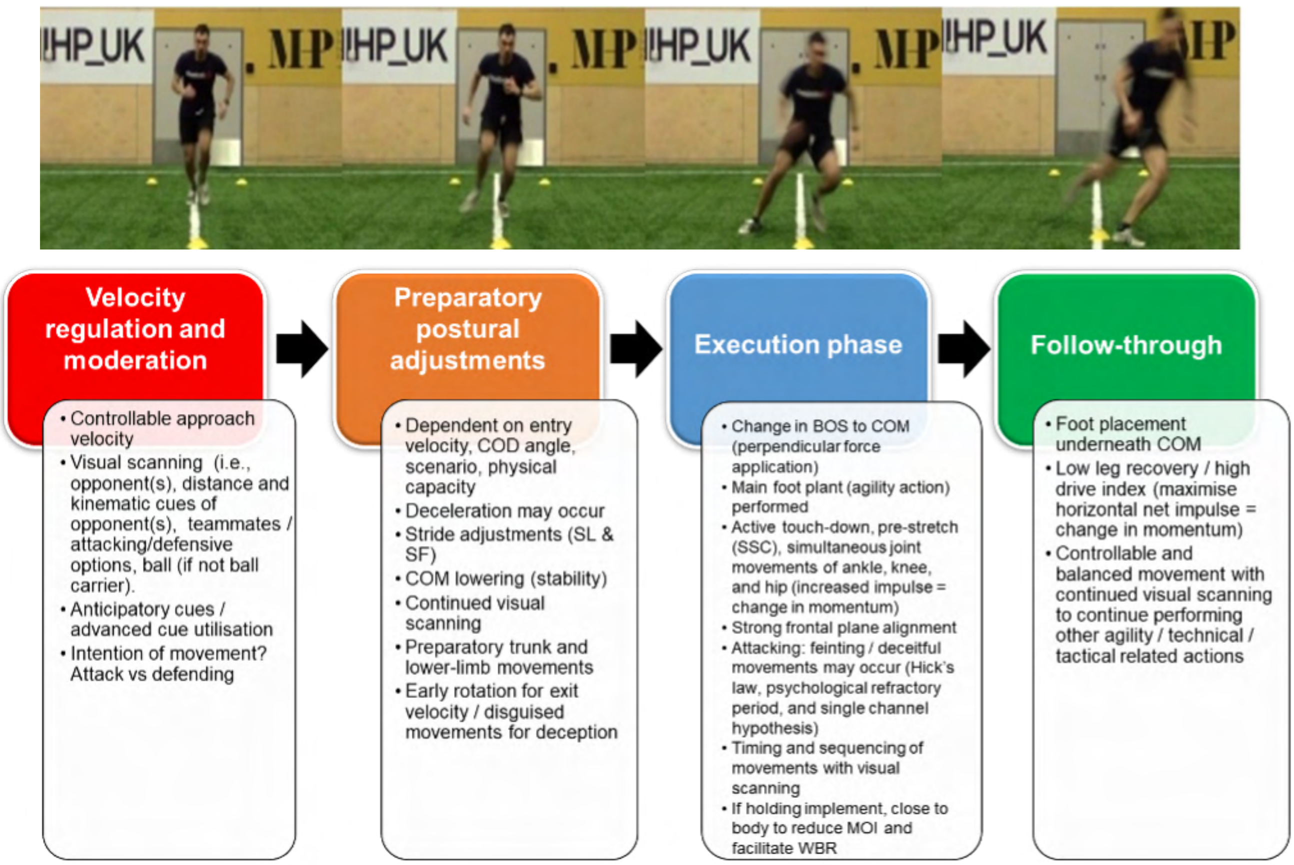

Figure 5. Agility technical characteristics and key movement principles. COD: Change of direction; COM: Centre of mass; SL: Stride length; SF: Stride frequency; BOS: Base of support; MOI: Moment of Inertia; WBR: Whole body rotation; SSC: Stretch shortening cycle.

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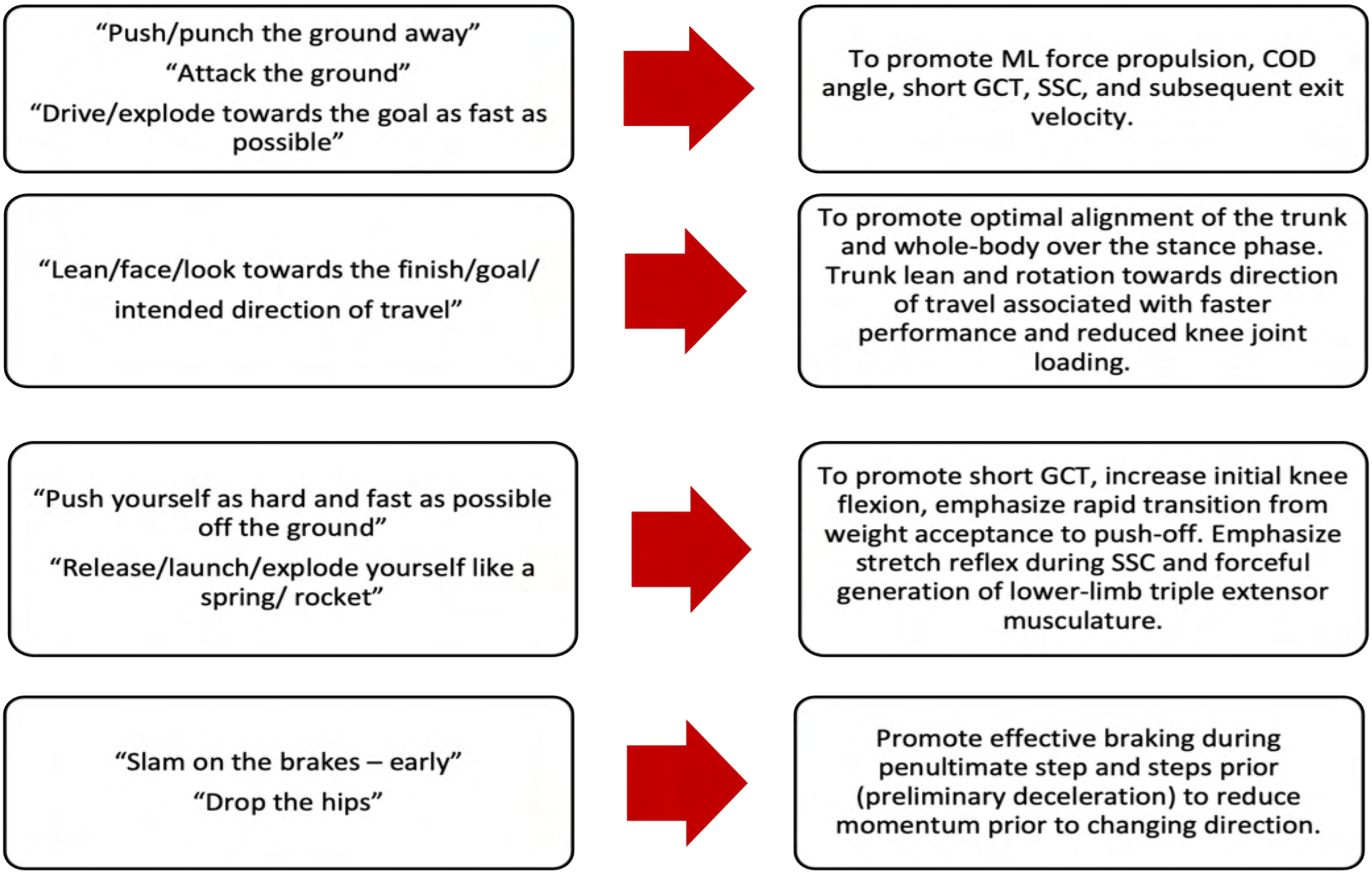

Figure 6. Example externally directed verbal coaching cues to promote faster and potentially safer change of direction technique. Adapted from Dos'Santos et al[57]. ML: medio-lateral; COD: change of direction; GCT: ground contact time; SSC: stretch shortening cycle.

the follow-through, as part of the multi-step action, is important to facilitate deflection of the centre of mass and permit an effective transition to allow other sport-specific technical actions to be performed by the athlete (Figure 5). Additionally, to facilitate development of agility techniques, verbal cues should be used to target the desired technical outcome (Figure. 6).

DEVELOPING PHYSICAL QUALITIES FOR AGILITY PERFORMANCE

Understanding the physical qualities that enhance agility performance is of significant value to S&C professionals working with invasion sports athletes, to help inform specific strategies for the design of agility-based training interventions[16,76]. Numerous studies have investigated associations between physical qualities and agility involving response to unpredictable stimuli in invasion sports. However, as noted previously[76] a high percentage of these studies used a Y-shaped agility action and involved responding to a generic light stimulus that is avoid of the myriad of information sources that inform complex and dynamic decision-making in real invasion sport environments[77]. Accordingly, many of the physical qualities identified in these generic light stimulus studies may mask true identification of the various physical qualities required to underpin the vast array of agility manoeuvres necessary to solve the unpredictable and emergent movement problems encountered in invasion sports competitive environments.

To the authors' knowledge there are only two studies to-date that have utilized an agility test requiring players to make movement decisions in anticipation or response to their opponents' actions, and which also incorporate some kind of sport-specific technical skill [2,3]. Young and Murray [2] reported that drop jump reactive strength index (DJ-RSI) from a 30 cm drop height had a large association with one vs. one defensive agility ($r = 0.63$), but may potentially hold even greater importance for successful attacking agility ($r = 0.73$). These findings corroborate Drake et al. [3] who used a similar one vs. one agility test, and also found a larger association with unilateral repeated hop height averaged from across

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successive 3 hops and successful attacking agility performance (r = 0.57). Collectively, these findings support the importance of reactive strength qualities, where high forces need to be generated across short ground contact times (i.e., a tall-thin impulse) to successfully evade opponents. Indeed, in rugby union backs, both bilateral and unilateral DJ-RSI, were the only physical qualities associated with 'clean breaks' (r=0.53-0.56), where high sprinting speeds and rapid CODs are necessary to exploit gaps in the defensive line [78]. For forwards, however, 'clean breaks' were also associated with countermovement jump (CMJ) height, relative peak power and unilateral CMJ peak power, suggesting attacking agility in this population was more reliant on slower stretch-shortening cycle (SSC) actions where force is generated over greater lower limb joint flexion range of motion and longer ground contact times. These position-specific differences are likely due to different individual anthropometric profiles and position-specific contextual factors that result in 'clean breaks' being executed across different running speeds and COD angles, subsequently demanding utilization of varying SSC actions to successfully perform a wide variety of attacking agility manoeuvres. For example, the 'angle-velocity trade-off' would infer greater reliance on slower SSC actions during more severe COD angles (i.e., > 60°) when longer ground contact times are necessary to generate the required braking impulse to reduce momentum prior to turning and re-accelerating. Conversely, faster SSC actions would likely predominate more shallow COD angles (< 60°) when less braking is required in order to maintain velocity [36].

Defensive agility places greater demand on player's ability to accurately anticipate or react to the kinematic cues of the attacker and has a different neural basis than attacking agility where movement actions are more internally initiated [79,80]. It could therefore be expected that successful defensive agility is associated with different neuromuscular performance qualities than those required for attacking agility. For example, it has been reported that defensive agility manoeuvres may require generation of higher braking forces to facilitate faster whole-body changes in direction or speed to counteract the visual processing times needed to detect and quickly respond to movements first initiated by an attacker [79]. Indeed, Wakatsuki et al. [80] reported a reactive advantage when performing a lateral side-step movement in response to a reactive stimulus due to 'Bohr's Law' (motor characteristic that facilitates faster reaction times when reacting to a stimulus) that facilitates higher initial impulses, and therefore faster foot manipulation speeds and initial movement times. This would support the association observed between DJ-RSI and successful defensive agility[2] in that athletes capable of generating greater negative (eccentric) forces within a specific time constraint (i.e., impulse) would have faster foot manipulation speeds and initial movement times, enabling quicker reactions to the offensive movements of an attacker(s). Furthermore, Drake et al. [3] reported the highest associations with successful defensive agility was CMJ propulsive duration (r^2 = 43%) and flight time-to-contraction time (FT:CT) ratio (r^2 = 34%). Essentially, CMJ FT:CT is the same as RSI-modified [81], a CMJ metric strongly associated with the ability to generate greater force and velocity in both the eccentric and concentric phase of the jump, and representative of enhanced "speed-strength" and SSC capabilities [81,82]. Since DJ and CMJ reflect different SSC qualities [83] and that defensive agility is associated with both, practitioners should look to integrate training approaches that can enhance both the force and velocity components of these jumps during both the eccentric (downward) and concentric (upward) phases As one example, accentuated eccentric loading (AEL) is a training method that prescribes eccentric loading magnitude in excess of concentric prescription during an exercise with coupled eccentric-concentric movement action without disruption to natural movement mechanics[84] (Figure 7).

When viewed holistically, although limited to one vs. one agility scenarios, current research seems to support the development of a multifaceted strength profile in-order to support the development of the various locomotor capacities (i.e., acceleration, deceleration, top speed and CODs) needed for 'all-round' agility performance [2,3]. Accordingly, perceptual-cognitive agility training should be carefully integrated with resistance training interventions that can enhance the physical and technical qualities needed to accelerate, decelerate, change direction and attain high running speeds repeatedly during match play. For example, although small-sided games training is clearly a key part of the puzzle for simultaneously developing the perceptual-cognitive and physical qualities of agility, it may not lead to enhanced mechanical capacities [85-89], which further emphasizes the importance of a "mixed-method" agility training approach. Furthermore, practitioners should also not discount development of movement proficiency in a diverse variety of "generic agility training" exercises that may help to facilitate more precise timing and regulation of movement forces [75]. For example, faster agility performance in youth male soccer players is associated with a superior

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Figure 7. Countermovement jump performed with accentuated eccentric loading using 'band release' method. A = Starting position with band tension, B = Braking phase and release of bands, C = Flight phase following propulsion. Note: Same exercise could be performed with dumbbells, other modes of resistance (e.g., trap bar) and from elevated platforms to further increase eccentric velocity (i.e., momentum) and eccentric-braking demands.

ability to perform generic motor exercises, such as in-line lunge (r=-0.60), active straight leg raise (r=-0.59) and quadruped rotary stability(r=-0.58) [89] .The in-line lunge and variations of this exercise can be viewed as an example of a "generic motor ability" exercise, challenging various unilateral strength, mobility and stability qualities fundamental to more intense sport specific agility manoeuvres (Figure 8).

Clearly, future research is needed to examine the physical capacities that transfer to various on-field agility performances, however it cannot be disputed that improving the impulsive abilities of athletes should transfer and improve the mechanical ability to perform the high intensity locomotor movements that underpin agility in invasion sports. To do this, practitioners should firstly identify the agility actions that are deemed most influential for their unique sport and positional demands and devise new "in-situ" agility training and assessment approaches.

Figure 8. Walking in-line lunge with overhead barbell resistance can be viewed as an example of a "generic motor agility" exercise, challenging various unilateral strength, mobility and stability qualities fundamental to more intense sport specific agility manoeuvres. A = Erect single leg stance, B = Left leg eccentric-braking phase, C = Left leg propulsive phase, D = Right leg pre-impact muscle activation, E = Right leg eccentric-braking phase. Note: Numerous adaptations can be considered with this exercise to stress different strength and stability qualities. For example, in this figure the athlete is challenged through "off-set" loading (i.e., slightly greater load on one side of the barbell) to place greater demand on trunk stabilisation.

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PERCEPTUAL COGNITIVE ABILITIES AND AGILITY

In the previous sections of this paper, it has been explained that for athletes to be successful in an agility scenario they must perceive information from the environment to produce an effective movement response. Anecdotally, we can look to the sport of basketball and arguably one of the better point guards in recent history. Steve Nash was noted for having superior agility on the court; however, his strength and power capabilities were not regarded as being superior. Presumably, his agility prowess could be linked to his ability to make quick and accurate decisions.

The ability to effectively perceive information and make the correct response is a discriminating factor between higher and lower-level performers in netball [90], rugby league [91], basketball [92], Australian football [93] and soccer [94]. Anticipation is a key component of agility and is influenced by three factors: visual scanning, situational knowledge, and pattern recognition [1]. Anticipation can be viewed as an all-embracing cognitive skill therefore it will be presented first.

Anticipation

Concerning sport, anticipation can be described as an athlete's capability to initiate a movement response before the completion of the stimulus [95]. Correct and timely anticipation requires the athlete to scan the environment effectively for relevant contextual information in the form of kinematic cues [95]. Additionally, an athlete's ability to recall past performances and recognise similar patterns within the environment and to possess situational awareness will allow them to comprehend the range of potential outcomes [96].

Visual scanning

Visual scanning is the ability to use vision to systematically search the environment and select pertinent information [97]. In relation to agility, effective eye gaze behaviour of an athlete in an agility scenario will allow them to perceive relevant visual information from their opponent to inform their movement strategy [98]. Research has shown that higher performing athletes are more efficient with their eye movements prior to deciding upon their movement strategy. These higher performing athletes make fewer fixations but focus on relevant information for longer periods of time [98]. For example, a defender in a one vs. one contest will visually scan the attacker's body for relevant cues that indicate their intended direction of movement (e.g., body lean prior to COD).

Pattern recognition

In sport, pattern recognition refers to the athletes' ability to recognise and recall patterns within game-play [99]. Moreover, expert athletes have demonstrated the ability to rapidly recognise patterns that they are regularly exposed to [96]. For example, in an agility scenario a defending athlete may be more successful tackling or corralling the attacker in a 1v1 open field situation if they have been previously exposed to the scenario. It is believed that an athlete's ability to "chunk" together multiple segments of pertinent information allow the process to occur quicker.

Situational knowledge

By understanding common situations and the probability of potential outcomes, athletes are more likely to produce a rapid and accurate movement response. Results from research have demonstrated that expert performers possess greater task-specific situational knowledge compared their lower performing counterparts [99,100]. In an agility specific context, a defending player may be better able to tackle or corral the attacker by understanding how likely certain outcomes are to occur. In the chaotic nature of an agility task, this becomes much more difficult as variables are added to the situation such as increased number of players, rules and time constraints.

Developing an athlete's perceptual cognitive abilities

When training the action component of an agility scenario, it is important that the movement is coupled with a context-specific perceptual-cognitive stimulus. However, the same may not be true when training the perceptual and cognitive components. There is evidence to suggest that an athlete's in-game anticipatory capabilities can be improved through methods where the perception and action are decoupled. Results from research indicate that anticipation can be trained via video-based occlusion methods where footage of an opponent is blocked at specific time points [95]. However, findings related to the effects of video-based perceptual cognitive training specific to agility performance in invasion sports is limited. A study in field hockey goalkeepers indicated that anticipation of drag-flick location in a game-like situation demonstrated a statistically significant improvement following three sessions of vid-

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eo-based occlusion training [101]. Using game-based training like small-sided games and one vs. one scenarios will have the greatest contextual specificity to in-game agility. Indeed, only these physical training methods can collectively target all of the cognitive factors discussed above. However, the use of 2-D video and virtual reality training focusing solely on the development of the perceptual-cognitive abilities may have utility when a player's training load is limited due to injury or the need for additional rest.

COACHING AGILITY

Given that agility performance is the result of the interaction of the athlete, the environment and the task, there will always be a great variety in the strategies and tactics used by different athletes in the completion of a given task [102]. Additionally, there is likely to be variation between the strategies used by a single athlete when faced with different tasks. Much of this difference will evolve around the fact that an athlete's strategy will often depend upon their agility "fitness", the unique agility related capacities they possess and how they interact with the task to be achieved. Another key consideration is that these strategies also rely on an evaluation of the fitness of other players affecting the environment at that given time [5]. In this context, a coach's role when developing agility extends beyond merely developing physical and motor qualities but extends to ensuring that athletes develop a broad fitness that allows them to solve contextual problems and maximise their success in the sport [5]. Clearly, this "fitness" will itself be highly individual, spanning multiple domains of technical (skill), physical, and perceptual-cognitive capacities. Consequently, the likelihood of finding a single coaching method or structure that optimally develops agility in all scenarios is highly unlikely, and so making definitive statements about optimal coaching in the context of agility must be done with extreme caution.

Another challenge is that the evidence-base regarding optimal strategies for agility development is minimal and affected by two key interlinked issues. First, the development of agility involves a learning process, yet it is impossible to measure learning directly and as a result, learning has to be inferred from performance. This then leads us naturally onto the second challenge, namely that in order to develop a measure of performance, a reductionist approach has often been taken, where the performance measured is not representative of the application of agility in the game [5]. As a result, there is a paucity of data pertaining as to how best to coach agility and as a result, much needs to be inferred from indirect studies and data from other realms.

In terms of how best to coach agility, the questions essentially revolve around two key constructs: structure and interaction. Structurally, the questions revolve around how best to organise programs and sessions to most effectively develop agility, whist the interactive issues revolve around aspects involved with the delivery of the sessions such as demonstrations, coaching cues, feedback etc., and how these impact upon agility development. Given the inherent complexity of agility performance, a crucial factor to keep in mind is that these questions will ultimately relate to the specific program and session objectives and not be all-encompassing considerations, where single methodologies are thought to be universally applicable [5].

Structurally, much current discussion focusses around two related concepts, that of linearity and the learning approach deployed. In terms of linearity, much of the discussion has emerged from the motor learning literature and considers how we learn skills and the optimal methods via which to structure practices. The concept of linearity has a number of considerations embedded within it. The first is that learning is a staged progression and that we need to progress through these stages in order to master skills. The second is the concept that there are best practices in developing skills that will apply to all athletes[103-105]. In a linear approach, skills are believed to be learnt through progressive repetition, and training sessions are typically repetitive and blocked and based on explicit learning. Non-linear approaches on the other hand are built around the concepts that skills emerge as an athlete interacts with the environment and by changing the constraints, practice can be varied to produce learning [103].

Within these broad categories are a number of approaches to skill development, but which broadly fall into two categories. Behavioural approaches developed out of the work of Thorndyke [104] (1911) and Skinner [105] (1953) tend to be linear in approach and focus on the concept that skill is related to the development of neural processes and motor programs [106]. They typically use blocked, repetitive, practice on drills that represent the skill to be developed, together with prescriptive instructions, and feedback. The concept is that this repeated practice will develop and consolidate motor programs based around a prescribed model of performance. Cognitive methodologies on the other hand such as the ecological

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approach[107], the dynamic systems method [108], and the constraints-based approach [109], focus on skill as an interactive entity, emerging out of practice as an athlete engages with the task and the environment. These cognitive methodologies are variations on the non-linear structure, where exploratory constraints replace prescriptive instructions and varied practice replaces blocked repetition [103,106,110]. Non-linear practice design emphasises the crucial role of variability of practice and how this contributes to both stability and adaptability of movement [103]. Given the interactive nature of agility, it is increasingly suggested that a non-linear approach has an advantage over a linear approach, especially in relation to the decision making and cognitive aspects of agility, as the degree of cognitive effort required promotes superior learning [111,112]. Consequently, exercises that integrate a perception-action coupling are increasingly being recommended to generate implicit learning as well as explicit learning [111]. Given that these conditions better reflect the task-specific nature of agility, they provide a powerful learning paradigm for agility development [112]. However, these recommendations are based more on conceptual evidence rather than their direct and recorded effect on agility performance. In relation to which cognitive approach is best to develop agility, this may be a futile search. Whilst research has typically focussed on comparisons between behavioural and cognitive approaches, there is little, if any, comparison between the differing cognitive approaches as they relate to agility. Indeed, whilst they stand separate as theoretical constructs, in practice there is an inherent similarity between many of these approaches and many exercises demonstrate the characteristics of a range of approaches. It is therefore likely that coaches will utilise approaches based on practical strategies rather than purely theoretical constructs.

However, this preference for a non-linear and cognitive approach hides an ugly truth: many top athletes have used and continue to use linear methodologies in their training [5]. Similarly, these methods are also used successfully in a number of fields such as music [114]. Ericsson's concept of deliberate practice suggests that the most important factor in skill development is the quantity and intensity of deliberate practice and that deliberate practice scaffolds new skills onto previous skills and suggests a degree of linearity to the skill development process [114,115]. Whilst agility performance is ultimately chaotic and random, it does require competency and bandwidth in a number of target movements, and these movements anchor effective agility [110]. Training on a specific movement strengthens the neural connections involved in that particular movement, and thereby increase the likelihood that this movement is successfully executed in the future; in other words, what is trained is developed [116]. Consequently, there is a rationale behind repetition of key movement patterns in order to develop stable and effective movement patterns. However, a reliance solely on repeated patterns is less likely to be successful in generating the capabilities involved in solving the OODA loop challenges of game-based agility [117]. In the OODA loop, a process which originated in aerial combat, athletes undertake a process of observation, orientation, deciding and acting, in an attempt to gain the advantage over an opponent, and this is most likely to be facilitated by the use of cognitive approaches to agility development [117].

While much of our research takes an either-or approach, comparing one method with another, coaching is rarely ideological and will more likely use whatever method gets the required results. Observation of coaching sessions will often reveal a combined approach rather than a purely singular approach. So, it could be that where an athlete has a challenge with the stability of a technique, they may benefit from a predominantly behavioural approach, but if they are struggling more with application, they are more likely to benefit from a cognitive approach [110]. Indeed, the approaches can be structured within a session or program to enable the benefits of both approaches to be elicited [118]. For example, the Raise phase of a The Raise, Activate, Mobilise, Potentiate (RAMP) warm-up may be built around a set-up that facilitates repeated closed actions such as back-pedalling, side-shuffling, deceleration, cutting etc. The Potentiation phase may then involve exercises that focus on a skill such as cutting, but utilise a progressive "opening" of the skill; for example, starting with a lateral cut from a linear run in, then progressively developing the level of challenge by adding a choice component such as reacting to a coach's movement, and then further progressing this into a one vs. one invasion drill, and finally into a invasion based game activity. In instigating this progression, the utilisation of constraints can be especially useful. Here the environment and the task can be controlled in a way that challenges the athlete's decision making and action processes. One v one drills for example are extremely flexible exercises that can be manipulated in a number of ways to present different levels of challenge and to elicit different training effects. Manipulating constraints such as the location of the attacker and defender, the speed at which a defender has to move, task rules and restrictions such as the requirement to get to a certain area, can

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add variety, progression and specificity to any exercise.

Importantly, effective coaching needs to exploit the "sweet spot" of challenge where progressive tasks are used to elicit an optimal amount of "struggle". All exercises ultimately lie on a continuum between closed and open and the concept and the application of degrees of freedom within exercises is a key tool allowing an athlete to move along this continuum[110]. Acutely, practices can be set up as highlighted above with a move from the closed side of the continuum to the more open side, which allows practice of the movement and an opportunity to apply this movement in context. Additionally, this type of progression can also be instigated longitudinally, where early-stage practices can focus predominantly on the closed side of the continuum, whilst practices for more skilled athletes can focus on the more open part of the continuum [110]. What is important is that the methods used are based on an analysis of the contextual challenge, and ensure that the tasks chosen allow movement to be expressed in a way that is representative of how it is applied in the game.

Ericsson [114] recommends that performers should always seek out and utilise supervised practice under the tutelage of experienced coaches who are able to facilitate their move to the next level of performance. As a result, effective coaching will always be a critical component of agility development. One of the key constraints that a coach can alter in relation to the session is the type and nature of their interaction [114]. Feedback is an essential part of purposeful practice, and whether it be internal or external, effective feedback allows for an evaluation of current performance in relation to the required level of performance and the identification of actions designed to facilitate the reduction in the gap [114]. The requirements for external feedback are generally at its greatest in the early stages of the skill acquisition process and is generally considered most beneficial when it is timely, of an appropriate precision, appropriately targeted and delivered in small doses [119]. One key factor that ties in with the concept of struggle, is that feedback should allow the athlete to figure out the challenge and potential ways of solving the puzzles before receiving feedback and/or instruction [114,118]. This delay is generally considered to heighten the learning potential of each exercise [5].

The manner in which a skill is introduced, and the associated instructions can also influence the degree of learning. Quality demonstrations supported by effective coaching cues have been shown to be important [120]. Additionally, small changes in practice task constraints can result in a major change in performance. In terms of skill learning, external cues, where the focus is on the result of an action or an action external to the body (e.g. "push the ground away" as a cue for jumping), are generally thought of as superior to internal cues where the focus is on the actions of the body or body parts (e.g. "extend at the hips" for the same jumping action) [120]. Part of this is thought to be due to the constrained action hypothesis where internal focus induces a sub-optimal environment for action [118]. However, not all agility training is concerned with learning and skill development. One important consideration is that skilled performance requires the athlete to possess a representation of movement patterns, and superior performers are believed to possess a keen kinaesthetic awareness, literally able to feel the movement and this may require an appropriate internal focus at certain times [114]. Similarly, there is little information currently available on the optimal focus during game play and how best to develop this during practice.

When considering how best to coach agility, there are still many gaps with much to learn. The likelihood of a single best method is low, and it is more likely that optimal combinations of methods will be required that are related to the specific objectives of the session and program, objectives that must relate to the needs of the athlete, the sport and the "fitness" required to best achieve the sport-related tasks.

SUMMARY AND CONCLUSIONS

We have approached an understanding of agility performance in invasions sports by discussing observations from animal predator-prey interactions, differences between COD ability and agility, and by considering technical, physical, and cognitive elements, as well as coaching methods. A key starting point is recognising that in invasion sports, critical situations where possession is contested requires different attacking (evasive) and defensive objectives. Attacking agility is needed to create time and separation from defenders, whereas defensive agility aims to reduce time and space to achieve a turnover of possession.

When considering animals in the wild, the prey may be viewed as the attacker in invasion sports, whereas the predator is like the defender who pursues the player in possession of the ball. Predators can gain an advantage with superior athleticism (e.g., capac-

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ity to accelerate and decelerate), but the outcome of a contest is also influence by manoeuvrability and control of movement, which requires a strategy of optimum rather than maximum speed of movement. Therefore, athletes need to combine the development of physical qualities with the skill to control their agility actions.

Pre-planned COD movements do not involve reacting to a stimulus and as such, the techniques used can be different to agility techniques requiring fast and accurate responses to opponent's actions. Therefore, blindly prescribing COD drills as the primary focus of an agility program with the hope of achieving a high degree of transfer to agility performance is not recommended. However, it is recognised that isolating agility skills can be coached to develop safe and effective techniques, especially as part of a progressive skill program.

Four phases of agility skill were identified, and each can be analysed to develop performance. The angle at which athletes can redirect themselves is influenced by their speed of movement whereby sharper turns necessitate slower approach speeds (angle-velocity trade-off), which should be considered when designing training. The technique required for effective agility can place the athlete at greater risk of injury such as ACL rupture (performance-injury conflict). S&C coaches should avoid coaching high risk techniques and should prescribe appropriate strength training to improve the robustness of soft tissues to mitigate the risk of injury.

There is limited evidence relating to the importance of various strength qualities to agility performance. However, explosive force production is important for both attacking and defending agility. Reactive strength is especially important for agility techniques involving relatively short ground contact times e.g., running at higher speeds and performing shallower turns. Due to the variability of agility demands in invasion sports, a holistic strength program is warranted.

In the absence of athleticism, some athletes can still be highly agile on the field, likely due to their superior perceptual and cognitive skill (e.g., fast thinkers). Therefore, cognitive function can distinguish higher standard players from their lower standard counterparts. The ability to anticipate opponent's actions is important, and can be influenced by visual scanning, the capacity to recognise patterns of play, and the capability to predict outcomes of surrounding players movements based on situations. These skills can be developed by one vs. one activities, small-sided games and video-based training.

Due to the interaction between the athlete, environment, and task, agility is varied and complex. Consequently, there is unlikely to be a single coaching methodology to best develop agility. There is merit in training that emphasises repetition with external instructional cues, but also in methods that foster learning via exploration of movement solutions by designing athlete, environment, and task constraints. Ultimately, coaches are recommended to apply coaching methods that suit the characteristics and needs of their individual athletes.

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