TRAINING AND TESTING OF 1V1 AGILITY IN AUSTRALIAN FOOTBALL

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<tr>
<td>2D</td>
<td>2-Dimensional</td>
</tr>
<tr>
<td>3D</td>
<td>3-Dimensional</td>
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<tr>
<td>ACL</td>
<td>Anterior cruciate ligament</td>
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<tr>
<td>AF</td>
<td>Australian football</td>
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<tr>
<td>AFL</td>
<td>Australian Football League</td>
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<tr>
<td>BMC</td>
<td>Bloomfield movement classification</td>
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<tr>
<td>COD</td>
<td>Change of direction</td>
</tr>
<tr>
<td>CODS</td>
<td>Change of direction speed</td>
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<tr>
<td>COM</td>
<td>Centre of mass</td>
</tr>
<tr>
<td>CSV</td>
<td>Comma-separated-values</td>
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<tr>
<td>FPS</td>
<td>Frames per second</td>
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<tr>
<td>GRF</td>
<td>Ground reaction force</td>
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<tr>
<td>ICC</td>
<td>Intra-class correlation coefficient</td>
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<tr>
<td>PX</td>
<td>Pixels</td>
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<tr>
<td>RAT</td>
<td>Reactive Agility Test</td>
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<td>SD</td>
<td>Standard deviation</td>
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SSG ........ Small-sided games
ABSTRACT

Little is known of how agility events occur in the sport of Australian football (AF). As a result, appropriate training and testing methods are unknown. This thesis investigated 1v1 agility in AF to evaluate alternative methods for training and testing agility. The thesis was undertaken in three studies.

Study one investigated if training and testing practices used in elite AF align with the demands of competition. A notational analysis revealed substantial variation in movement patterns used by, and the cognitive demands of, athletes in agility events. A survey of high-performance managers in the AFL revealed that a mixture of open and closed training methods are used in elite AF, and that subjective agility assessment is preferred to formal testing.

Study two assessed the reliability and ecological validity of a field-based test of attacking and defending agility for AF. The test exhibited excellent inter-rater and intra-rater reliability, as well as moderate test-retest reliability. Characteristics of the test were compared to the notational analysis to assess the ecological validity of the test. While the test did not fully replicate the agility demands of AF, the test improved ecological validity when compared to previous tests described in the literature.

Study three evaluated the effectiveness of a four-week 1v1 training intervention for improving attacking and defending
agility in Australian footballers. In addition, the study assessed the crossover of attacking training to defending agility and defending training to attacking agility. Improvements in attacking agility were found which were greater for attacking-trained athletes. However, no improvements in defending agility were realised.

This thesis indicates that 1v1 training and testing is suitable for assessing and developing agility in Australian footballers. However, 1v1 training may be more suitable for improving attacking agility. Further, agility is context-specific, and testing and training should consider the role of the athlete.
STATEMENT OF AUTHORSHIP

Except where explicit reference is made in the text of the thesis, this thesis contains no material published elsewhere or extracted in whole or in part from a thesis by which I have qualified for or been awarded another degree or diploma. No other person’s work has been relied upon or used without due acknowledgement in the main text and the list of references of the thesis. No editorial assistance has been received in the production of the thesis without due acknowledgement. Except where duly referred to, the thesis does not include material with copyright provisions or requiring copyright approvals.

January 2020

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Part I

MAIN BODY
INTRODUCTION

1.1 BACKGROUND

Agility, defined as “a rapid whole-body movement with change of velocity or direction in response to a stimulus” (166) is a vital component of sports performance. In the context of invasion sports, including Australian football (AF), agility serves a multitude of purposes both inside and outside of attacker/defender scenarios. For example, during a turnover, an athlete is required to change direction to reposition on the field in response to the changing environment. Also, due to the irregular shape of an Australian football, unpredictable ball movements are frequent and may create agility events in multiple ways. Athletes must often react and change direction in response to the unpredictable bounce of the ball, a ricochet, or a misguided kick. However, attacker/defender scenarios whereby the attacker must attempt to evade a defender are common and often result in a significant impact on the game. AF, like some other invasion sorts, is 360 degree, and chaotic in nature, despite the use of set structures and plays. Since the overall objective of the defending team in AF is to dispossess the attacking team, numerous contests result in agility events. The ability of an attacking team to maintain possession creates
scoring opportunities. At the same time, effective defensive agility in 1v1 events allows the defender to tackle or create pressure to create a turnover, thereby creating an opportunity to counter-attack \(212\). Due to the importance of 1v1 agility on the outcome of AF games, this PhD is limited to attacker/defender 1v1 agility scenarios. The above definition implies that agility is contingent upon the perceptual information available to the athlete. Indeed, in an agility scenario, the movement of one athlete is dependent on the movement of their opposition, creating a fundamental relationship between the athlete’s perception of his/her environment, and the movement that the athlete adopts. The athlete must be able to anticipate their opponent’s movements and quickly and accurately respond to changes in the environment while demonstrating the physical capacity to change direction or speed rapidly. Unfortunately, this complex integration of cognitive and physical agility components has not been recognised in the majority of literature. Rather, research has primarily focused on the physical quality of change of direction speed (CODS), independent of cognitive influences \(20, 103, 104, 211\).

The reduction of agility to its physical and technical components has likely been preferred due to the immediacy of its application to the field of strength and conditioning. If agility may be understood and improved purely by its physical and technical factors, the role of a strength and conditioning coach in the development of agility is clear. However, by removing the cognitive element of an agility task, an athlete’s perceptual landscape is modified and, the athlete’s movement
strategy is fundamentally altered (23, 89). Therefore, a focus on the physical and technical components of agility, without regard to the cognitive environment that influences them may be insufficient. For this reason, this PhD examines agility from an ecological dynamics perspective (160).

Ecological dynamics combines dynamical systems theory with ecological psychology to produce a framework which treats athletes and their environment as interconnected parts of the same system (8). It is understood that athletes are influenced by their environment while simultaneously influencing the environment around them. Agility performance is affected by the context that the scenario occurs in, and the behaviour of the opposing athlete. This is in line with current research which has demonstrated the situation-specific nature of agility (21, 195).

While agility is believed to be important for AF (212), little is known about how agility events occur in game. Only one study has described agility events in AF by means of notational analysis by describing the angle of sprinting directional changes in-game (41). The study showed that the majority of changes of direction while sprinting occurred to an angle of fewer than 90 degrees. However, as sprinting accounted for only 4-6% of movement time by on-field athletes, it is likely that the study did not describe the majority of agility scenarios. Nevertheless, some notational analyses exist that have described changes of direction in other invasion sports (19, 74, 122, 133, 152, 153, 193–195). Consistent findings throughout the notational analysis literature in rugby union, soccer, and netball have been that slight changes
of direction (<90 degrees) are more frequent (19, 74, 122, 133, 152, 153, 193–195) and that the side-step is the preferred movement technique (122, 153, 193, 194). However, all notational analysis to notate the preferred movement technique at all speeds have occurred in rugby union (122, 153, 193, 194), and therefore agility movement characteristics in AF are unknown. Further, the notational analysis literature has not distinguished between attacking and defensive agility; as the roles of attacking and defensive athletes differ, movement characteristics between these two roles will likely be dissimilar. Finally, the cognitive demands in agility scenarios have not been described, leaving the context of directional changes unclear. By evaluating movement patterns and their context during agility scenarios in the AFL, this PhD will provide an understanding of AF specific agility demands.

1.2 AGILITY TESTING

In laboratory-based “agility” research, the majority of the literature has used CODS testing whereby the athlete is required to sprint along a pre-determined path, directed by obstacles, as fast as possible (131). In the sport of AF, the AFL planned agility test is used at the professional level for the purposes of talent identification (214). However, due to the lack of a cognitive component to the test, the test is not a test of agility, but rather, is a test of CODS. The test has not been developed to be specific to the movement patterns or technical demands inherent in AF. Further, research which has compared
CODS testing to agility tests has shown a lack of validity in CODS test results (165, 207, 208). As a result, to assess agility, the use of an agility testing method which incorporates both the physical and cognitive aspects must be used. To this end, some research has incorporated a stimulus in agility testing protocols (60, 73, 82, 97, 115, 155, 157, 162, 165, 207), however, in laboratory testing, movement patterns have been fixed, and the stimulus provided to attacking and defensive athletes has often been generic in nature (60, 73, 82, 97, 115, 155, 157, 162, 165, 207). Further, most testing methods have not distinguished between attacking and defensive athletes, compromising the ecological validity of the test results. To improve on previous testing methods, a test that incorporates sport-specific stimuli and produces movement patterns similar to those seen in AF is needed. While the importance of a sport-specific stimulus has been demonstrated in the literature (156, 207), prior to this PhD, movement patterns produced during agility scenarios in AF were unknown. As a consequence, little agility training research exists that adequately assesses improvements in attacking and defensive agility. This constitutes a significant lack of knowledge to practitioners in the field who are unable to provide evidence-based agility training to their athletes.

Some laboratory-based research in ecological dynamics has described 1v1 agility while investigating dyadic systems (80, 134, 135). This research has used collective variables that describe interactions between athletes to capture collective behaviours that may not be evident when assessing athletes in isolation (80, 134, 135). This research has demonstrated that the
stability of attacker-defender systems are compromised at small interpersonal distances (80, 134, 135). That is, when attackers and defenders are too far apart, attackers do not attempt evasive manoeuvres, likely due to the defender’s increased time available to respond. While this research has demonstrated the ability for collective variables to describe agility events through a dynamical systems lens, this research is in its infancy. To better explain agility as it occurs in-game, there is a need for more research which analyses attacker-defender agility events with the attacker-defender system intact.

1.3 Agility Training

Training methods that allow the attacker-defender system to remain intact may be likely to improve agility performance. By providing athletes with information-rich game-like scenarios, athletes may be able to regulate their movement based on information provided by their sporting environment. In addition, by training in variable training tasks, athletes are able to search for functional movements that address the needs of the agility scenarios faced in-game. One effective agility training method that allows for variation in information-rich scenarios is small-sided games (SSG) (214). Improvements in agility in SSG can likely be attributed to context-specific cognitive improvements in performing athletes (38). By practising in a representative environment, it is likely that athletes in SSG become attuned to the properties of their
performance environment that allow for successful agility movement (160). In an environment deprived of the key features that determine agility movements, it is likely that learning may be hindered. Nevertheless, while SSG has been demonstrated to be effective for improving agility (214), SSG training may unevenly expose some athletes to more agility events than others. This may hinder learning for athletes exposed to a low number of agility events. Therefore, 1v1 training may be a viable alternative that allows the necessary perceptual information to be maintained while allowing for a large number of agility events to be practised. Nevertheless, no training studies that assess the use of 1v1 training interventions exist in the literature.

Despite a significant body of agility research, numerous gaps exist in the AF agility literature, which may hinder agility development for coaches. It is currently unknown how agility events occur in AF, or how they are currently trained or tested. Therefore, it is unknown if current testing methods assess agility in a manner representative of the sporting environment. In addition, it is unknown if 1v1 training methods can improve agility performance in Australian footballers. This PhD aimed to fill the mentioned gaps by determining the movement patterns used during agility scenarios, and training and testing methods used in elite AF. This information was then used to assess an attacking and defensive agility testing protocol which observes athlete interactions during 1v1 scenarios. By determining if movement patterns observed during the test are similar to those encountered in AF matches, the ecological validity of this testing
procedure was assessed. Finally, the PhD used information from the first two studies to assess the effectiveness of 1v1 training. One versus one training is a method which reduces the agility event into a simulated 1v1 dyadic sub-phase to allow the athlete to respond to a simplified sport-specific stimulus in order to elicit an improvement in agility.

1.4 RESEARCH QUESTIONS

Based on gaps identified above, this project sought to answer the following research questions.

*Study 1: Do current agility training practices in elite Australian football align with the demands of competition?*

1. What are the characteristics of agility scenarios in AF?
   a) What footwork patterns are used in agility scenarios during AF matches?
   b) What are the cognitive demands of agility scenarios during AF matches?
   c) What are the differences between attacking and defensive agility during AF matches?
   d) What is the association between outcomes and movement patterns? (Outcome is either success or failure)
2. What are the current agility training practices implemented by physical preparation coaches in elite AF?
   
a) What footwork patterns are used?

b) Do training methods used in elite AF reflect the agility demands of AFL matches?

**Study 2: Reliability & validity of field tests of attacking & defending agility**

1. Is a field test for attacking and defending agility in AF valid and reliable?
   
a) What is the test re-test reliability of the field-based test?

b) What is the inter-rater reliability of the field-based test?

c) What is the intra-rater reliability of the field-based test?

d) Are movement patterns used in the field-based tests the same as seen in the game? (ecological validity)

**Study 3: Evaluation of 1v1 agility training**

1. Is 1v1 training effective in improving attacking and defending agility in Australian footballers?

2. Does attacking training improve defending agility?

3. Does defensive training improve attacking agility?
1.5 SIGNIFICANCE OF THE THESIS

While there is a substantial body of agility literature, minimal literature has described agility events that occur at submaximal intensities in AF, and subsequently little is known about the presentation of agility in matches. Further, as no research has sought to understand the training and testing of agility that occurs in professional AF clubs, it is unknown if the training and testing that clubs undertake reflects the demands of the game. This PhD seeks to understand the characteristics of agility, and how agility is trained and tested to, in turn, develop suitable training and testing methodologies. Recent research has identified attacking and defensive agility as unique skills in invasion sports (212); however, no research has assessed the validity and reliability of a suitable test to assess this skill. As a result, appropriate training and testing methodologies are currently not fully understood. The assessment of a 1v1 field-based test of agility and the development of a subsequent 1v1 training procedure will provide a valuable foundation for coaches, sport scientists, and researchers looking to improve agility in AF. 1v1 training may be an appropriate training method for agility development; however, no literature currently exists that assesses its effectiveness. This PhD assesses a 1v1 training intervention to guide practitioners wishing to use this methodology to develop agility in their athletes.
1.6 Thesis Organisation

This thesis has been structured to address the training and testing of 1v1 agility in Australian football. The following chapter is an in-depth review of the current literature pertaining to 1v1 agility in Australian football. It discusses previous agility training and testing research, both in Australian football as well as similar invasion sports, while discussing likely mechanisms for the development of 1v1 agility. The literature review was used to inform chapter 3, which investigates the nature of 1v1 events in AF and how they are currently trained and tested. By understanding how agility occurs in AF, a field-based test of 1v1 attacking and defensive agility was refined. Chapter 4 addresses the inter-rater reliability, intra-rater reliability, and validity of a new field-based test of the 1v1 attacking and defending agility designed to address limitations with previous testing methodologies. This test was then implemented to assess 1v1 training for the development of 1v1 attacking and defensive agility in AF in Chapter 5. The final chapter is a discussion and summary of the results from this PhD, followed by practical applications for coaches and suggested directions for further research. All references are presented at the conclusion of chapter 7.
1.7 THEORETICAL FRAMEWORK

A useful framework to integrate ideas from dynamical systems theory to agility training and testing is ecological dynamics. This framework combines dynamical systems theory with ecological psychology to provide an explanation for human coordination at the athlete-environment scale (8, 160, 216). Key to this approach is the idea of direct perception (69). That is, athletes perceive rich information about the environment that does not require further cognitive processing. In movement contexts such as agility events, athletes move in response to this incoming perceptual information, and as a result of this movement, the perceptual information itself changes (69). For example, in a 1v1 scenario, an attacking athlete will move based on their visual information of the defensive athlete, but by moving will gain further information about new movement options. From the perspective of agility, training tasks which maintain this relationship between perception and action allow athletes to practice with the key information sources necessary for performance.

In ecological dynamics, the movement options that are available to the athlete in their environment are called affordances (8, 53, 68, 69). As athletes and performance environments differ, and dynamically change, the concept of affordances is useful in capturing the functional relationship between the athlete and their environment (53). In the case of agility in AF, the movement strategies used by the athlete are
affected by the physical and psychological characteristics of the athlete and their opponents, as well as the situational specifics of the game. For example, an athlete who is confident in their physiological capacity to perform a powerful side-step may be more likely to attempt to side-step past an opponent rather than disposing of the ball. However, as the in-game scenario will dynamically evolve, so will the athlete’s affordances, and by extension, their movement solution. The affordances available to athletes must be considered when designing testing and training activities (53, 142).

Although not expressly agility research, some research has been conducted using the theory of ecological dynamics to examine attacker-defender scenarios (80, 134, 135). As such, this research has used a systems framework for the analysis of agility. This approach to agility research allows for the examination of agility scenarios inside their sport-specific context instead of a non-specific environment. By using variables that collectively describe the behaviour of the attacker and defender simultaneously, such as interpersonal distance and velocity, this research has analysed collective behaviour that may not have been evident in isolation (80, 134, 135). Therefore, the research has maintained a representative design whereby athletes may respond to game-like affordances (24). The sport-specificity of the testing environment has been shown to be an important factor when testing agility performance (60–62, 155–157, 165, 188, 207, 212). Despite ecological dynamics advantages as a framework for analysing agility performance, little agility research exists which has used this framework.
1.8 ASSUMPTIONS

- Characteristics of agility events in the analysed games are typical of elite AF agility events.

- Survey participants responded to the survey honestly.

- Participants undertook training and testing with maximum intensity.

- Participants were honest regarding their caffeine consumption prior to testing and training.

- The training and testing procedures were fully understood by all participants.

- The standardised warm-up used prior to training and testing was adequate.

1.9 DELIMITATIONS

- The cohort of the notational analysis was professional male athletes.

- The cohort of respondents in the survey were high performance managers of elite AF clubs. Perceptions of training and testing practices may differ for other personal in the club.

- The cohort of the reliability and validity study was recreationally trained male athletes.
• The cohort of the 1v1 training study was recreationally trained male athletes.

• The results of the 1v1 training study are specific to the exact training protocols used. Training effects may vary based on intervention duration, training frequency, in-session volume, and rest.

1.10 LIMITATIONS

• Some respondents of the survey have authored agility research at Federation University Australia, as such, their responses may have been influenced by this previous experience.

• 8 high-performance managers in the AFL did not respond to the survey and may use different training and testing methodologies.

• Other than caffeine, participant dietary intake was not controlled during the training study.

• Recovery practices were not controlled during the training study.

• The use of recreationally trained athletes allowed for room for improvement in the training study compared to elite athletes.

• As research was conducted at a university, the majority of participants were university students themselves, and
results may not necessarily be applicable for all demographics.

- The reliability and validity, and training study were performed indoors on a synthetic rubberised floor to remove the effects of weather on the research. Performance may differ in an outdoor, field-based environment.

- The sample sizes in all studies were restricted by the availability of participants. Therefore, there may be an increased chance of type 1 and type 2 error.

- Testers used in training and testing may have become fatigued over the study period.

- Testers may have improved by undertaking multiple testing trials.

- As no previous 1v1 training studies exist, no specific research existed to guide the details of the intervention study.
LITERATURE REVIEW

2.1 INTRODUCTION

As discussed in the introduction, agility is “a rapid whole-body movement with change of velocity or direction in response to a stimulus” (166), which implies that a stimulus must be present to be considered an agility event. The ability to produce a rapid COD independent of a stimulus is a separate skill referred to as change of direction speed (CODS). A recent paper by Young, Dawson and Henry (205), adapted a model from previous research (210) to break the skill of agility during invasion sports down to its component parts. While this model appears to isolate agility performance into cognitive, physical and technical factors; change of direction does not occur in invasion sports without a stimulus present. Therefore, research which has trained and tested CODS in isolation to agility, attempting to infer changes to agility performance, compromises ecological validity (82, 165, 213). The majority of the literature described as agility research refers to CODS and will not be reviewed in detail in this thesis.
2.2 DIFFERENCES BETWEEN ATTACKING AND DEFENDING AGILITY

As the aims of attacking and defensive agility in 1v1 events differ, separate strategies and movement patterns are used (211). An attacking athlete must evade their opponent to move the ball towards the opposing goal for a subsequent scoring opportunity. Meanwhile, the defensive athlete must attempt to reduce space from their opponent and create pressure or tackle to produce a turnover. Therefore, an attacking athlete may use deceptive actions to mislead their opponent; however, deception by defending athletes is likely uncommon. Despite differences in objective, most agility research has concentrated on defensive agility while neglecting attacking agility (60–62, 64, 154–157, 165, 188, 212).

Just two studies have used an comprehensive and ecologically valid methodology that is specific to attacking agility (48, 212). The papers revealed a common variance of 24% and 45% between attacking and defensive agility, indicating a distinct difference between the two skills. As such, it is possible that ideal training methods for the two skills will differ and should be trained and tested independently. More research which compares both skills is needed to confirm this hypothesis.
2.3 LIMITATIONS OF A REDUCTIONIST APPROACH TO AGILITY

Reductionism refers to the concept that high-level ideas can be reduced to their component parts (109). This idea can take many forms, but this literature review is concerned with the limitations of inter-level reductionism of agility (7); that is, the limitations of reducing agility to its component parts and investigating them independently.

The shortcomings of a reductionist approach to scientific research have been well discussed throughout the literature (7, 109). In the case of agility, a reductionist approach would assume that by understanding the cognitive, physical or technical factors of agility in isolation, an understanding of agility as a whole is developed. While this approach may provide some insightful information, such as the identification of factors that may influence agility performance, it ignores the complex interaction between physical, technical, and cognitive components of agility. In AF, agility scenarios never occur in isolation but rather in response to the environment around the athlete, and environmental stimuli modify the physical technique used by the athlete to change direction (23, 89). This, in turn, may influence the physical expression of force production by the athlete.

Nevertheless, due to the dominant reliance on a reductionist approach to agility research, a plethora of CODS studies have been published which claim to provide insights to
agility (20, 103, 104, 211). Recent research has questioned the validity of a reductionist approach (82, 165, 208, 213). Instead, testing methods which allow for all components of agility to be expressed simultaneously have been proposed (15, 55, 60–64, 73, 82, 115, 132, 154–157, 161, 162, 165, 175, 188, 208, 212).

As the reductionist approach appears to be inappropriate, a different method of thinking must be used to understand agility. Holism refers to the contrasting approach to reductionism. In the context of agility, that is, rejection of the idea that agility can be analysed as the sum of its component parts (7). The development of systems thinking has emerged as a way to approach scientific enquiry holistically. Dynamical systems theory has been proposed as an appropriate systems-thinking model for understanding agility (86, 95). Unfortunately, the literature fails to describe the use of dynamical systems theory for agility research in detail, with just one paper claiming to describe a dynamical systems approach to training agility. However, outside of the title, dynamical systems was not mentioned (86). Therefore, more research is required to conceptualise the framework of dynamical systems theory to agility training.

2.4 Characteristics of AF

AF, a popular sport in Australia (36, 99), is a team-based, field, invasion sport played on a large, oval-shaped playing field. During a match, two teams compete over four 20-30-minute
quarters. Eighteen athletes per team are permitted on the field at any one time, with four additional athletes on the bench (71). During recent times, teams have been described as consisting of three fixed forward, three fixed backs, 11 nomadic players and one ruckman (99). The primary aim of fixed forwards is to receive possession and kick goals, nomadic players must move the ball from defence towards the attacking goals, and may also kick towards goal; while fixed backs primarily defend the goal to prevent the opposition from scoring. To force a turnover, tackling of the ball-carrying athlete is permitted between the knees and shoulders. Once tackled, the ball carrier must immediately kick or punch the ball with a closed fist, or a turnover is granted.

Physiological qualities of Australian footballers have been identified as important for success and individual career progression (25, 67, 145, 200, 203). Lower-body power, aerobic, endurance, speed, acceleration, and agility have all been shown to be important qualities for AF, and are developed by strength and conditioning coaches in clubs. However, agility is unique to other physical qualities due to the degree of cognitive influence (166). Due to the large playing area and the high number of athletes on the ground at once, agility events in AF are varied, and stimuli may occur from any direction around a footballer’s body. The complexity of agility in AF may likely be greater than other invasion sports which use more structured playing formations such as rugby codes. However, more research is required as details of the specific movement demands in AF agility events is limited.
2.5 NOTATIONAL ANALYSES OF AGILITY EVENTS

Some notational analyses exist which have aimed to describe movement patterns used in agility events in sport (19, 41, 74, 122, 152, 153, 193, 194). However, many limitations exist in the current literature. Some notational analyses have described changes of direction in sport using the Bloomfield movement classification (BMC) (19), a tool for noting all purposeful turns. While the BMC is useful for describing the movement demands of sport by notating all purposeful turns, it is difficult to understand the nature of the agility event. Some purposeful turns in-game will occur in response to a direct opponent, but, changes of direction outside of the direct ball contest, in response to changes in the overall game dynamics, will also occur. Further, the BMC does not differentiate between attacking and defending agility, which, in invasion sports are independent skills and may have different movement strategies (212). While research in rugby union has differentiated between attacking and defending agility, all descriptions of agility technique have focused entirely on attacking agility, with no literature describing the agility demands of defensive agility (122, 152, 153, 193, 194). Therefore, research which enables practitioners to understand the movement demands of defensive agility is necessary.

Of the agility notational analyses that exist, only four studies have described the choice of agility footwork techniques used by athletes, all in the sport of rugby union (122, 152, 193,
In this research, the side-step has been consistently identified as the most commonly used footwork technique. However, in AF, agility events can occur from all angles, while in rugby union, an offside rule exists which prohibits players from assisting with play when in-front of their ball-carrying team-mate, resulting in more front-on agility scenarios. Therefore, as the demands of AF differ to those of rugby union, it is possible that different footwork techniques may be frequently used in AF.

Just one notational analysis, conducted more than 15 years ago, has described the movement patterns in AF agility events. The analysis described the angle of all lateral movements undertaken while sprinting for one player in each AFL game played in Perth in the 2000 AFL home and away season. Movement angles were recorded in discrete categories, and results demonstrated that the majority of sprints involved a COD of <90 degrees. This preference for slight changes of direction is consistent with notational analyses from soccer and netball. Nevertheless, as the article limited the notation of agility events to those occurring while sprinting, and agility events likely occur at a variety of speeds, many agility events may not have been captured. Therefore, it is possible that the data does not accurately represent all agility scenarios. In addition, while the literature has described multiple footwork patterns that may be used in agility events, the footwork patterns used by athletes in the study were not recorded, and are currently unknown. Finally, attacking and defensive agility were not differentiated, and it is
unknown if differences identified in a laboratory setting exist in AF games.

2.6 Physical Muscle Qualities

2.6.1 Leg Muscle Qualities

Research exists which has discussed the role of leg muscle qualities on agility (e.g. 173, 175, 211). However, the majority of "agility" research which examines leg muscle qualities has been conducted using CODS testing (e.g. 27, 43, 88, 101, 118, 130, 139, 181, 182, 199). By looking at only the leg muscles in isolation, a simplified view of agility has been used (206). It is possible that ground reaction forces (GRF) from a lateral lower-body push may not transfer to the whole body lateral movement efficiently due to energy loss through the kinetic chain (206). Furthermore, research using CODS does not provide practitioners with a complete understanding of agility as it relates to performance as it omits the cognitive component of the skill.

Many studies have examined the relationship between lower body strength and CODS (27, 43, 88, 101, 118, 130, 139, 174, 175, 181, 182, 199, 211). These studies have focused on eccentric, concentric, isometric and dynamic contractions, usually in isolation. One study compared all four strength qualities to each other and found a significant correlation between CODS and all types of strength (r=0.79 – 0.89) (175). Each strength quality likely contributes to a different extent
during each phase of a cutting manoeuvre. During the braking phase, eccentric strength is important to decelerate the athlete’s centre of mass (COM) \((72, 101, 171, 206, 210)\). Once decelerated, isometric strength and later concentric strength are used to control the manoeuvre and re-accelerate \((175)\). Of these strength types, in isolation, eccentric strength is the strongest predictor of CODS performance \((175)\). Nevertheless, in a cutting manoeuvre, the athlete must absorb an eccentric load, and perform a subsequent re-acceleration. This capacity which encapsulates all three phases, is discussed in more detail in a later section.

Overall, the current literature suggests that leg strength plays an important role in CODS performance. However, agility research has not shown a strong relationship with strength \((173, 211)\). Instead, a small relationship between agility and lower leg strength has been found \((r = 0.12)\) \((211)\), with strength unable to distinguish between higher and lower performers \((p > 0.05)\) \((173, 211)\). Furthermore, when comparing the correlation between strength and a CODS or agility task, a stronger relationship with strength has been found to CODS than agility \((175, 211)\).

2.6.1.1  Power

During a cutting manoeuvre, depending on entry velocity and COD angle, athletes spend little time on the ground \((0.23-0.77 \text{ s})\) \((14, 119, 172, 173)\). Therefore, as force production must be rapid, it is likely that lower body power is important for changes of direction which occur during agility events. Nevertheless,
while research assessing the role of power on CODS is abundant in the literature (14, 43, 88, 116, 118, 120, 127, 189, 209, 210), considerably less agility research exists (9, 48, 81, 120, 175, 211). Research which explores the relationship between leg power and agility is summarised below in Table 2.1.

<table>
<thead>
<tr>
<th>Study</th>
<th>Agility Test</th>
<th>Power Test</th>
<th>Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Henry et al. (81)</td>
<td>Video-Based RAT</td>
<td>CMJ&lt;sub&gt;Height&lt;/sub&gt;</td>
<td>r=-0.28</td>
</tr>
<tr>
<td>Spiteri et al. (175)</td>
<td>Video-Based RAT</td>
<td>CMJ&lt;sub&gt;Force&lt;/sub&gt;</td>
<td>r=-0.2</td>
</tr>
<tr>
<td>Young et al. (211)</td>
<td>Video-Based RAT</td>
<td>CMJ&lt;sub&gt;Force&lt;/sub&gt;</td>
<td>r=0.12</td>
</tr>
<tr>
<td>Matlák et al. (120)</td>
<td>Matlák Agility Test</td>
<td>CMJ&lt;sub&gt;Height&lt;/sub&gt;</td>
<td>r=-0.32 - 0.24</td>
</tr>
<tr>
<td>Drake et al. (48)</td>
<td>Field-Based 1v1 Test</td>
<td>CMJ&lt;sub&gt;Force&lt;/sub&gt;</td>
<td>Att: r=0.41</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Def: r=0.27</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Com: r=0.4</td>
</tr>
<tr>
<td>Åslin (9)</td>
<td>Åslin Agility Test</td>
<td>CMJ&lt;sub&gt;Force&lt;/sub&gt;</td>
<td>r= 0.08 - 0.16</td>
</tr>
</tbody>
</table>

CMJ<sub>Force</sub> = Relative power (W·BW<sup>-1</sup>), CMJ<sub>Height</sub> = Vertical jump height, Att = Attacking agility, Def = Defending agility, Com = Composite agility (Att+Def)

Research using Y-shaped agility tests to compare the correlation between leg power and agility has shown small to trivial correlations (r=0.12 – r=0.28) (81, 175, 211). However, more recent research which has used field-based agility testing protocols has shown a medium correlation between attacking agility and leg power (r=0.41), but small correlations between defending agility and leg power (r=0.27) (48). This finding suggests that strength qualities are expressed to a greater extent in = attacking agility than defending agility. As discussed in previous research concerning reactive strength (212), this is likely due to the need for attacking athletes to perform more powerful side-steps at a higher velocity. In the 1v1 agility test, an attacking athlete may perform a powerful change of
direction in an attempt to evade their opponent, whereas a defending athlete is more likely to perform smaller directional changes to corral or maintain a good position to react to changes. While this research provides valuable information for practitioners aiming to better understand agility, research discussing leg power and agility is sparse and more research is needed to better understand the relationship between the two qualities.

2.6.1.2 Reactive Strength

During an on-field agility scenario, the athlete must change direction rapidly, and in doing so, spend minimal time in contact to the ground (172, 173). This indicates that the athlete’s leg musculature must rapidly decelerate and subsequently accelerate the athlete’s COM, thereby using the stretch-shortening cycle. This ability for a muscle group to rapidly change from an eccentric to a concentric contraction is referred to as reactive strength (204). Therefore, reactive strength may be important to agility performance.

Due to the requirement to absorb an eccentric loading and produce a subsequent concentric contraction in the lower leg, the drop jump test is a widely used measure of reactive strength (43, 209–211). Despite much research in COD (209, 211), just two studies have examined the relationship between reactive strength and agility (211, 212). Nevertheless, in the existing literature, reactive strength has shown a varied correlation with defensive agility (r=-0.10 to r=0.63) with one
study finding a small correlation (211) and an alternate study finding a large correlation (212). Just one paper has examined the relationship between reactive strength and attacking agility (212) and found a very large correlation between the two measures ($r=0.73$). The authors hypothesised that leg muscle function might be expressed to a greater extent during an aggressive side-step when aiming to evade a defender. However, a defender may use less powerful footwork patterns such as corralling, which do not allow for the same expression of leg muscle function. Nevertheless, while preliminary evidence suggests reactive strength may be more important for attacking agility than defensive agility, more research is needed in this area. Also, as agility manoeuvres are usually unilateral and horizontal, the drop jump test lacks specificity, and an alternate test may be more appropriate.

2.6.2  Core Strength

Core strength may contribute to agility as, during a COD, the lateral ground reaction force produces a shift in the athlete’s COM. It is likely that when performing this manoeuvre, a stiff trunk would allow efficient force transfer to the COM rather than absorption by a compliant trunk. Further, as a compliant trunk has been associated with increased anterior cruciate ligament (ACL) load and subsequent injury risk, improved trunk stiffness is likely to reduce ACL injury risk (94).
The core has been poorly defined, with multiple, ambiguous definitions published (85, 93, 215). This, along with a recent definition of agility, has made it difficult to appropriately assess the role of core strength in agility. As such, just one study has used appropriate testing to determine the contribution of core strength on agility (52). Researchers performed three-dimensional (3D) motion analysis during an agility test where athletes were required to respond to a generic light-based stimulus. Trunk motion relative to the pelvis was used to split participants into two groups based on trunk stability. Researchers found that participants with greater trunk stiffness were slower during an agility task than those with lower trunk stiffness. While contrary to the author’s hypothesis, it was suggested that decreased trunk stiffness might allow the athlete to better orientate their COM in relation to their base of support. Nevertheless, more research is needed, particularly using a more specific stimulus during the task. In addition, a training study would be useful in demonstrating the role of core strength on agility performance.

2.7 Technical factors of agility

Agility requires complex manipulation of the athlete’s body in order to produce an efficient and rapid COD. As such, technical factors such as foot placement, stability and posture, as well as correct movement pattern choice, are likely important to agility.
While research exists which has examined biomechanical factors of unplanned cutting tasks \((23, 112)\), the majority of this research concerns knee injury prevention. Nevertheless, one article has sought to compare attacking agility technique with COD technique in rugby union athletes \((195)\). This study measured COM velocity and foot position during side-stepping and the previous step. Researchers found that while COM velocity was slower in agility scenarios; athletes faster in an agility task displayed faster COM velocity compared to slower performers. Furthermore, athletes who performed worse at the agility task displayed greater lateral foot displacement, that is, their foot was planted further from their COM.

The effectiveness of three attacking movement patterns during AF was investigated in a 2011 study \((21)\). The techniques analysed were the side-step, shuffle, and split-step; three agility techniques thought to be common in AF. The study found the split-step to be most effective despite the increased time needed to complete the manoeuvre. It was suggested that its effectiveness was due to the ability of the attacker to disguise their movement direction, thereby delaying specifying information to the opponent. Despite this finding, the authors noted that the split-step is likely not the optimal technique choice in all situations, highlighting the situational specificity of agility and the need for more research in this area.
2.7.1 Linear Speed and Acceleration

In a model of factors that determine agility in invasion sports, straight speed and acceleration were highlighted as agility components (205). As such, research assessing the relationship between these measures and agility is worth undertaking (60, 61, 115, 165, 211). Of the available research, sprints between 5 metres and 40 metres have been used. As only short distances have been assessed, athletes are unlikely to reach top speed and, as such, these studies have assessed acceleration. Nevertheless, three studies found a significant relationship between agility and short sprints (10 and 20m) with moderate correlations (r=0.33 to r=0.49) found using a 10m sprint (61, 115, 165) and a large correlation (r=0.51) when using a 20m sprint (61). Studies which have assessed both agility and CODS’s relationship with acceleration have found a higher correlation with CODS than agility (61, 115, 165, 211). Therefore, it is likely that acceleration contributes more to CODS than agility. This may be due to the time contribution of increased cognitive demands causing an increase in total completion time and therefore reducing the contribution of acceleration.

2.8 Cognitive Factors of Agility

Agility is distinguished from CODS due to the inclusion of a cognitive component (166). It is this component which has been noted in the literature as the factor responsible for
distinguishing between higher and lower performers (157). Furthermore, when researchers have tested athletes of varying standards using an agility and CODS test, agility has been able to discriminate between higher and lower performers (115, 162, 165, 208). Therefore, a review of the cognitive components identified by the 2015 model of factors that determine agility in invasion sports (205) is of importance. These factors include visual scanning, anticipation, pattern recognition, and knowledge of situations.

2.8.1 Anticipation

Anticipation is defined as the ability for an athlete to make accurate predictions from incomplete sources of visual information (123). This quality is important as, in an AF agility scenario, athletes are required to make rapid decisions based on limited visual input. Therefore, it would seem that by anticipating future actions, an athlete can make faster, more precise and appropriate agile manoeuvres. For example, a defending athlete wishing to tackle an attacker may be better able to be in an ideal position if they detect movement cues from the attacker quicker and subsequently make an earlier response.

In a 2009 review, anticipation is identified as an overarching cognitive skill which incorporates pattern recognition, visual scanning, and the ability to predict outcomes.
due to knowledge of situations (197). These components will be discussed separately as sub-components of anticipation.

2.8.1.1 Pattern Recognition

The ability to draw upon past experience to recognise familiar patterns would likely be of benefit for improving agility. In the context of AF, exposure to regular games would allow athletes to predict movements of other players and make an appropriate subsequent decision. For example, an attacking athlete may decide to evade their team members’ future location if they have seen the scenario previously.

The majority of pattern recognition research has been conducted outside of a sporting context (12, 140). However, some sport research does exist, to which meaningful interpretations can be made (4–6, 65, 66, 126, 178, 196). The process of pattern recognition is believed to occur due to ‘chunking’ of stimulus in the brain (159, 198). Through this process, multiple segments of information are perceived as a whole, thereby allowing one stimulus group to be more easily interpreted. By speeding up the process of stimulus recognition, the familiar scenario places less mental burden on the athlete, freeing up mental resources for the other tasks. Furthermore, a response to a particular chunk may be coupled to a resulting movement, thereby resulting in a rapid action (198).

Research into pattern recognition of board game players has highlighted the ability for expert performers to rapidly recognise familiar patterns of play indicating that expert
performers may be better able to recognise patterns that they are regularly exposed to (29, 30, 42). A seminal study into pattern recognition during chess required players to view familiar patterns on a chessboard for a short interval (29). Following this, expert players were significantly better at recalling board configuration. This study was then repeated with a second condition whereby performers were shown unfamiliar patterns (29, 30). When familiar patterns were presented, expert performers were more skilled at recalling board configuration, but when unfamiliar patterns were shown recall was identical between skilled and unskilled performers. This suggests that it is not short-term memory but rather a developed task-specific knowledge that improves pattern recognition.

Similar study designs have since been adopted in athletic populations and highlighted superior pattern recognition of advanced athletes in multiple sports (4–6, 65, 66, 126, 178, 196), including AF (16). This suggests that, when developing agility, it is important that a sport-specific stimulus is used to allow the opportunity to develop knowledge of patterns and improve recall. For example, SSG and 1v1 training interventions may allow athletes sufficient exposure to specifying information. Furthermore, when testing agility, the inclusion of sport-specific stimuli rather than generic stimuli would allow these familiar patterns to be used.
2.8.1.2 **Visual Scanning**

As agility scenarios typically occur under time constraints; the ability to optimise gaze behaviours may allow athletes to better assess relevant visual cues and optimise movement decisions. To assess the visual search capabilities of athletes, gaze fixation has been analysed to infer the athlete’s approach to extracting information from the environment (1, 3, 13, 78, 79, 117, 141).

Three distinct approaches have been used for visual search research; still-slide, film, and field-based approaches (198). In all approaches, eye movement has been tracked while observing sporting events to analyse gaze fixations.

Still-slide approaches have required participants to view slides depicting sporting situations and indicate their possible action as a result of the scenario (13). Slide approaches have been widely criticised for their inability to provide a relevant stimulus to the athlete (1). In an agility context, the lack of movement in still-slides prevents the athlete from focusing upon dynamic movements which may provide information about task outcomes. Film-based approaches have substituted still-slides with footage of sporting scenarios to create a more representative stimulus (78, 79). Although this allows athletes to view dynamic sporting scenarios, it reduces the scenario to a two-dimensional (2D) representation. As such, athletes are unable to use all relevant cues such as depth perception (3). To address the limitations of still-slide and film-based approaches, recent research has tracked eye movement of athletes during
field-based tests (141). This approach allows athletes to fixate on sport-specific 3D cues.

Consistent among visual scanning research is the finding that high-performing athletes perform fewer fixations before making a movement decision than their lower-performing counterparts (117). This may suggest that via more efficient visual scanning, expert performers are better able to fixate on relevant cues. Furthermore, when using video or field-based approaches, it appears expert athletes have longer gaze fixations prior to decision-making (117). This is contrary to still-slide research which shows expert athletes to use shorter gaze fixations.

The form of stimulus presented in research influences the ability of researchers to distinguish between higher and lower performers. One meta-analysis of visual scanning literature showed that field-based methods were most able to distinguish standards with video and still-slide stimulus able to make the separation to a lesser extent (117). This suggests that athletes rely on realistic visual cues to make movement-decisions. Therefore, the use of field-based measures that employ representative design should be preferred when conducting agility research.

The need for a relevant stimulus extends beyond the form of presentation to sport-specificity. When presented with a sport-specific visual stimulus, likely due to contextual differences, invasion sport athletes use fewer gaze fixations than athletes in other sports (117). This suggests that when testing and training
agility in Australian footballers, the visual stimulus must be representative of the sport.

2.8.1.3 Knowledge of Situations

By understanding common situations and the probability of subsequent outcomes, athletes are better equipped to produce rapid and accurate agility manoeuvres. Early research into this area showed that reaction time is slower during uncertain situations, but that uncertainty can be reduced through practice, thereby reducing reaction time (70).

This research has since been extended to include the sporting domain (54, 138, 192). Researchers found that greater knowledge of task-specific situational probability was possessed by expert performers. In the context of AF, this would suggest that a defender is better able to tackle by understanding the probabilities of a ball-carrier’s movements. Further, an attacker is better equipped to make accurate judgements on the defender’s movement, and anticipate future movements, to successfully evade.

2.9 Testing Agility

As mentioned previously, a valid testing procedure of agility requires a stimulus to be present. Multiple forms of stimuli have been used throughout the literature, including flashing lights, video stimuli as well as human stimuli (137).
2.9.1 Light Based Stimulus

Many studies have required the athlete to react to a light (15, 73, 82, 115, 132, 156, 161). A light stimulus is convenient as the introduction of the stimulus to the athlete’s visual field can be accurately controlled. As the use of a generic stimulus allows for a controlled testing environment, high reliability would be expected. Studies which have determined the reliability of generic testing procedures have reported intra-class correlations between 0.81 and 0.88 (15, 73, 82, 115, 132, 156, 161). According to Hopkins (87), this reflects very large reliability. One study has attempted to determine the reliability of a light-based agility test for Australian footballers (82). During this study, 12 athletes performed two Y-shaped, light-based agility tests, one week apart. Test-retest reliability was determined to be very high (ICC = 0.81).

Despite the advantage of a reliable procedure, the validity of a light-based stimulus has been questioned in recent literature (82, 137). One argument against light-based testing is the inability of the procedure to differentiate between playing standards. Some studies have shown a light-based testing procedure to be able to differentiate between higher and lower standard performers (73, 115) but this finding is not consistent (e.g. 82, 124). However, one study in AF, which found a light stimulus to be able to distinguish between playing standards showed the light stimulus to be inferior to a video alternative. One study which assessed teenage female field hockey players
was unable to differentiate between school/club athletes and those selected in a regional performance centre when using a light-based stimulus (124). However, this study was able to distinguish standards when a human stimulus was used. In a similar study in AF which compared a generic arrow stimulus to a video stimulus, a video stimulus was able to distinguish playing standards, but a generic stimulus was not (208). This finding may be due to the lack of sport specificity during generic testing protocols. When performing an agility manoeuvre during a game, athletes are required to recognise familiar, complex patterns relating to their sport (2, 207). The use of a generic stimulus does not allow athletes to read specific cues and anticipate movements. Therefore, the use of flashing lights in agility testing is likely inappropriate.

2.9.2 Video Stimulus

In an attempt to provide a more specific stimulus, some studies have used 2D video recordings of an athlete, sometimes in the scene with other athletes, performing a COD for the tested athletes to respond to (55, 63, 82, 163, 175, 208). By allowing the defender to respond to more specific cues, increased validity could be expected. While the use of video recordings allows for the precise control of timing to ensure that the stimulus is always identical when presented to different athletes. Some research has attempted to assess the construct validity of video-based testing methods by assessing the test’s ability to
differentiate playing standards (55, 82, 83, 208). In studies which have used projected videos of attacking athletes, the test has been able to distinguish standards. One paper which compared the projection of a generic stimulus (a pointing arrow) to a specific stimulus (footage of an attacking athlete), showed that the arrow projection was unable to differentiate standards while the projection of the athlete was (208). This suggests that superior agility performance is reliant on the inclusion of sport-specific stimulus in the visual field. The effect of a more sport-specific video stimulus has been assessed in the literature in multiple ways (83, 113, 114, 177). One study compared the effects of a feint on the ability for a test to distinguish between playing standards of Australian footballers (83). This study found that higher-standard players were more agile when faced with the increased temporal stress associated with a feint, whereas lower standard players’ agility skill deteriorated. Another study compared defensive agility using video stimulus of multiple attacking athletes to video footage of an individual athlete (113). The study found that, when presented with a more complex game-like scenario, the test was better able to distinguish playing standards. Furthermore, more game-like screen size as well as the inclusion of a 3D, rather than a 2D stimulus, all contributed to a greater ability to separate playing standards (114, 177).

The literature suggests that a sport-specific video-based stimulus improves the validity of the assessment compared to tests using a generic stimulus (207). While an improvement, this methodology is perhaps still an over-simplification of the agility
scenario seen in the field of play. Nevertheless, to expose athletes to more varied stimuli, video-based studies typically determine agility performance by using multiple trails which show different scenarios and varied visual information. It would be expected that testing of agility in a context closest to the athletic environment would result in the most valid testing procedure. As most testing using 2D-video reduces the complexity of the agility task, a more complex testing environment may be needed.

2.9.3 Human Stimulus

To create a more game-like stimulus, recent research has used human opponents (60–62, 64, 154–157, 165, 188, 212). First proposed by Sheppard et al. (165), the majority of testing scenarios have involved a defensive athlete moving to the left or right in a Y-shaped pattern, as shown in Figure 2.1, in response to a human attacker. While this has the advantage of more realistic cues for the defensive athlete to respond to, as with video and light-based tests, it does not allow the defensive athlete to make a variety of responses; instead, the athlete is constrained to a left or right decision. Also, attacking movement patterns are simplified to one or two steps followed by a side-step, unlike in-game scenarios and the athlete is only exposed to front-on scenarios. Furthermore, the commonly used Y-shaped testing procedure has predominantly tested only the defensive athlete. Attempts to test the attacking athlete (172,
176) have been questioned for their ability to reflect in-game perceptual and decision making tasks (212). In the aforementioned testing procedure, the tested athletes were instructed to run in the opposite direction to the “defender”. This is unrealistic because, in field-sports, the defender does not usually perform a distinct side-step without responding to the attacker first.

Figure 2.1: Reactive Agility Test. Adapted from (33)

To address these limitations, Young and Murray (212) developed a field-based test of attacking and defensive agility. Constrained by a 15 x 15-metre testing area, in varied starting positions, an attacking athlete attempted to evade their opponent to reach an end-line, simultaneously, the defensive athlete attempted to simulate a tackle. An attacking athlete received a maximum score when they were able to fully evade a defender, whereas a defender received a maximal score if they could place both arms around the attacker’s torso. Therefore, the test is scored based on the athlete’s relative proximity to their opponent. This testing protocol addresses the limitations
mentioned earlier by allowing the athlete to use a range of strategies to achieve the goal of creating or reducing space from their opponent. The test was later adapted for rugby union athletes by Drake et al. (48, 49). The testing area was reduced to a 12 x 12-metre area, and athletes started facing each other in the middle of the testing area. Despite the increased variability in 1v1 testing procedures, Young and Murray (212) showed very high test-retest, and inter-rater reliability for both attacking (ICC=0.85, r=0.99) and defending (ICC=0.91, r=0.99) agility. Similarly, Drake et al. (49) found high inter-rater reliability of athlete’s aggregate test result (κ=0.86).

Drake et al. compared a 1v1 field-based test to a light-based RAT and found a common variance of 33% for attacking agility and 5% for defending agility (49). This finding indicates that the light-based RAT, despite including a reactive element, may inadequately assess agility in the context of 1v1 events, especially for defending athletes. This is likely due to the lack of ecological validity, as discussed above.

While human-based testing protocols, including field-based tests, represent a shift towards improved agility testing protocols, more research is required to develop ecologically valid testing protocols. Table 2.2 presents limitations to the ecological validity of current invasion sport testing protocols that exist in the literature. This PhD presents a new agility test that attempts to overcome the limitations of previous test protocols.
Table 2.2: Tests of agility in invasion sports

<table>
<thead>
<tr>
<th>Attacking or Defending</th>
<th>Technique</th>
<th>Angle</th>
<th>Speed</th>
<th>Deceptive Manoeuvres</th>
<th># of COD</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light-Based RAT</td>
<td>NA</td>
<td>Side-Step</td>
<td>45 Degrees</td>
<td>Maximal</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>Modified Light-Based RAT</td>
<td>NA</td>
<td>Side-Step</td>
<td>37 Degrees</td>
<td>Maximal</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>90°Light-Based RAT</td>
<td>NA</td>
<td>Side-Step</td>
<td>90 Degrees</td>
<td>Maximal</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>Futsal Agility Test</td>
<td>NA</td>
<td>Varied</td>
<td>Varied</td>
<td>Maximal</td>
<td>No</td>
<td>6</td>
</tr>
<tr>
<td>Stop’n’go RAT</td>
<td>NA</td>
<td>Varied</td>
<td>Varied</td>
<td>Maximal</td>
<td>No</td>
<td>5</td>
</tr>
<tr>
<td>Video-Based RAT</td>
<td>Defending</td>
<td>Side-Step</td>
<td>45 Degrees</td>
<td>Maximal</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>Modified Video-Based RAT</td>
<td>Defending</td>
<td>Side-Step</td>
<td>45 Degrees</td>
<td>Maximal</td>
<td>No</td>
<td>2</td>
</tr>
<tr>
<td>Video-Based RAT w/feint</td>
<td>Defending</td>
<td>Side-Step</td>
<td>45 Degrees</td>
<td>Maximal</td>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>Defending Human-Based RAT</td>
<td>Defending</td>
<td>Side-Step</td>
<td>45 Degrees</td>
<td>Maximal</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>Attacking Human-Based RAT</td>
<td>Attacking</td>
<td>Side-Step</td>
<td>45 Degrees</td>
<td>Maximal</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>1v1 Field-Based Agility Test</td>
<td>Both</td>
<td>Varied</td>
<td>Varied</td>
<td>Varied</td>
<td>Yes</td>
<td>Varied</td>
</tr>
</tbody>
</table>
2.10 TRAINING AGILITY

2.10.1 Physical Training

Despite correlational research, due to the relatively recent introduction of a precise definition of agility, limited training studies exist in the literature. A table of physical intervention studies is presented in Table 2.3.
<table>
<thead>
<tr>
<th>Study</th>
<th>Intervention</th>
<th>Measure</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serpell (162)</td>
<td>Video</td>
<td>Video-RAT&lt;sub&gt;TT&lt;/sub&gt;</td>
<td>5.8% (ES = 0.37)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Video-RAT&lt;sub&gt;PRT&lt;/sub&gt;</td>
<td>88.2% (ES = 1.42)</td>
</tr>
<tr>
<td>CON</td>
<td>Video</td>
<td>Video-RAT&lt;sub&gt;TT&lt;/sub&gt;</td>
<td>-2.6% (ES = 0.31)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Video-RAT&lt;sub&gt;PRT&lt;/sub&gt;</td>
<td>-18.2% (ES = 0.19)</td>
</tr>
<tr>
<td>Cochrane (33)</td>
<td>Vibration</td>
<td>Light-RAT</td>
<td>1.0% (ES = -0.15)</td>
</tr>
<tr>
<td>CON</td>
<td>Light-RAT</td>
<td></td>
<td>1.0% (ES = -0.05)</td>
</tr>
<tr>
<td>Young and Rogers (214)</td>
<td>SSG</td>
<td>Video-RAT&lt;sub&gt;TT&lt;/sub&gt;</td>
<td>-3.8% (ES = 0.93)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Video-RAT&lt;sub&gt;DT&lt;/sub&gt;</td>
<td>-31.4% (ES = 2.32)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Video-RAT&lt;sub&gt;MRT&lt;/sub&gt;</td>
<td>1.0% (ES = 0.12)</td>
</tr>
<tr>
<td>CODS</td>
<td>Video-RAT&lt;sub&gt;TT&lt;/sub&gt;</td>
<td>0% (ES = 0)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Video-RAT&lt;sub&gt;DT&lt;/sub&gt;</td>
<td>-3.6% (ES = 0.16)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Video-RAT&lt;sub&gt;MRT&lt;/sub&gt;</td>
<td>2.1% (ES = 0.20)</td>
</tr>
<tr>
<td>Chaouachi et al. (28)</td>
<td>SSG</td>
<td>Human-RAT v1</td>
<td>-4.8% (ES = 0.59)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Human-RAT v2</td>
<td>-7.5% (ES = 0.70)</td>
</tr>
<tr>
<td>CODS</td>
<td>Human-RAT v1</td>
<td>-3.6% (ES = 0.30)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Human-RAT v2</td>
<td>4.9% (ES = 0.35)</td>
<td></td>
</tr>
<tr>
<td>CON</td>
<td>Human-RAT v1</td>
<td>-2.6% (ES = 0.34)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Human-RAT v2</td>
<td>-4.9% (ES = 0.63)</td>
<td></td>
</tr>
<tr>
<td>Chaalali et al. (26)</td>
<td>AT</td>
<td>RAT&lt;sub&gt;noball&lt;/sub&gt;</td>
<td>-9.37% (ES = 2.28)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RAT&lt;sub&gt;ball&lt;/sub&gt;</td>
<td>-7.73% (ES = 2.99)</td>
</tr>
<tr>
<td>CODS</td>
<td>RAT&lt;sub&gt;noball&lt;/sub&gt;</td>
<td>-4.59% (ES = 1.09)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RAT&lt;sub&gt;ball&lt;/sub&gt;</td>
<td>-5% (ES = 1.03)</td>
<td></td>
</tr>
<tr>
<td>CON</td>
<td>RAT&lt;sub&gt;noball&lt;/sub&gt;</td>
<td>-1.48% (ES = 0.4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RAT&lt;sub&gt;ball&lt;/sub&gt;</td>
<td>-4.28% (ES = 0.71)</td>
<td></td>
</tr>
<tr>
<td>Trecroci et al. (184)</td>
<td>SAQ</td>
<td>Human-RAT</td>
<td>4.2% (ES = 0.8)</td>
</tr>
<tr>
<td>CON</td>
<td>Human-RAT</td>
<td>1.1% (ES = 0.2)</td>
<td></td>
</tr>
</tbody>
</table>

AT = Agility training, CON = Control, DT = Decision time, ES = Effect size, MRT = Movement response time, RAT = Reactive agility test, SAQ = Speed agility quickness training, TT = Total time

2.10.1.1  **CODS and RAT Training**

Four studies have investigated the effects of CODS training intervention on agility performance, and have found trivial to moderate improvements in agility performance (ES = 0 – 1.09) (26, 28, 184, 214). Two of the four studies compared the effects of agility training with SSG, while one study compared the effects
of CODS training with a RAT-style agility intervention. All studies demonstrated a greater improvement in agility when a reactionary stimulus was included. This greater improvement in agility is likely due to the development of perceptual-cognitive capacities in addition to COD capacities. Athletes within SSG and agility training scenarios are likely able to attune to cues from their opponents to allow for faster anticipation of future movement demands.

2.10.1.2 Small Sided Games

SSG refer to training activities with reduced player numbers (e.g. 2-10 athletes) usually performed in a restricted playing area (28, 214). Two studies have examined the use of small-sided games (SSG) for improving agility (28, 214). SSG have been proposed due to their ability to train cognitive and technical factors simultaneously. Chaouachi et al. (28) compared the effects of SSG with COD training. During this study, SSG improved agility to a greater extent than COD training. Using a group of 25 junior Australian footballers, Young and Rogers (214) also showed improvements in video-based agility testing following SSG training. During testing, the total time to complete the agility test was broken down into decision time and movement response time. Following SSG training, decision time improved while movement response time showed no significant improvements (214). Therefore, it was concluded that improvements in agility following SSG training could be
attributed to cognitive improvements rather than physical and technical improvements.

2.10.2 Cognitive-Only Training

As perceptual and decision-making skill is an important component of agility performance, it could be thought that training to improve this component in isolation would result in superior agility performance. Only one study has tested this by assessing the effects of a video-based cognitive training study on agility performance in rugby league athletes (163). During this study, a training group underwent three weeks of video-based perceptual training while a control group undertook no training. Following the training period, the perceptual training group significantly improved in the agility test while the control group showed no improvements. These results suggest that perceptual training may be beneficial to agility, but more research is needed.

2.10.3 Constraints-Led Approach

The constrains-led approach to athlete development has recently emerged as a method to develop athletes in a holistic manner (128). Developed from ecological dynamics (149), the approach achieves motor learning outcomes by allowing goal-directed behaviour while manipulating constraints (128). Constraints are features or boundaries that limit the
possibilities of the athlete and are often categorised as athlete, environmental, or task constraints (37). Athlete constraints refer to constraints on the individual athlete such as anthropometry, physical fitness, mental skills and personality. Environmental constraints refer to environmental factors such as temperature, lighting and ground surface. Task constraints refer to constraints on equipment, playing area, rules and the number of players.

In this framework, athletes are conceptualised as complex dynamical systems that self-organise their behaviour towards a goal (32). By doing so, ordered, functional movement emerges inside the confines of interacting constraints (39). It is the role of the strength and conditioning coach to modify the constraints of a task to manipulate the affordances available to the performing athlete (68). One task constraint modification commonly used for agility development is the manipulation of player numbers as in SSG (28, 214). Constraints-based agility training allows 1v1 as well as SSG, to be tailored towards training goals, while still providing athletes with appropriate, sport-specific, cognitive feedback. Further by manipulating training activities from a systems-perspective, the athlete-environment relationship is maintained (149). This is useful for practitioners wishing to improve agility as, by training skills in context, the technical and perceptual components of agility remain coupled (69). Therefore, the constraints-led approach presents a shift away from isolated COD training to include the cognitive and decision-making skills inherent in agility performance.
A framework for constraints-led approaches to developing agility has been proposed by Jeffreys (95). This paper discusses a theoretical model to agility development using ideas from dynamical systems theory. While, in theory, the methods of agility training introduced in the aforementioned paper may improve agility performance, minimal training studies have adopted a constraints-led approach (28, 214).

2.11 SUMMARY

In summary, while substantial recent progress has been made in the understanding of agility, there is currently a lack of research which explains the agility demands of AF. For this reason, it is unknown if training and testing methods that are used to train and test agility for Australian footballers translate to the demands of the game.

The recent development of field-based agility testing methods has allowed for the assessment of agility within the context of agility events (48, 212). This development has allowed for the individual assessment of attacking and defending agility and has demonstrated that attacking and defending agility are separate skills (48, 212). However, as the introduction of field-based agility testing methods is recent, the validity of these training methods is currently unknown, and more research is needed which uses field-based testing methods for assessment.
Due to the recent adoption of an agility definition (166), a lack of agility training interventions are described in the literature. In particular, while it is likely that the development of leg and core strength and power would translate to agility performance, it is unknown if traditional resistance training is effective for developing agility. In the agility training research, SSG has been demonstrated to be an effective holistic training method for agility that allows for the effective use of the constraints-led approach (e.g. 28, 214). Nevertheless, more constraints-led training research, such as research using 1v1 training interventions, is needed to fully understand the effectiveness of this approach.
STUDY 1: DO CURRENT AGILITY TRAINING PRACTICES IN ELITE AUSTRALIAN FOOTBALL ALIGN WITH THE DEMANDS OF COMPETITION?

3.1 INTRODUCTION

As demonstrated in the literature review, little is known of how agility scenarios occur in the sport of AF, or how agility is subsequently developed. Currently, practitioners are forced to assume AF’s physical and cognitive demands and to derive training methods that may not accurately simulate the demands of the sport. The primary objective of the first study within this PhD was to understand the demands of agility in elite AF and to determine what training and testing is undertaken at elite AF clubs. This goal was met by developing and conducting a notational analysis of 1v1 agility events in elite AF, and surveying high-performance managers working in elite AF to determine current training and testing methods.

While some notational analyses exist which have described agility scenarios in other invasion sports (19, 41, 74, 122, 152, 153, 193, 194), these studies only describe attacking agility and not defending agility. Similarly, a description of changes of direction that occur in elite AF exists within the literature (41); however,
the study did not separate attacker/defender agility scenarios from those that occurred away from a contest, nor did the study describe specific movement techniques. This poses a major limitation, as, while changes of direction occur many times throughout invasion sports, changes of direction in response to a direct opponent account for just a subsection of all directional changes. To account for this, this PhD has defined agility events as “a defined change of velocity or direction by the ball-carrier in response to an opponent”. 1v1 scenarios were chosen due to their critical nature in AF, situations whereby an athlete must respond to a direct opponent are more likely to result in a turnover and are therefore crucial to team success.

To understand the characteristics of agility in AF, it is necessary to know what footwork patterns are used within agility events. Therefore, this chapter of the thesis has divided footwork patterns into three categories; movement technique, COD angle, and approach speed. Previous attempts have been made to describe the movement techniques used in agility events (21, 96). However, it is unknown what agility techniques are used in AF gameplay. Further, some notational analyses describe the angles of all COD in sport (122, 193), however, no current literature describes COD angles within attacker/defender agility events. Similarly, little is known on the speed of agility events in AF, and agility events likely occur at a variety of speeds. Indeed, slow speeds of some agility events may occur either deliberately by the athlete to provide themselves with more time for decision making, or as a consequence of the limited on-field space available. Therefore, to develop a complete understanding
of agility in AF, it is necessary to understand not only high-speed agility scenarios, but also those that occur at a sub-maximal speed.

While the physical characteristics of agility scenarios are vital to understanding how agility events happen in AF, the cognitive component of agility is what distinguishes agility scenarios from simple COD events (166). While some notational analyses have described on-field changes of direction, they have typically described all changes of direction, irrespective of what the athlete is reacting to (122, 193). The notational analyses that do exist do not describe the cognitive stimuli that are presented to athletes. Subsequently, little is known about the cognitive element of agility events. To better understand the cognitive factors that determine agility performance, this study recorded the location of the defender in relation to the attacker during agility events, and the use of deceptive manoeuvres by the attacker. The location of the opponent in an agility event determines the visual input available to the athlete to determine an appropriate movement strategy and therefore, may influence the choice of movement pattern. For example, an attacking athlete who is confronted by a defender directly in front may be more likely to approach at a slower speed or change direction to a sharper angle. Similarly, the use of deceptive manoeuvres by attacking athletes likely influences the characteristics of an agility scenario. Indeed, the effectiveness of attacking deceptive manoeuvres has been demonstrated in the literature (83, 92). The method of deception used by the attacking athlete in agility scenarios is usually in the form of a fake; either in the form of a
faked change of direction, whereby an athlete performs a short COD to the unintended direction of travel, which is immediately reversed; or a fake disposal, where an attacking athlete motions to either kick or handpass the ball, without releasing it. Both techniques are intended to slow the reaction time of the defending athlete by introducing uncertainty or to force the defending athlete to make a COD to the incorrect direction. While research on the effect of deceptive manoeuvres in AF has focused on faked directional changes (83), it is likely that a fake disposal will also impair the defender’s ability to detect and respond to the attacker, thereby slowing their COD. Nevertheless, due to the lack of a notational analysis which describes the cognitive demands of agility in AF, it is unknown how or if deceptive manoeuvres occur in-game in AF.

In a typical 1v1 agility event, the attacker and defender while both attempting to change speed or direction in response to a stimulus, are doing so with contrasting goals. The goal of the attacking athlete is to increase space from the defender to progress the ball towards the goal, or to dispose of the ball to a teammate; while the defending athlete is attempting to reduce space to force a turnover or tackle. Indeed, the difference between attacking and defending agility has been recognised in research which has shown low correlations between the two skills (212). As attacking and defending are dissimilar roles in the game, it is likely that movement strategies used will vary. However, as no notational analyses have differentiated between attacking and defending agility, the differences between the two skills in sport are unknown.
In addition to understanding the physical and cognitive demands of agility, to allow coaches to prioritise agility training time, it is necessary to understand what characteristics of agility are associated with success. It is possible that some movement and cognitive strategies that are commonly used or trained within AF are ineffective. As such, in addition to describing attacking and defending agility in AF, the notational analysis aims to determine which strategies are effective.

To gather a full insight into agility in AF, it is necessary to know what training and testing methods are used to develop and assess agility. Despite a growing body of agility research, it is unknown if evidence-based strength and conditioning training is currently implemented within high-performance AF environments. Challenges to implementation of evidence-based practice have been discussed throughout the literature (183). Coaches often rely on fellow coaching professionals rather than published research due to a perceived lack of studies that are directly relevant to the applied sport setting (59, 147, 148). Further, due to the dearth of agility training research, strength and conditioning professionals have limited specific evidence to guide their training in practice. As academic research often fails to align with the needs of coaches (151), by understanding how training and testing is implemented in the field, agility research may be tailored to fit coach requirements.

It is possible that a myriad of strength and conditioning methods may be used in practice, and approaches may differ between clubs. For this reason, this PhD supplemented the notational analysis of in-game 1v1 agility scenarios with a
survey of high-performance managers within the AFL to better understand applied practice. Respondents were asked to describe agility training and testing methods used within their clubs. This information, combined with the results from the notational analysis, was then used to determine if training methods reflect the in-game demands of AF.

In summation, the purpose of this study is to understand the movement and cognitive characteristics of agility, what movement and strategies are successful, and to determine if agility training within elite AF clubs reflects the demands in-game.

3.2 NOTATIONAL ANALYSIS

3.2.1 Methods of Notational Analysis

Data processing of video footage from the 2016 AFL home and away season was undertaken by the lead researcher to allow for accurate and consistent recording during the notational analysis process. Following video processing, the notational analysis was performed by both the lead researcher and an assistant to establish inter-rater reliability. Following data collection, all subsequent analyses were undertaken by the lead researcher.

3.2.1.1 Sample

The study was conducted using footage of every game during round five and round 10 of the 2016 AFL home and away season,
obtained from the AFL for the purpose of the project. This sample size of 18 matches was chosen to allow for each team to play two opponents, thereby competing against opponents of varying abilities. Footage from three separate camera angles was obtained to allow for the agility scenarios to be observed from multiple vantage points at all times during play. The camera angles consisted of a view behind the goals, side view of the ground, as well as the televised match footage in the highest quality. The behind-the-goals view provided an elevated, full view of the ground from one end of the field; the camera was fixed. The side view provided an elevated view from one side of the ground with the camera panned to track the ball location. The broadcast footage consisted of footage identical to that televised to the public. High definition video was sourced (1280 x 720 x 25fps) which was compressed using advanced video coding (H.264).

3.2.1.2 Data Processing

To allow simultaneous viewing of all three camera angles, the video sources were stitched together using video editing software (Adobe Premiere Pro 6.0), as shown in Figure 3.1. To ensure simultaneous play for the coders, the footage was synced to the first ball-bounce, which marks the beginning of play.
Prior to the analysis of match footage, a notational analysis form was developed to allow for systematic collection of data related to the proposed research questions (Appendix A). In addition, operational definitions were developed to improve the reliability of collected data Table 3.1. To determine the attacking and defending footwork patterns used during agility events, the speed of approach, angle of COD and movement technique were recorded. To maximise the reliability of this data, distinct categories were chosen for each response. To determine footwork patterns, the speed of approach, angle of COD, movement technique, and change in defenders’ gait were recorded. Cognitive demands were determined by the defender’s location with respect to the attacker, as well as any deceptive technique used by the attacking athlete, and the location on the ground.
Table 3.1: Operational definitions for notational analysis

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stationary</td>
<td>The athlete remains in a fixed position without stepping</td>
</tr>
<tr>
<td>Walk/ Slow Jog</td>
<td>The athlete moves without immediate urgency</td>
</tr>
<tr>
<td>Striding</td>
<td>The athlete moves with urgency at a sub-maximal intensity</td>
</tr>
<tr>
<td>Sprint</td>
<td>The athlete moves at maximal intensity</td>
</tr>
<tr>
<td>Fake Disposal</td>
<td>The athlete motions to kick or handpass the ball without subsequent disposal</td>
</tr>
<tr>
<td>Fake COD</td>
<td>A short COD to the unintended direction of travel, which is immediately reversed</td>
</tr>
<tr>
<td>Side-Step</td>
<td>A distinct change of direction performed using the outside foot</td>
</tr>
<tr>
<td>Crossover-Cut</td>
<td>A distinct change of direction performed using the inside foot</td>
</tr>
</tbody>
</table>

The outcome of the agility event was determined to be a success or failure based on the ability of the attacker to create space from the defender, and the ability of the defender to reduce space to the attacker. If the attacker avoided being touched by both of the defender’s hands, the outcome was deemed successful. Conversely, if the defender touched the attacker with both hands, the attacker’s agility manoeuvre was considered a failure for the attacker. These criteria were reversed for the defender so that a two-handed touch was deemed a success.

Prior to undertaking the video analysis, pilot-testing using match footage of a match separate to those present in the final analysis was performed by the lead researcher to address
any issues with the data collection technique and to refine descriptions used in notational analysis questions. During this process, categories of speed, angle and movement technique were refined to allow for reliable data collection. For example, the initial draft included a “lateral” category for change of direction angle which was subsequently removed due to the ambiguity between lateral and the adjacent categories. Further, the split-step and shuffle were not removed from the initial draft as they occurred prior to the propulsive phase of the COD and often coincided with a deceleration or repositioning of the attacking athlete, making their identification inconsistent.

Data was then collected simultaneously by both the lead researcher and a research assistant using video analysis software (Kinovea, 0.8.15, France). This software allowed researchers to use slow motion, frame by frame analysis, as well as A-B looping features. A-B looping refers to the ability for an observer to extract one section of footage and temporarily inspect it in isolation to the whole file. This feature allows researchers precise control over the specific section of footage being analysed. To undertake the video analysis, both the lead researcher and research assistant separately watched a football match from the beginning of play with the intention of identifying agility events. Once an event was identified, the researcher isolated the event using the A-B looping feature mentioned earlier. The researchers primarily used the broadcast footage to identify and describe agility events; however, if the event wasn’t clear researchers reverted to use of the side view or behind the ground footage. Using a questionnaire (Appendix
A), the researcher systematically collected data related to the proposed research questions. This process was repeated until all matches had been fully analysed. The list of identified agility events was shared with the research assistant to allow for analysis of the same agility events. Following the notation of all agility events by both researchers, statistical analysis was undertaken, then, once inter-rater and intra-rater reliability had been analysed, the results obtained by the researchers were used for further analyses.

### 3.2.1.3 Data Analyses

Data were coded by both researchers and recorded as a comma-separated-values (CSV) file to be statistically analysed using R version 3.5.1 (R Foundation for Statistical Computing, Vienna, Austria). Significance was set to \( p < 0.05 \) for all analyses.

### 3.2.1.4 Reliability

**Inter-Rater Reliability**

To determine inter-rater reliability, all agility events were notated by the PhD student and an assistant strength and conditioning coach in their final year of an Exercise and Sport Science degree. The notational analysis was conducted separately, without communication between researchers to limit bias. The level of agreement between researchers was determined using Cohen’s Kappa (\( \kappa \)) statistics, of which, unweighted Kappa statistics were used for nominal variables,
and weighted Kappa statistics were used for ordinal variables. As Kappa statistics above 0.4 or above represent a moderate or greater agreement, the variable was determined to be reliable if the Kappa statistic was above 0.4 (110). Qualitative descriptions of agreement are reported as described in Landis and Koch 1977 and below in Table 3.2 (110).

Table 3.2: Qualitative descriptors of kappa agreement (110)

<table>
<thead>
<tr>
<th>Kappa</th>
<th>Strength of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.00</td>
<td>Poor</td>
</tr>
<tr>
<td>0.00 - 0.2</td>
<td>Slight</td>
</tr>
<tr>
<td>&gt; 0.2 ≤ 0.4</td>
<td>Fair</td>
</tr>
<tr>
<td>&gt; 0.4 ≤ 0.6</td>
<td>Moderate</td>
</tr>
<tr>
<td>&gt; 0.6 ≤ 0.8</td>
<td>Good</td>
</tr>
<tr>
<td>&gt; 0.8 ≤ 1</td>
<td>Very Good</td>
</tr>
</tbody>
</table>

*Intra-Rater Reliability*

To enable the assessment of intra-rater reliability, a subsection of the first 100 agility events was coded twice by the primary researcher. This was performed more than two months following the initial data collection period to minimise the risk of bias due to retention of results. As for inter-rater reliability, the level of agreement between time points was determined using Cohen’s Kappa statistics. A variable was determined to be reliable if the Kappa statistic was above 0.4.
3.2.1.5 Descriptive analyses

To analyse the distribution of technique, approach speed, and COD angles used by both the attacker and defender; as well as the change of gait employed by the defender, frequency distributions were formed and frequencies, along with percentages were reported. To determine the cognitive demands of agility scenarios, the location of the defender in relation to the attacker, as well as any deceptive manoeuvres used by the attacker were recorded and reported in frequency tables.

Chi-square tests of independence were used to determine the significance of relationships between variables, as in similar research (122). Chi-square tests were reported with the Chi-square statistic, degrees of freedom, significance, and effect size in the form of ($\chi^2(o) = 0$, $p = 0.00$, $\phi_c = .00$). In cases where expected values of the chi-square test were below 5, p-values were computed using a Monte Carlo simulation based on 2000 replicates (136). Cramér’s V statistic was calculated to determine the effect sizes for all Chi-square tests of independence and is indicated by $\phi_c$ throughout. Qualitative descriptors from Cohen were used to describe the magnitude of effect (34). Descriptors are listed below in Table 3.3. As Cramér’s V is inversely related to the size of the contingency table used to calculate $\chi^2$, adjusted effect size descriptors are provided for instances of $r > 2$, where $r =$ the smallest dimension of the contingency table. Adjusted magnitude thresholds were calculated using $\phi_c = \frac{\omega}{\sqrt{r-1}}$ as derived from the equation $\omega = \phi_c \sqrt{r-1}$ described in the literature (34, 167).
### Table 3.3: Qualitative Descriptors of Cramér’s V Effect Sizes (34)

<table>
<thead>
<tr>
<th>Descriptor</th>
<th>$r=2$</th>
<th>$r=3$</th>
<th>$r=4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negligible</td>
<td>$&lt; 0.1$</td>
<td>$&lt; 0.07$</td>
<td>$&lt; 0.06$</td>
</tr>
<tr>
<td>Small</td>
<td>$\geq 0.1 &lt; 0.3$</td>
<td>$\geq 0.07 &lt; 0.21$</td>
<td>$\geq 0.06 &lt; 0.17$</td>
</tr>
<tr>
<td>Medium</td>
<td>$\geq 0.3 &lt; 0.5$</td>
<td>$\geq 0.21 &lt; 0.35$</td>
<td>$\geq 0.17 &lt; 0.29$</td>
</tr>
<tr>
<td>Large</td>
<td>$\geq 0.5$</td>
<td>$\geq 0.35$</td>
<td>$\geq 0.29$</td>
</tr>
</tbody>
</table>

Post-hoc analysis of chi-square tests was conducted by deriving adjusted standardised residuals (SR) to determine each cell’s individual contribution to the chi-square result, as demonstrated in the literature (164). For each set of adjusted standardised residuals, a Bonferroni correction was applied to determine a corrected alpha level to control for the increased risk of familywise type 1 error. SR $\geq 2.0$ indicates a value that is greater than expected, while $\leq -2.0$ represents a value that is less than would be expected.

#### 3.2.2 Results of Notational Analysis

#### 3.2.2.1 Reliability

*Inter-rater Reliability*

The inter-rater reliability of all nominal variables are summarised in Table 3.4, and inter-rater reliability of all ordinal variables are summarised in Table 3.5. All but two variables were determined to be reliable by reaching the threshold Kappa statistic of 0.4; the attacker’s COD technique and the defender’s change in gait did not reach a moderate level of agreement.
### Table 3.4: Inter-rater reliability of nominal variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Agreement</th>
<th>Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attacker’s deceptive manoeuvre</td>
<td>Moderate</td>
<td>0.56†</td>
</tr>
<tr>
<td>Attacker’s COD technique</td>
<td>Fair</td>
<td>0.37†</td>
</tr>
<tr>
<td>Defender’s COD technique</td>
<td>Substantial</td>
<td>0.65†</td>
</tr>
<tr>
<td>Did the attacker successfully evade</td>
<td>Substantial</td>
<td>0.77†</td>
</tr>
</tbody>
</table>

† = p < 0.001

### Table 3.5: Inter-rater reliability of ordinal variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Agreement</th>
<th>Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attacker’s approach speed</td>
<td>Substantial</td>
<td>0.78†</td>
</tr>
<tr>
<td>Defender’s approach speed</td>
<td>Substantial</td>
<td>0.63†</td>
</tr>
<tr>
<td>Attacker’s angle of COD</td>
<td>Substantial</td>
<td>0.64†</td>
</tr>
<tr>
<td>Defender’s angle of COD</td>
<td>Fair</td>
<td>0.34†</td>
</tr>
<tr>
<td>Defender’s location in relation to attacker</td>
<td>Substantial</td>
<td>0.74†</td>
</tr>
</tbody>
</table>

† = p < 0.001

### Intra-rater Reliability

As with inter-rater reliability, the intra-rater reliability of all nominal variables are summarised in Table 3.6 and intra-rater reliability of all ordinal variables are summarised in Table 3.7. Every variable except for the attacker’s deceptive manoeuvre and defender’s COD angle reached an acceptable level of agreement.

### Table 3.6: Intra-rater reliability of nominal variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Agreement</th>
<th>Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attacker’s deceptive manoeuvre</td>
<td>Fair</td>
<td>0.38†</td>
</tr>
<tr>
<td>Attacker’s COD technique</td>
<td>Moderate</td>
<td>0.47†</td>
</tr>
<tr>
<td>Defender’s COD technique</td>
<td>Moderate</td>
<td>0.51†</td>
</tr>
<tr>
<td>Did the attacker successfully evade</td>
<td>Substantial</td>
<td>0.77†</td>
</tr>
</tbody>
</table>

† = p < 0.001
Table 3.7: Intra-rater reliability of ordinal variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Agreement</th>
<th>Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attacker’s approach speed</td>
<td>Substantial</td>
<td>0.77†</td>
</tr>
<tr>
<td>Defender’s approach speed</td>
<td>Substantial</td>
<td>0.62†</td>
</tr>
<tr>
<td>Attacker’s angle of COD</td>
<td>Moderate</td>
<td>0.45†</td>
</tr>
<tr>
<td>Defender’s angle of COD</td>
<td>Fair</td>
<td>0.36†</td>
</tr>
<tr>
<td>Defender’s location in relation to attacker</td>
<td>Moderate</td>
<td>0.66†</td>
</tr>
</tbody>
</table>

† = p < 0.001

3.2.2.2  Footwork patterns used in 1v1 agility events

Agility Technique

Analysis of COD technique used in 1v1 was explored using frequency distributions and bar charts, distributions of COD technique used by attacking and defending athletes are presented in Figure 3.2. Attacking athletes most frequently used a side-step as their COD technique, followed by crossover cuts, decelerations, acceleration, or blind turns. While defending athletes also preferred the side-step, the distribution of COD techniques was more even. Other techniques used by defenders were curved run, deceleration, crossover cut, and acceleration. In 30 cases, the defender did not perform any agility manoeuvre as the defender was evaded and play continued before he made a response.
Approach Speed

As shown in Figure 3.3, the most common approach speed for attacking athletes was a stride, followed by walk/ slow jog, stationary approach, and a sprint. Defenders most often entered agility events striding, followed by sprinting, walk/slow jogging, and stationary approaches.
COD Angle

As shown below in Figure 3.4, attacking athletes favoured shallow COD angles of fewer degrees, followed by COD angles of more than 90 degrees, while rarely accelerating or decelerating only. Defending athletes showed a similar trend preferring COD angles of less than 90 degrees, more than 90 degrees, followed by an acceleration or deceleration only, while making no change of direction or speed in 30 cases.
To determine if approach speed, technique and COD angle are associated, Chi-square tests of independence were performed. Results are summarised in Tables 3.8 and 3.9. Results indicated a small association between attacking approach speed and attacking technique ($\chi^2(12) = 79.72, p = <.001; \phi_c = 0.27$) as well as a small, significant association between defending approach speed and defending technique ($\chi^2(15) = 69.56, p = <.001; \phi_c = 0.25$). Post-hoc analysis of adjusted standardised residuals showed that a stationary start to an agility event was associated with an acceleration for attacking athletes (SR = 7.59). Accelerations occurred infrequently (SR = -3.52), and decelerations occurred frequently (SR = 3.76) at striding approach speeds for attacking athletes. Similar results were found for defending athletes who also decelerated frequently at striding approach speeds (SR = 3.29). Further, for defending
athletes, a side-step typically occurred while walking or slowly jogging (SR = 3.78), while side-steps were uncommon while sprinting (SR = -3.27). While sprinting, defending athletes were likely to not use any technique to attempt a change of velocity or direction (SR = 3.66).

### Table 3.8: Relationships between attacking footwork components

<table>
<thead>
<tr>
<th>Variable</th>
<th>Attacking Technique</th>
<th>Attacking Approach Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attacking COD Angle</td>
<td>$\chi^2 = 279.34^{\dagger}$</td>
<td>$\chi^2 = 32.05^{\dagger}$</td>
</tr>
<tr>
<td></td>
<td>$\phi_c = 0.63$, r=3</td>
<td>$\phi_c = 0.21$, r=3</td>
</tr>
</tbody>
</table>

$\chi^2 = $ Chi-Square statistic, $\phi_c =$ Effect Size (Cramér’s V),
$\dagger = p < 0.001$, $r =$ the smallest dimension of the contingency table

### Table 3.9: Relationships between defending footwork pattern components

<table>
<thead>
<tr>
<th>Variable</th>
<th>Defending Technique</th>
<th>Defending Approach Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defending COD Angle</td>
<td>$\chi^2 = 277.16^{\dagger}$</td>
<td>$\chi^2 = 33.31^{\dagger}$</td>
</tr>
<tr>
<td></td>
<td>$\phi_c = 0.65$, r=4</td>
<td>$\phi_c = 0.18$, r=4</td>
</tr>
</tbody>
</table>

$\chi^2 = $ Chi-Square statistic, $\phi_c =$ Effect Size (Cramér’s V),
$\dagger = p < 0.001$, $r =$ the smallest dimension of the contingency table

A large, significant relationship was found between both attacking technique and attacking COD angle ($\chi^2(8) = 279.34$, p = <.001; $\phi_c = 0.63$), as well as defending technique and defending COD angle ($\chi^2(10) = 277.16$, p = <.001; $\phi_c = 0.65$). When an
attacking athlete used an acceleration or deceleration technique, they were more likely to not make a direction change (4.5%, SR = 9.18; 7%, SR = 13.2). When side-stepping, attacking athletes frequently made an acute change of direction (>90 degrees) (35%, SR = 4.36). For defending athletes, curved runs were commonly performed at a shallow COD angle (<90 degrees) (15.7%, SR = 4.92).

A moderate relationship was found between attacking approach speed and attacking COD angle ($\chi^2(6) = 32.05, p = <.001; \phi_e = 0.21$), as well as defending approach speed and defending COD angle ($\chi^2(9) = 33.31, p = <.001; \phi_e = 0.18$).

Post-hoc analysis revealed attacking athletes performed more acute changes of direction (>90 degrees) when approaching at a walk/slow jog often (17.1%, SR = 2.99). In addition, attacking athletes did not often make a change of direction when stationary (3.2%, SR = 4.63). Defending athletes performed acute COD (>90 degrees) frequently when approaching at a sprint (3.6%, SR = 3.81).

3.2.2.4 Cognitive Demands of Agility Events

Of 357 total agility events, 171 occurred with the attacker in front of the defender, 107 with the attacker to the side of the defender, and 79 with the attacker behind the defender. The attacker used a deceptive manoeuvre in 120 of 357 recorded agility scenarios, of these the attacker performed a feint 56 times, and a fake disposal 64 times. A summary of results is presented in Figure 3.5.

3.2 NOTATIONAL ANALYSIS
The relationship between the cognitive demands of 1v1 agility events and the footwork pattern used is presented in Table 3.10. The technique used by the attacker was not significantly related to the location of either the attacker or defender ($p > 0.05$). However, the technique used by the defender showed a medium significant relationship to defender location ($\chi^2(10) = 34.2, p < 0.001; \phi_c = 0.22$). Post-hoc analysis revealed that when the defender was behind the attacker, the defender was likely to perform a curved run (9.8%, SR = 3.66).

Chi-square testing revealed the location of the defender in relation to the attacker had a medium, significant association to the approach speed of the attacker ($\chi^2(6) = 40.22, p < 0.001; \phi_c = 0.24$), and the defender ($\chi^2(6) = 50.826, p < 0.001, \phi_c = 0.27$). Post-hoc analysis of the adjusted standardised residuals found that the attacking athlete was often stationary when the defender was in front (10.1%, SR = 3.85), while the defender was likely
Table 3.10: Relationship between cognitive demands and footwork pattern (r=3)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Attacker Location</th>
<th>Deceptive Manoeuvre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attacker Technique</td>
<td>$\chi^2(8) = 13.30, \phi_c = 0.14$</td>
<td>$\chi^2(8) = 17.54, \phi_c = 0.16$</td>
</tr>
<tr>
<td>Attacker Approach Speed</td>
<td>$\chi^2(6) = 40.22 \dagger, \phi_c = 0.24$</td>
<td>$\chi^2(6) = 11.63, \phi_c = 0.13$</td>
</tr>
<tr>
<td>Attacker COD Angle</td>
<td>$\chi^2(6) = 7.15, \phi_c = 0.1$</td>
<td>$\chi^2(4) = 9.62, \phi_c = 0.12$</td>
</tr>
<tr>
<td>Defender Technique</td>
<td>$\chi^2(10) = 34.2 \dagger, \phi_c = 0.22$</td>
<td>$\chi^2(10) = 19.48^*, \phi_c = 0.17$</td>
</tr>
<tr>
<td>Defender Approach Speed</td>
<td>$\chi^2(6) = 34.2 \dagger, \phi_c = 0.27$</td>
<td>$\chi^2(6) = 8.25, \phi_c = 0.11$</td>
</tr>
<tr>
<td>Defender COD Angle</td>
<td>$\chi^2(6) = 50.83 \dagger, \phi_c = 0.1$</td>
<td>$\chi^2(6) = 7.27, \phi_c = 0.10$</td>
</tr>
<tr>
<td>Deceptive Manoeuvre</td>
<td>$\chi^2(4) = 14.78^{**}, \phi_c = 0.14$</td>
<td></td>
</tr>
</tbody>
</table>

$\chi^2 = $ Chi-Square Statistic, $\phi_c = $ Effect Size (Cramér’s V),

$^* = p < 0.05, \ ^{**} = p < 0.01, \ ^\dagger = p < 0.001, r = $ the smallest dimension of the contingency table.

to approach at a sprint when they were behind the attacker (2.8%, SR = 4.29). The location of the defender in relation to the attacker showed a medium, significant relationship to the COD angle of the attacker ($\chi^2(4) = 35.33, p < 0.001; \phi_c = 0.22$), but not for the defender ($p > 0.05$). Post-hoc testing revealed that when the defender was in front of the attacker, the attacker was more likely to perform a shallow (<90 degrees) COD (19.3%, SR = 2.85), but less likely to perform a sharp (>90 degree) COD (14.3% SR = -3.17). Chi-square analysis revealed a small relationship between the location of the defender in relation to the attacker and the use of a deceptive technique ($\chi^2(4) = 14.78, p = 0.006, \phi_c = 0.14$). Post-hoc analysis revealed, when the defender was in
front, attackers were less likely to use a fake disposal (10.9%, SR = -3.71).

A chi-square test of independence revealed a small relationship between the use of a deceptive manoeuvre by the attacking athlete and the subsequent agility technique used by the defending athlete ($\chi^2(10) = 19.48$, $p = 0.03$, $\phi_c = 0.17$). Post-hoc analysis revealed that defending athletes performed a side-step less frequently when no deceptive manoeuvre was used (21.9%, SR = -3.28). No significant relationship was found between the use of a deceptive technique by the attacker, and the approach speeds of the defender ($p > 0.05$). A small relationship was found between the use of a deceptive technique by the attacking athlete and the attacker’s COD angle ($\chi^2(4) = 9.62$, $p = 0.047$, $\phi_c = 0.12$), however, no relationship was found with the defender’s COD angle. Post-hoc analysis revealed that attacking athletes performed more shallow changes of direction (<90 degrees) when a fake disposal was used (11.5%, SR = 3.01).

### 3.2.2.5 Differences between attacking and defending agility

Differences between attacking and defending agility were determined using chi-square testing and are presented below in Table 3.11. There was a large, significant association between the role of the athlete (either attacking, or defending), and the agility technique used, as revealed by a chi-square test of independence ($\chi^2(6) = 212.13$, $p < 0.001$; $\phi_c = 0.55$). Post-hoc analysis of adjusted standardised residuals revealed that for the
attacking athlete, side-steps (73.9%, SR = 9.43), crossover cuts (9.8%, SR = 3.11), accelerations (5.9%, SR = 3.2), and blind turns (2.8%, SR = 3.18) were more frequent ($p < 0.004$), while decelerations (7.6%, SR = -5.81), and curved runs were less frequent. The inverse was true for defending athletes. That is, decelerations and curved runs were more frequent, while side-steps, crossover cuts, accelerations, and blind turns were less frequent.

A small, significant association with the role of the athlete was found for speed of approach ($\chi^2(3) = 59.81, p < 0.001; \phi_c = 0.29$). Slow approach speeds either stationary or at a walk/slow jog occurred more for attacking athletes (11.2%, SR = 4.21; 33.1%, SR = 5.5), and less for defending athletes (3.1%, SR = -4.21; 15.4%, SR = -5.5), while striding and sprinting occurred less for attacking athletes (46.8%, SR = -4.36; 9.1%, SR = -3.7), and more for defending athletes (63%, SR = 4.36; 18.5% SR = 3.7).

A small, significant association was found between the role of the athlete and the COD angle ($\chi^2(2) = 17.86, p < 0.001; \phi_c = 0.16$). Acute changes of direction (>90 degrees) were more frequent for attacking athletes (40.6%, SR = 3.63), and less frequent for defending athletes (27.7%, SR = -3.63), while events with no changes of direction were more frequent for defending athletes (8.1%, SR = 5.5), and less frequent for attacking athletes (0%, SR = -5.5).
Table 3.11: Comparison between attacking and defending: agility technique, approach speed, and COD angle (n = 714)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>n</th>
<th>Attacker</th>
<th></th>
<th></th>
<th></th>
<th>Defender</th>
<th></th>
<th></th>
<th>Chi Square</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>n</td>
<td>%</td>
<td>SR</td>
<td></td>
<td>n</td>
<td>%</td>
<td>SR</td>
<td></td>
</tr>
<tr>
<td>Technique</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side Step</td>
<td>403</td>
<td>264</td>
<td>73.9</td>
<td>9.43</td>
<td></td>
<td>139</td>
<td>38.9</td>
<td>-9.4</td>
<td>$\chi^2(6) = 212.13^\dagger$</td>
</tr>
<tr>
<td>Deceleration</td>
<td>110</td>
<td>27</td>
<td>7.6</td>
<td>-5.81</td>
<td></td>
<td>83</td>
<td>23.2</td>
<td>5.81</td>
<td>$\phi_c = 0.55$</td>
</tr>
<tr>
<td>Curved Run</td>
<td>86</td>
<td>0</td>
<td>0</td>
<td>-9.89</td>
<td></td>
<td>86</td>
<td>24.1</td>
<td>9.89</td>
<td></td>
</tr>
<tr>
<td>Crossover Cut</td>
<td>49</td>
<td>35</td>
<td>9.8</td>
<td>3.11</td>
<td></td>
<td>14</td>
<td>3.9</td>
<td>-3.1</td>
<td></td>
</tr>
<tr>
<td>Acceleration</td>
<td>26</td>
<td>21</td>
<td>5.9</td>
<td>3.2</td>
<td></td>
<td>5</td>
<td>1.4</td>
<td>-3.2</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>30</td>
<td>0</td>
<td>0</td>
<td>-5.6</td>
<td></td>
<td>30</td>
<td>8.4</td>
<td>5.6</td>
<td></td>
</tr>
<tr>
<td>Blind Turn</td>
<td>10</td>
<td>10</td>
<td>2.8</td>
<td>3.18</td>
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<td>0</td>
<td>0</td>
<td>-3.2</td>
<td></td>
</tr>
<tr>
<td>Approach Speed</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Stationary</td>
<td>51</td>
<td>40</td>
<td>11.2</td>
<td>4.21</td>
<td></td>
<td>11</td>
<td>3.1</td>
<td>-4.2</td>
<td>$\chi^2(3) = 59.81^\dagger$</td>
</tr>
<tr>
<td>Walk/ Slow Jog</td>
<td>173</td>
<td>118</td>
<td>33.1</td>
<td>5.5</td>
<td></td>
<td>55</td>
<td>15.4</td>
<td>-5.5</td>
<td>$\phi_c = 0.29$</td>
</tr>
<tr>
<td>Stride</td>
<td>392</td>
<td>167</td>
<td>46.8</td>
<td>-4.36</td>
<td></td>
<td>225</td>
<td>63.0</td>
<td>4.36</td>
<td></td>
</tr>
<tr>
<td>Sprint</td>
<td>98</td>
<td>32</td>
<td>9.0</td>
<td>-3.7</td>
<td></td>
<td>66</td>
<td>18.5</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>COD Angle</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>0 Degrees</td>
<td>122</td>
<td>44</td>
<td>12.3</td>
<td>-3.38</td>
<td></td>
<td>78</td>
<td>21.6</td>
<td>3.38</td>
<td>$\chi^2(2) = 17.86^\dagger$</td>
</tr>
<tr>
<td>0 - 90 Degrees</td>
<td>319</td>
<td>168</td>
<td>47.1</td>
<td>1.27</td>
<td></td>
<td>151</td>
<td>42.3</td>
<td>-1.3</td>
<td>$\phi_c = 0.16$</td>
</tr>
<tr>
<td>&gt;90 Degrees</td>
<td>244</td>
<td>145</td>
<td>40.6</td>
<td>3.63</td>
<td></td>
<td>99</td>
<td>27.7</td>
<td>-3.6</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>30</td>
<td>0</td>
<td>0</td>
<td>-5.5</td>
<td></td>
<td>30</td>
<td>8.4</td>
<td>5.5</td>
<td></td>
</tr>
</tbody>
</table>

\[\chi^2 = \text{Chi-Square Statistic}, \phi_c = \text{Effect Size (Cramér’s V)}, \star = p < 0.05, \star\star = p < 0.01, \dagger = p < 0.001\]

3.2.2.6 Association between agility strategy and success

The relationship between the agility strategy used and success was investigated using chi-square tests of independence (Table 3.12). Chi-square tests of independence revealed the technique used by the attacker and the defender had a small association with success ($\chi^2(4) = 13.13, p = 0.01 \phi_c = 0.19; \chi^2(5) = 14.11, p = 0.01, \phi_c = 0.2$). When adjusted standardised residuals were examined for the attacking athlete, no individual results were significant following Bonferroni corrections. However, significance was reached for observations on the defending athlete. Successful defending agility was observed less when
the defender performed a curved run, or decelerated as their primary agility technique (6.7%, SR = -2.63; 4.5%, SR = -4.5), nevertheless, they were more frequently successful when side-stepping (13.2%, SR = 7.64).

The approach speed of the attacker showed a small, significant relationship to success ($\chi^2(3) = 12.89, p = 0.005; \phi_c = 0.19$). When adjusted standardised residuals were examined, a stationary approach was less likely to be successful (5.3%, SR = 3.25). No significant relationship was found between the approach speed of the defender and success ($p > 0.05$).

No significant relationship was found between the attacker’s angle of COD and success ($p > 0.05$), however, a small, significant relationship was found for the defender’s angle of COD and success ($\chi^2(2) = 9.13, p = 0.01; \phi_c = 0.17$). However, following a Bonferroni correction, no statistically significant results were obtained from post-hoc analysis.

A moderate relationship was found between the deceptive technique of the attacker and success ($\chi^2(3) = 39.03, p < .001; \phi_c = 0.33$). Post-hoc analysis revealed that attacking agility success was less likely when no deceptive manoeuvre was used by the attacking athlete (42.8%, SR = -3). The location of the defender in relation to the attacker was not significantly related to success ($\chi^2(2) = 2.95, p = 0.23; \phi_c = 0.09$).
Table 3.12: Relationship between agility strategy and attacking success (n = 357)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Overall Sample</th>
<th>Successful Evasion (Attacker)</th>
<th>Unsuccessful Evasion (Attacker)</th>
<th>Chi Square Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>SR</td>
<td>N</td>
</tr>
<tr>
<td><strong>Attacker Technique</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side Step</td>
<td>264</td>
<td>192</td>
<td>77.1</td>
<td>206</td>
</tr>
<tr>
<td>Deceleration</td>
<td>27</td>
<td>14</td>
<td>5.6</td>
<td>-2.11</td>
</tr>
<tr>
<td>Crossover Cut</td>
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<td>26</td>
<td>10.4</td>
<td>0.62</td>
</tr>
<tr>
<td>Acceleration</td>
<td>21</td>
<td>14</td>
<td>5.6</td>
<td>-0.32</td>
</tr>
<tr>
<td>Blind Turn</td>
<td>10</td>
<td>3</td>
<td>1.2</td>
<td>-2.78</td>
</tr>
<tr>
<td><strong>Attacker Approach Speed</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stationary</td>
<td>40</td>
<td>19</td>
<td>7.6</td>
<td>-3.25</td>
</tr>
<tr>
<td>Walk/ Slow Jog</td>
<td>118</td>
<td>90</td>
<td>36.1</td>
<td>1.89</td>
</tr>
<tr>
<td>Stride</td>
<td>167</td>
<td>115</td>
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<td>-0.34</td>
</tr>
<tr>
<td>Sprint</td>
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<td>25</td>
<td>10.0</td>
<td>-1.08</td>
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<td><strong>Attacker COD Angle</strong></td>
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<td></td>
</tr>
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<td>25</td>
<td>16.2</td>
<td>-1.99</td>
</tr>
<tr>
<td>0 - 90 Degrees</td>
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<td>119</td>
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<td>0.42</td>
</tr>
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<td>0.091</td>
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<td><strong>Defender Technique</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side Step</td>
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<td>9</td>
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<td>-2.43</td>
</tr>
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<td>-2.44</td>
</tr>
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<td>17</td>
<td>10.2</td>
<td>-1.63</td>
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<td><strong>Defender Approach Speed</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>11</td>
<td>10</td>
<td>4.0</td>
<td>1.55</td>
</tr>
<tr>
<td>Walk/ Slow Jog</td>
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<td>40</td>
<td>16.1</td>
<td>0.52</td>
</tr>
<tr>
<td>Stride</td>
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<td>158</td>
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<td>0.25</td>
</tr>
<tr>
<td>Sprint</td>
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<td>-1.49</td>
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<td><strong>Defender COD Angle</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>78</td>
<td>62</td>
<td>24.9</td>
<td>2.12</td>
</tr>
<tr>
<td>0 - 90 Degrees</td>
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<td>-1.78</td>
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<td></td>
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<td>Feint</td>
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<td>1.61</td>
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<tr>
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<td>237</td>
<td>153</td>
<td>61.4</td>
<td>-3.00</td>
</tr>
<tr>
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<td></td>
</tr>
<tr>
<td>In Front</td>
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<td>117</td>
<td>47.0</td>
<td>0.52</td>
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<tr>
<td>Side</td>
<td>107</td>
<td>81</td>
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</tr>
<tr>
<td>Behind</td>
<td>79</td>
<td>51</td>
<td>20.5</td>
<td>1.14</td>
</tr>
</tbody>
</table>

\(\chi^2\) = Chi-Square Statistic, \(\phi_c\) = Effect Size (Cramér’s V), * = \(p < 0.05\), ** = \(p < 0.01\), † = \(p < 0.001\)
3.2.3 Discussion of Notational Analysis

3.2.3.1 Footwork patterns used in agility scenarios

The notational analysis aimed to describe footwork patterns used in elite AF. The results of this research should consider the reliability of the measured variables. All but two variables pertaining to the footwork patterns used in agility scenarios reached the study’s reliability threshold of $\kappa = 0.4$. Attacking agility technique did not reach the $\kappa = 0.4$ threshold for intra-rater reliability, while defensive COD angle did not meet the threshold for either inter-rater or intra-rater reliability. As such, findings involving attacking technique and defensive COD angle are limited by low reliability and findings pertaining to these variables must be interpreted cautiously. Low agreement in these variables is likely due to difficulty delineating individual movement patterns during unpredictable AF gameplay. Nevertheless, some general patterns relating to these variables did emerge as discussed below.

While some research exists which has described attacking agility in rugby union (122, 193), the movements used in 1v1 AF agility events have not been previously identified. This notational analysis found both attacking and defending athletes most frequently used the side-step technique to change direction (74% and 39% respectively). However, a larger variability in movement technique was found in this study when compared to previous research in rugby union (122, 193). This is likely due to the 360-degree nature of AF as well as the
large playing field in AF (100) which may allow for more high-speed encounters. Due to these factors, Australian footballers may encounter stimulus from a range of directions and speeds, whereas agility events in rugby union may be more structured due to an offside rule.

Despite the large playing area in AF (100), the notational analysis identified that agility events do not often occur at a sprint (9% of the time for attackers, 18.5% of the time for defenders), and instead are usually approached at a stride (46.8% of the time for attackers, 63% of the time for defenders). By not entering agility events at a sprint, attacking athletes allow themselves more time to select an appropriate technique and to make a controlled and considered change of speed or direction. This is contrary to agility testing research which artificially constrains athletes to maximal intensities (15, 55, 60, 73, 82, 83, 97, 115, 132, 155–157, 161, 162, 165, 172, 173, 175, 176, 188).

The current study found that attacking and defending athletes performed changes of direction of fewer than 90 degrees in the majority of cases (47.1% for attackers, 42.3% for defenders). However, in a substantial number of cases, athletes performed acute directional changes (40.6% for attackers, 27.7% for defenders), more frequently than has been reported in rugby codes (122). The variation in COD angle calls into question the idea of an ideal COD technique and provides evidence that COD angles used in AF games may be context-dependent. As the majority of testing procedures limit the athlete to COD of less than 90 degrees (60, 73, 82, 97, 115, 188).
tests are likely not specific to the demands of AF. Testing procedures that require the athlete to make context-specific changes of direction at multiple COD angles are needed. Finally, the change of direction angles used in agility scenarios is of interest to strength and conditioning practitioners as the angle of COD directly affects joint kinematics and kinetics, and subsequent injury risk (108). An increase in COD angle is associated with increased knee abduction moments (90, 102, 108), knee internal rotation (90), and hip internal rotation (90), which is of particular concern due to an elevated risk of ACL rupture (51, 150). Further, as a COD of greater than 90 degrees will likely result in a rapid deceleration followed by a subsequent re-acceleration, the GRF experienced by the athlete is likely to be high. Therefore, acute COD angles are of particular injury concern.

Interaction between footwork pattern components

As 1v1 agility scenarios are specific to the situation that they occur in, it is likely that the agility technique, approach speed, and COD angle will be related, and that changes in one component of footwork will lead to subsequent changes in the other aspects of the skill. Indeed, chi-square testing revealed that for both the attacking and defending athlete’s agility technique was related to approach speed ($\chi^2(12) = 79.72$, $p = <.001$; $\phi_c = 0.27$; $\chi^2(15) = 69.56$, $p = <.001$; $\phi_c = 0.25$), and COD angle ($\chi^2(8) = 279.34$, $p = <.001$; $\phi_c = 0.63$; $\chi^2(10) = 277.16$, $p = <.001$; $\phi_c = 0.65$). This indicates that the technique used in
training and testing should be dependent on the approach speed and COD angle of the event. Training methods that restrain athletes to one agility technique, and that do not consider the context of the situation, are likely limited in transfer potential.

3.2.3.2 Cognitive characteristics of agility events

The notational analysis aimed to determine the cognitive demands of 1v1 agility events in AF by examining the location of the defender in respect to the attacker, as well as any deceptive manoeuvres performed by the attacking athlete. While the location of the defender in relation to the attacker reached the threshold of reliability of $\kappa > 0.4$, the deceptive manoeuvre used by the attacker had an intra-rater reliability of $\kappa = 0.38$ indicating limitations with the reliability of this variable.

As the location of the defender in respect to the attacker influences the visual field of both the attacking and defending athlete, the inter-athlete location was chosen as one facet of agility cognitive demands. The current study found that the defender is located in front of the attacker in the majority of agility scenarios (47.9%). Front-on agility events are common in other invasion sports; however, due to the 360-degree nature of AF, agility events from other angles are also common. More than half (52.1%) of agility events in AF occurred with the defender either to the side or behind the attacking athlete. When the defender was in front of the attacker, the attacking
athlete was more likely to be stationary prior to an agility event (SR = 3.85). By maintaining a stationary position, rather than advancing forward, the attacking athlete provides himself with more time to make a change of direction, or to dispose of the ball. In addition, when behind the attacking athlete, the defending athlete was more likely to use a curved run (SR = 4.76), and more likely to approach at a sprint (2.8%, SR = 4.29). With the defender behind the attacking athlete, it is likely that the defender is required to chase the attacking athlete, making a sprint the most useful approach speed. To maintain speed following the location of the athlete in front, it is possible that less defined changes of direction are needed by defending athletes when behind. These findings indicate a need for training where the inter-athlete location of attacking and defensive athletes is varied. Many 1v1 training and SSG scenarios place athletes directly in-front of each other, and may not expose athletes to all scenarios that may occur in-game.

In addition to the defender location, deceptive techniques were recorded as a measure of cognitive demand on the defending athlete. The use of a deceptive technique by the attacker may force the defending athlete to move in the incorrect direction (83). If the athlete rectifies their mistake and later moves to the correct direction, a delay is created, allowing the attacking athlete time to create space, or dispose of the ball (83). However, the inclusion of a deceptive manoeuvre may also lead to an increase in the movement time of the attacking athlete, causing the effectiveness of a deceptive manoeuvre to be dependent on the context of the agility scenario (83). Results
of this study indicated that in the AFL, the choice to use a deceptive manoeuvre is generally a successful attacking strategy, with less successful events recorded when no deceptive manoeuvre was used (SR = 3). The observed success of deceptive manoeuvres may be due to the sample of elite Australian footballers who may be better able to select an appropriate time to perform a deceptive manoeuvre and may be more effective at disguising their true movement intention to their opponent (83). Nevertheless, the results indicate a need to familiarise athletes with deceptive manoeuvres, and allow opportunities for deception to be practised in training, in both attacking and defending roles.

3.2.3.3 Differences between attackers and defenders

The independence of attacking and defending agility has been of interest in recent research (212). During agility events in AF, the role of the attacking athlete is to create space and time to score or dispose of the ball, while the role of the defender is to reduce space and time from the attacker to either tackle or force a turnover. However, it is unknown how the movement techniques, approach speeds, or COD angles differ between attackers and defenders in the sport of AF.

The current study aimed to determine the relationship between the role of the athlete (attacker or defender), and the movement technique, speed, and angle used. Results indicated that the role of the athlete influences the movement technique used ($\chi^2(6) = 212.13, p < 0.001; \phi_c = 0.55$), with side-steps,
crossover cuts, accelerations, and blind turns favoured by attackers; and decelerations, and curved runs favoured by defenders. This indicates that the role of the athlete influences the choice of agility technique and that both attacking and defending athletes may need to be treated separately. However, common training and testing methods whereby the athlete must respond to a stimulus to move left or right are almost always only focused on attacking or defending in isolation (60, 73, 82, 97, 115, 156, 157, 162, 165, 207), preventing the athlete from developing or assessing the opposing skill. While the side-step was the preferred technique for both attacking and defending athletes, the use of the side-step was significantly less for defending athletes (SR = -9.4). This is likely due to the added time-stress of the defending agility manoeuvre. While the attacking athlete often enters an agility event with time to make an informed movement decision, the defending athlete is often time-stressed and must react immediately to movement decisions made by the ball-carrier. This added time-pressure might make the choice of a preferred movement solution less likely and force the defending athlete to use a faster, less preferred movement pattern. Further, as training outcomes are likely dependent on the athlete’s exposure to specific movement patterns, and differences were found between attacking and defending agility.

In addition to movement technique, differences between approach speed of attacking and defending athletes were found ($\chi^2(3) = 59.81, p < 0.001; \phi_c = 0.29$), further indicating independence between attacking and defending agility. While
both attacking and defending athletes entered agility events while striding the majority of the time, post-hoc analysis revealed slow approach speeds (stationary or walk/slow jog) occurred more frequently for attacking athletes than defensive athletes, while fast approach speeds (stride or sprint) occurred more frequently for defensive athletes. Interestingly, entering an agility event at a sprint was uncommon for either athlete (9%, 18.5%), suggesting that training methods that require the athlete to perform a COD at maximal intensity may be ineffective. Further, maximal intensity training provides a significant amount of load on the athlete. This may be unwanted, especially in-season, and slower agility tasks may increase specificity and reduce the GRF experienced by the athlete while cutting. As with technique, coaches should also consider the specificity of training dependent on the athlete’s role.

COD angle was associated with the role of the athlete; however, the magnitude of the effect was small ($\phi_c = 0.16$), and lower than for technique or approach speed. While attacking and defending athletes performed the majority of COD in agility events at shallow angles (<90 degrees) (47.1% for attackers, 42.3% for defenders), acute changes of direction (>90 degrees) were observed more frequently for attacking athletes (SR = 3.63). As biomechanical differences in COD technique are observed at different COD angles (76), differences between attacking and defending agility COD angles further imply the need for specific training and testing for individual roles while allowing a range of COD angles to be performed in training.
A medium relationship was found between speed and COD angle, and post-hoc analysis revealed that attackers performed acute changes of direction (>90 degrees), more when approaching at a walk/slow jog (SR = 2.99). This finding is consistent with CODS research that has shown slower approach speeds when cutting to 90 degrees compared 45 degrees in a CODS task (77). It is likely that attacking athletes reduce their approach speed in anticipation of a sharp COD which requires a significant deceleration. However, the notational analysis found that defending athletes performed acute COD (>90 degrees) more frequently when approaching at a sprint (3.6%, SR = 3.81). This discrepancy between attacking and defending agility further highlights the need to treat both as independent skills when training and testing.

3.2.3.4 Association of agility strategies with success

By understanding the agility strategies that are associated with success, coaches are better able to train successful agility manoeuvres while discouraging unsuccessful strategies. The current study showed a significant association between success and; the attacker’s technique, approach speed, and the use of deceptive manoeuvres. Stationary approaches to agility events by attacking athletes were frequently unsuccessful (SR = 3.25). It is likely attacking athletes were stationary prior to agility events due to immediate defending pressure, thereby reducing the time available to make a successful agility manoeuvre. It is possible that training in space-restricted environments where
the attacker begins from a stationary position may be effective in improving attacking success. Attackers were less successful when no deceptive manoeuvre was used (SR = -3) suggesting that the use of a deceptive manoeuvre is advantageous.

Defending technique and COD angle were associated with success ($\chi^2(5) = 14.11, p = 0.01, \phi_c = 0.2; \chi^2(2) = 9.13, p = 0.01; \phi_c = 0.17$). However, due to Bonferroni correction for multiple comparisons, post-hoc analysis did not reveal where the association occurred. Nevertheless, as COD angle and technique are related, training that allows athletes to perform agility events to a variety of COD angles may result in the use of more varied defending techniques.

3.3 Survey

A survey was conducted to determine the agility training and testing practices used in the AFL. This information was later used to ascertain if elite AF training and testing methods correspond with the agility demands of AFL matches (as described in the notational analysis).

3.3.1 Methods of Survey

3.3.1.1 Sample

All high-performance managers within the AFL were invited via email with the aim of obtaining a representative data-set of the AFL. Prior to invitation, the recruitment details, survey, and
research design were approved by the Federation University research ethics committee (Appendix B). Email addresses for all participants were obtained through personal contacts within the league. In the invitation email, all participants were informed that their involvement in the study was voluntary. Of the 18 high-performance managers employed by AFL clubs to oversee the physical performance of their team, ten anonymously responded to the survey invitation (55.6%).

3.3.1.2 Instrument Design

A short survey was developed using google forms (Google Inc, California, USA) which included two closed-ended questions and five open-ended questions that aimed to understand current agility training and testing practices in the AFL. The survey was designed for quick completion by coaches with the expected time commitment under 15 minutes. The closed-ended questions consisted of a Likert scale designed to ascertain the frequency that common agility training methods are used in AFL clubs. Open-ended questions then required the participants to elaborate on their training and testing procedures and to discuss aspects of agility that may require further research. The development of the chosen survey questions was underpinned by previous research which investigated current coaching practice in the area of agility (50) and coach education resources published by the AFL and the Australian Strength and Conditioning Association (10, 111). Prior to sending the survey, the survey was trialled on local
strength and conditioning coaches with experience in AF to ensure its quality. The full survey is presented in Appendix C.

3.3.1.3 Procedures

Following survey instrument design, the survey was uploaded to an online survey tool (SurveyMonkey, San Mateo, USA) to collect data for further analysis. High-performance managers of all 18 AFL clubs were invited via email by the PhD principal supervisor to participate. Invitations were delivered during the regular home and away season. Potential participants were re-invited to participate two weeks after the survey opening, and the survey was closed after a 4-week period. All respondents completed the survey in one sitting with an average completion time of eight minutes and 38 seconds.

3.3.1.4 Data Analyses

Data was exported as a CSV file from the online survey tool. Likert data from the closed-ended questions were separated from open-ended questions using Microsoft Excel (Microsoft Corporation, USA), and open-ended responses were input into ATLAS Ti (GmbH, Germany) for further analysis. A descriptive data analysis of the closed-ended questions was performed using Microsoft Excel (Microsoft Corporation, USA), and percentages and counts were obtained. Graphing of the Likert results was performed using R version 3.5.1 (R Foundation for Statistical Computing, Vienna, Austria).
As the current agility training and testing procedures used within elite AF are unknown, an inductive coding of the open-ended data was undertaken as described by Braun and Clarke (22). This thematic coding process involved an initial familiarisation of the data whereby data was read and inspected to allow the researcher to become acquainted with possible themes. Then codes were systematically applied to features of the open-ended question that were relevant to the research aims. Themes were then identified throughout the codes and reviewed before reporting the results. This was an iterative process that required the researcher to move forwards and backwards between the outlined steps, a sequential outline of the process is provided below in Figure 3.6.

![Survey coding process diagram](image-url)

Figure 3.6: Survey coding process
3.3.2 Results of Survey

Ten of the 18 (55.5%) high-performance managers in the AFL responded to the invitation to participate in the study. All participants responded to questions pertaining to the current training and testing procedures that they use within their AFL club. However, just five participants responded to the final two questions which were designed to identify further research and to allow the respondents a chance to make further comment. As the final two questions did not directly assess current training and testing practice, it is likely that the non-respondents did not identify, or wish to identify further research or have additional comments. Full survey responses are presented in Appendix D.

Some of the high-performance managers within the AFL have a previous relationship with the researchers and/or the university, and two have been involved in previous agility research at the university. Therefore, it is possible that the decision to respond and the choice of responses may be biased from past experiences. To address this, as the survey was completed anonymously to ensure that respondents knew that their identity would be obscured.

3.3.2.1 Training Methods Used in Elite AF

Training methods currently used within elite AF were described in questions 1, 2, 3, and 7. Question 1 required high-performance managers to indicate the frequency that they use common agility training methods, as shown below in Figure 3.7.
The results of question 1 indicate that agility training methods that are open in nature such as full ground match play, SSG, and 1v1 scenarios are most popular. However, some form of closed COD tasks was used sometimes or often by nine out of ten respondents. 1v1 training using agility belts was particularly uncommon with seven out of ten clubs never training agility using agility belts, and the three that do use agility belts employing them rarely.

Question 2 required the respondents to indicate the frequency that they coach common individual footwork patterns. The survey used the side-step, split-step, blind-turn and crossover-cut as the potential responses. Results are shown below in Figure 3.8.
While results from question 2 indicate that all four footwork manoeuvres are coached within elite AF clubs, only the side-step was coached by all respondents. Considerable variation existed with the frequency of coaching for the other three footwork manoeuvres, with some clubs providing time to coach them, and some clubs never coaching the movements.

Respondents further elaborated on the training methods used within elite AF in question 3. Results from question 3 indicated that a combination of closed CODS activities and open-scenarios were used by high-performance managers in the AFL. Isolated CODS training that did not involve a cognitive stimulus tended to be used to focus on isolated COD technique, while open-scenarios were incorporated to allow for sport-specificity, and to improve transfer. Closed training methods that were mentioned included isolated strength training, COD technique training, training with poles, and training with ladders. Open training methods that were mentioned included SSG, tackling drills, and “reactive agility” training. Of the open methods reported, SSG were most
frequently used. Five of the ten respondents referenced the use of SSG as a training method, and two respondents discussed constraint manipulation as a method of modifying the SSG to induce the desired training stimulus.

Individualisation and timing of training were identified as considerations to agility training. Individualisation was deemed important by four of the ten high-performance managers surveyed. The identified need for individualisation varied, with the role of the athlete and the athlete’s current agility skill identified as possible reasons for individualisation. The timing of agility training was mentioned in regards to the in-session placement of agility training, as well as periodisation within the year. Three high-performance managers mentioned undertaking COD and agility training in the warm-up, and progressing from closed COD activities to open agility tasks. Two respondents mentioned periodisation with one respondent indicating that specific footwork training occurs for some of their athletes in the pre-season period.

3.3.2.2 Testing Methods Used in Elite AF

Question four asked respondents to elaborate on the CODS and agility testing methods that are used at their club. Themes were coded from the responses and are visualised below in Figure 3.9.
Only two of the ten respondents indicated that they implement formal CODS or agility testing, of which, one club only assessed agility in first-year players using a flashing light stimulus. Further, six of the ten respondents reported relying entirely on subjective means of analysis for understanding the agility capabilities of their athletes. Of the clubs that relied entirely on subjective analysis, four clubs reported using video to assist.

Respondents who objectively assessed agility and COD capacity of their athletes used technology to allow for quantitative assessment. Two clubs reported using wearable technology in the form of GPS and accelerometry to gather data on their athlete’s agility capabilities. However, one respondent did question the validity of GPS accelerometry.

The CODS test used by the AFL to identify talented athletes for drafting is the AFL Planned Agility Test (145). The survey asked high-performance managers how much value they place on the results of this test, and to identify any alternative test that they would prefer to see at the AFL Draft
Combine. Nine out of ten high-performance managers reported finding little or no value in the AFL Planned Agility Test results. Three participants indicated that they would prefer an agility test wherein the athlete must react to a stimulus, while two respondents would prefer a different CODS test. Two high-performance managers highlighted the importance of subjective appraisal of an athlete’s agility, either personally, or by recruiting staff.

3.3.3 Discussion of Survey

The survey of high-performance managers in the AFL provided insight into the current training and testing practices of agility in elite AF. Interestingly, formal agility testing was undertaken by only one respondent, while another used CODS testing in their club. The majority of respondents indicated that they rely on subjective testing methods to assess agility. Subjective testing of agility may allow skilled coaches to glean subtle information about athlete movement that may not be captured in formal testing. Further, by testing in an open-environment or assessing during the game, the perceptual environment and variability of movement may be maintained. However, the reliability of the subjective assessment is unknown, and due to a lack of formal testing protocol, it is possible that coach biases may influence their understanding of their athlete’s agility. To augment subjective analysis with objective measures, two clubs indicated using wearable accelerometers. While some research indicates
that 2-dimensional (2D) player-load derived from accelerometer data may increase along with increased agility demands (40), reliability of accelerometer data was questioned by one respondent, and more research is needed to ascertain the reliability of accelerometer data for assessing agility.

Results of the notational analysis indicated a preference towards training methods that allowed for variation in movement with all respondents indicating that they use SSG, 1v1 training, and full-ground match play. These open training methods may be particularly useful for the development of agility as they allow for the coupling of the athlete’s physical COD with the perceptual stimulus that guides the movement in-game. By doing so, the athlete may learn to use movement strategies appropriate to their own movement capacities, as well as the constraints of the playing environment.

In addition to open training methods, most survey respondents did indicate that they use closed CODS training methods in training. However, the use of CODS training was dependent on the individual athlete and situated in the context of a larger training program. However, the use of CODS training is predominantly used to train movements believed to underpin agility. By doing so, coaches are likely attempting to develop generalised motor programs that can be later applied to dynamic agility environments (158). However, as agility is an open skill, and the movement used in agility scenarios is likely an emergent property of the agility event (128), the development of underlying motor programs outside of the context of the sport may be inefficient. Indeed, despite the
perception that CODS training may underpin agility development, research has shown biomechanical differences between the movement patterns used for agility, to those used for CODS. This indicates that the movement techniques trained in CODS training may not be the same movement skills used in agility events (17, 195).

3.4 DISCUSSION OF NOTATIONAL ANALYSIS WITH SURVEY

The following section discusses the link between the notational analysis and the survey. As such, this study aimed to understand the characteristics of agility scenarios by attacking and defending athletes in 1v1 agility events in elite AF. In addition, this study aimed to understand the current agility training and testing practices used in elite AF clubs to determine if current practice reflects the game demands.

3.4.1 Agility footwork patterns

This study investigated agility technique, speed, and COD angle to determine agility footwork patterns. Results indicated substantial variability of agility technique, speed, and angle. As technique is largely sport-specific, the training procedures that are used by coaches must replicate the demands of the sport, and in the case of AF, many training procedures do not allow for the degree of movement variability seen in this study. Training methods that require the athlete to make
pre-determined movements around stationary obstacles are of particular concern as it is likely that the athlete will revert to the preferred side-step movement pattern and neglect the development of other movement techniques. Indeed, nine of the ten high-performance managers who responded to the survey on current training and testing techniques reported performing pre-defined COD activities during training either sometimes or often. However, some respondents indicated that the CODS training used in AFL clubs is individualised and context-dependent, and just one part of a larger training program. Indeed, all surveyed high-performance managers reported using full-ground match play, SSG, and 1v1 training, indicating that athletes in elite environments are regularly prescribed a variable stimulus.

Testing protocols that account for the variable nature of AF found in the notational analysis may be best suited to 1v1 agility development (212). However, the majority of tests that are currently used to assess agility artificially constrain the athlete to a pre-determined movement technique and time demands (60, 73, 82, 97, 115, 156, 157, 162, 165, 207). CODS tests justified for their ability to assess an underlying movement quality, are almost always performed using side-steps (131). In elite AF environments, the formalised testing of agility and COD appears to be rare. Just one surveyed high-performance manager reported undertaking formalised time-based agility testing, and one high-performance manager reported using time-based CODS testing. AFL clubs rely more heavily on subjective observation of agility movements in training and
game scenarios. Subjective agility assessment may allow coaches to understand agility capabilities in both low and high-speed situations. However, to fully understand the utility of subjective approaches to agility assessment, more research is required.

### 3.4.1.1 Cognitive Demands of Agility

The cognitive demands of agility scenarios have been acknowledged in the literature for the past 40 years \(^{(31)}\); however, the cognitive demands in the context of AF are unknown. By definition, all agility events include a cognitive component; however, a description of the cognitive demands of AF agility events is absent in the literature. The notational analysis showed substantial variation in the approach angle of attackers in relation to defenders with less than 50% of agility scenarios occurring front-on. This variation is likely due to the 360-degree nature of AF, whereby attackers and defenders may interact in a multitude of scenarios. This finding indicates the use of SSG or 1v1 scenarios that allow for a variety of angles as useful methods for developing agility. Indeed, all surveyed high-performance managers indicated using SSG and 1v1 training in their programs.

In addition to inter-athlete location, the use of deceptive manoeuvres was recorded to indicate the cognitive demands of agility scenarios. The notational analysis found that deceptive manoeuvres by attacking athletes were common (33.6%), and when employed were generally successful (SR = 3). This
indicates that environments that allow athletes to develop deceptive abilities are likely advantageous. While no respondents of the survey indicated that they deliberately teach deceptive manoeuvres in their training practice, six of the ten high-performance managers mentioned the use of open training methods such as 1v1 and SSG training. In these tasks, it is likely that deceptive manoeuvres would be practised. More research is needed to know if open training activities allow for sufficient exposure to improve both the attacker’s ability to successfully execute deceiving movements, or the defender’s ability to respond. Further, as only two agility tests reported in the literature allow for the use of deceptive manoeuvres, more development of testing protocols that allow for deception is needed (49, 83, 212).

3.4.1.2 Differences Between Attackers and Defenders

The notational analysis found significant differences in the movement technique, speed, and COD angle used by attacking and defensive athletes. This finding supports previous research that has indicated that attacking and defensive agility are distinct skills (212). As such, differences between the two skills must be accounted for when developing training and testing. Open training tasks such as SSG and 1v1 training allow athletes to adopt attacking and defensive training roles and may be a suitable method for ensuring exposure to both capacities. This aligns well with the survey results which showed that all responding AFL clubs currently use SSG and 1v1 training.
The findings of this study indicate a need for training and testing procedures that better reflect the demands of AF. Agility in-game occurs in context to the individual situation and a variety of techniques, speeds, and COD angles are used by attacking and defending athletes. This reflects a need for training and testing methods that match these demands.

The use of agility tests that artificially constrain the athlete to a pre-determined COD angle or technique fails to replicate the variation seen in-game. The majority of agility testing procedures are time-based (131), and therefore require athletes to perform at maximal intensities (131). As this is contrary to how 1v1 agility events occur in-game, the ecological validity of these testing procedures is compromised. This presents a greater need for testing procedures that allow the athlete to choose an appropriate speed for the given situation. Further, as testing methods that require athletes to perform at maximal physical intensity increase the GRF experienced by the athlete (187), they are likely more dependent on physical strength qualities than 1v1 agility scenarios in-game. As the notational analysis found that defensive agility occurs at higher speeds than attacking agility, the assessment of defending agility should include more higher-speed scenarios than the assessment of attacking agility. Further, coaches are encouraged to adopt testing protocols that encourage variation, and that don’t restrict athletes to maximal intensities, such as field-based
testing (212). An often-used strategy in elite AF is to use subjective analysis to determine agility performance. While this may be effective in understanding the nuances of agility performance, particularly with experienced coaches, more research is required to determine the reliability of this assessment.

The training of agility must also reflect the demands of on-field agility scenarios in AF. The use of closed COD training tasks fails to place the athlete into a context-specific agility environment and prevents athletes from developing agility skill that is suitable to the chaotic sporting environment. This presents a need for the development of open, context-specific training tasks which allow for variation. 1v1 training and SSG may be a suitable alternatives for encouraging variability (28, 49, 214).

As agility events frequently occur at sub-maximal intensities, to reflect the demands of the game, practitioners should undertake the majority of training at speeds lower than maximal. Further, it is recommended that coaches vary the inter-athlete location so that attackers and defenders have adequate exposure to agility events where they approach their opponent from in-front, to the side, and from behind. Indeed, as less than 50% of agility scenarios in the notational analysis occurred from front-on, training where the defensive athlete begins behind the attacker is likely useful. Shadowing activities such as the use of agility belts may be of practical benefit to train for this scenario.
Differences between attacking and defending agility found throughout the notational analysis highlight the need to treat attacking and defending agility as separate skills. When training defending agility, coaches should prescribe more changes of direction at higher speeds than when training attacking agility, and training attackers in space-restricted environments from a stationary position may be effective in improving attacking success. Further, to allow for the development of successful attacking agility, attackers should be encouraged to practice deceptive techniques in training. Similarly, defenders should be encouraged to practice facing deceptive manoeuvres to allow for more accurate anticipation of their opponent’s agility movement.

As well as training and testing implications, deceptive movements may have injury-risk implications. As deceptive manoeuvres increase the time-pressure applied to the defending athlete, it is likely that athletes will be unable to consciously adopt an ideal movement pattern. This constraint likely causes increased external valgus and external rotation moments at the knee (17) and subsequent ACL injury risk (190). This presents a need to familiarise defending athletes with deceptive manoeuvres to allow for better anticipation of deceptive visual cues, thereby increasing the available time to optimally orient their body for the agility event.
4.1 INTRODUCTION

As discussed in the previous chapter, agility events in AF are variable in nature. In a chaotic sporting environment, the use of a hypothetical ideal movement is rare. Athletes select movements based upon the demands of the event and in the confines of their environment. Instead, variation in movement technique is common. This variation extends to the speed of approach, the COD angles, and the specific footwork pattern used. Further, the movement technique applied by athletes differs between attackers and defenders.

In the majority of testing protocols presented in the literature, the athlete’s footwork technique, COD angle, and approach speed has been fixed. Further, the perceptual information in agility tests has usually been simplified (137). This suppression of movement options and perceptual information has been preferred in the literature to control for confounding variables. By removing sources of potential error in the testing procedures, observed changes in "traditional" agility tests are easily attributable to changes in performance. Nevertheless, by simplifying both the movement and cognitive
demands of agility tests, it is unlikely that results are representative of an athlete’s agility in invasion sports. Therefore, "traditional" agility tests likely lack ecological validity.

To account for the above limitations of previous testing methods, this study examined the reliability and validity of a new field-based test of attacking and defending agility. The proposed test, adapted from previous research (212), places athletes in a series of simulated 1v1 scenarios to assess agility in a more representative environment. The test is scored on the ability of the attacker to evade the defender and create space, and the ability of the defender to reduce space and tackle. By doing so, the test assesses attacking and defending agility while maintaining the complex interaction between physical, technical and cognitive factors of agility.

An earlier version of the 1v1 agility test was found to have adequate test-retest and inter-rater reliability (212). However, some issues with ecological validity were observed during previous iterations of the test. Since then, through pilot testing, significant modifications have been made to overcome the observed limitations, as described in detail in the methods section below. As considerable constraint modifications were made to the test, reliability required re-analysis. Further, to evaluate the utility of the new test, the validity was also assessed by comparing the characteristics of the test to agility in AF matches.

The 1v1 test of attacking and defending agility aims to improve on previous agility tests by capturing the variability
inherent in AF agility scenarios while allowing athletes to respond to a game-like stimulus. However, the increased variability in the test possibly corresponds to a reduction in reliability. As the specifics of each individual agility scenario in AF vary considerably, to keep the error in acceptable limits and to allow the test to differentiate between athletes, the test was simplified to 1v1 scenarios. However, as agility scenarios in AF do not occur in isolated 1v1 events, the new test does represent a somewhat simplified view of agility.

The validity of previous 1v1 testing protocols has not been determined. Therefore, to ensure the quality of subsequent research, this PhD analysed both the reliability and the ecological validity of the 1v1 testing procedures. To determine reliability, test-retest, inter-rater and intra-rater reliability were established. Ecological validity was determined by comparing movement patterns during the agility test with movement patterns used in AF agility events (as presented in Chapter 3).

4.2 METHODS

Twenty-two community level Australian rules football players were recruited to participate in the study. Sample-size for the study was calculated using PASS 15 (NCSS LLC, USA), using test-retest intra-class correlation coefficients (ICC) as the primary outcome measure. The sample size of 15 participants was required to reach a power of $1 - \beta = 0.80$ for $ICC = 0.6$, and an alpha of $\alpha = 0.05$. As such, the final sample size of $n=22$
achieved sufficient power to detect an ICC of 0.6 (191). To be eligible for inclusion in the study, participants were required to comply with the following:

- Be male.

- Be aged between 18 and 35.

- Have at least two years of Australian football playing experience.

- Have played AF in the past 12 months.

- Be injury-free for six months prior to the commencement of the study.

- Not be participating in any formal sport training programs.

Participants were recruited from the local community via digital and poster advertising over a 1-month period. Prior to recruitment, the study was reviewed and approved by the Federation University research ethics committee (Appendix E).

To ensure informed consent was obtained, the study design was fully described to all participants during recruitment. Participants were provided with a plain language information statement prior to participation which clearly informed participants of the details of this study (Appendix F). After participants were clearly informed of the study requirements, informed consent was given prior to participation in the form of a signed consent form (Appendix G).
4.2.1 Procedures

The study implemented a single-group design with athletes participating in three testing sessions separated by one week. In the first week, prior to initial testing, athletes undertook familiarisation to mitigate any learning effect from one session to the next. During familiarisation, athletes practised attacking and defending testing procedures and performed the tests in full. In the following week, athletes undertook both the attacking and defending agility tests, and data was recorded. One week later, under identical conditions, athletes were re-tested. A timeline of this is presented below in Figure 4.1.

![Figure 4.1: Reliability and validity study timeline](attachment:image)

Testing was conducted at a single facility on an indoor, rubberised surface in the university’s sport science department. The venue and surface were chosen to provide adequate friction to reduce slippage and minimise surface variability, the effects of weather, and temperature fluctuations. The thermostat in the facility was set at 20°C. Prior to each testing session, the floor was cleaned to reduce dust and to improve the frictional qualities of the surface. Athletes were instructed to wear running shoes with minimal wear during all sessions to ensure optimal surface friction.
For the purposes of reliability, participants were split into 11 pairs. Each pair tested attacking and defending agility against each other for the duration of the study. In doing so, testing was conducted against the same opponent in each stage of the study, thereby eliminating variability from changing opponents. However, to standardise athlete testing, as in the following chapter, athletes’ opponents must be substituted for standardised testers to compare results between athletes or between time-points.

Four athletes arrived at the testing facility at the same time of day for both testing sessions. Upon arrival, the athletes performed a supervised, standardised warm-up, as shown in Appendix H. The purpose of the warm-up was to reduce injury risk during testing and to maximise physical performance. Following the warm-up, athletes undertook the test as either the attacker or defender, chosen at random. Each test consisted of ten trials with a minimum of 20 seconds rest allocated between trials. Following the completion of all ten trials, athletes received five minutes rest, followed by the alternative test. For example, if the athlete performed the attacking agility test first, they then undertook the defensive test following a five-minute rest. All testing sessions were supervised by the PhD student, along with two research assistants.
4.2 METHODS

4.2.2 Agility Test Protocol

Each trial of the agility test began with an attacker and defender stationary in an 11x11 metre area bounded by cones (Figure 4.2). Prior to testing, the attacking and defending athletes were given a small sheet of paper that listed their starting positions for each of ten trials. Each sheet indicated the athlete’s starting position, but not the position of their opponent, thereby blinding the athlete’s starting positions from each other. The order of the starting positions was randomised from a list of pre-determined pairs of starting positions (Appendix I). Prior to the commencement of the test, the attacking athlete was given the following instructions:

“Your aim is to evade your opponent and get nearer to the end line without being touched. If you go outside the designated area or try to fend off your opponent, you will receive a zero score. You are permitted five seconds to evade, after which time you will receive a zero score. You will get maximum points if you get passed the defender without being touched at all, but you can get a lesser score if you are touched with one or two hands. The defender will try to get both arms around you briefly, but will not attempt to tackle. The test involves ten trials. Do you have any questions?”

Similarly, the instructions given to the defending athlete were:
“Your opponent is going to try to get around you towards the end line without being touched. Your aim is to try to get both arms around him with the elbows bent as if to tackle, but without performing a tackle. If you achieve this, you will get maximum points, but if not, you will receive a lesser score. The attacker is not allowed outside the designated area and is not allowed to fend you off. The test involves ten trials. Do you have any questions?”

Figure 4.2: Agility trail vectors. Each arrow begins at the attacker’s starting position and points to the defender’s starting position for each trial.

After athletes understood the test procedure, the attacking athlete was instructed to move to their given starting position first and to face away from the testing area. Once the attacker
was in position, the defender moved to their given starting position. Once both athletes were in position, a research assistant indicated to both athletes that the test may begin when the attacker is ready. Each trial was initiated at the first movement of the attacker, after which, the attacker was required to attempt to evade, and pass the defender, or reach the end line. Therefore, it was the goal of the attacker to create space from the defender, while the defender attempted to simultaneously reduce space in an attempt to tackle. As such, scoring of the test was based on the athlete’s ability to reach the specific goals of the agility task rather than complete a course in a minimal amount of time, as is the standard procedure of ‘traditional’ agility tests. This is likely a more valid scoring procedure as the goals of the athlete are similar to that of an athlete during a match. Therefore, the speed and technique of the agility manoeuvre are more likely to align those seen in the sport of AF. Following the conclusion of each trial, athletes were given a minimum of 20 seconds to find their next starting position, and the process was repeated until all ten trials were completed. At the completion of all trials, roles were reversed, and the test procedure was repeated in full. For example, the attacking athlete assumed the role of defender, while the defensive athlete assumed the role of attacker.

Following the test, footage from three separate cameras in front of and behind the testing area was used to assess the trials (Figure 4.2). Camera 1 was a Sony (Sony Corporation, Tokyo, Japan) video camera (FDR-X1000V) which provided a high-speed, wide-angle view and was set to record at (1920 x 1080 x 119.88fps). Cameras 2 and 3 were Panasonic camcorders
(Panasonic Corporation, Osaka, Japan) set to record at (1440 x 1080 x 25fps). All videos were compressed using advanced video coding (H.264). Video analysis software (Kinovea, 0.8.15, France) was used to slow footage and ensure accurate scoring of each event. Camera 3 was used as the primary camera for video-review as it provided a panning view of the agility event. If the score was not certain from Camera 3, the other two cameras were used. The scoring format for each trial is shown below in Table 4.1. The total attacking and defensive agility score is obtained for each athlete to achieve a total possible score of 30.

<table>
<thead>
<tr>
<th>Score</th>
<th>Defending</th>
<th>Attacking</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Both arms around torso simultaneously with elbows flexed</td>
<td>No touch of body at all</td>
</tr>
<tr>
<td>2</td>
<td>Both arms around torso simultaneously with arms straight (elbows extended)</td>
<td>One hand touch on torso</td>
</tr>
<tr>
<td>1</td>
<td>One hand touch on torso</td>
<td>Both arms around torso simultaneously with arms straight (elbows extended)</td>
</tr>
<tr>
<td>0</td>
<td>No touch of body at all</td>
<td>Both arms around torso simultaneously with elbows flexed or went outside area, or didn’t cross end line, or fend</td>
</tr>
</tbody>
</table>

Examples for the attacker and defender scores are provided below in Figure 4.3
4.2.3 Constraint Modifications to Previous Agility Test Protocol

As mentioned previously, the attacking and defending agility test protocols were adapted from previous testing methodologies to address observed limitations in prior testing procedures (212). Limitations to the previous testing procedure and changes made are listed below:

1. **Athletes in the test may be able to memorise the sequence of agility scenarios.**

In the previous published testing methodology (212), the
order of starting positions remained constant and did not change between sessions or between participants. For this reason, it is possible that an athlete may be able to commit the starting positions to memory. By memorising the test sequence, athletes may be able to adopt pre-planned movement strategies. This compromises the ecological validity of the testing procedure, as in-game athletes are required to choose movements in a time-restricted, constantly-changing sporting environment. To address this limitation, in the modified protocol, the order in which trials were delivered to athletes was randomised.

2. **Attacking athletes may perform a straight-line sprint, thereby eliminating agility demands in some trials.**

   In the previous testing procedure, attacking athletes, if fast enough, were able to sprint past defending athletes in some trials. To account for this, the testing area was reduced to 11x11m from the previous size of 15x15m (212). By limiting the interpersonal space available, the attacking athlete is given less opportunity to evade using a straight-line sprinting, and must instead evade by decelerating or changing direction in the majority of cases.

3. **Attacking athletes were able to pre-plan their movement strategy.**

   In addition to the change of the testing area, a rule change was added whereby the attacking athlete was required to face away from the testing area prior to the trial beginning. The defending athlete was then able to move
into position without the attacking athlete’s knowledge of their position. Once athletes were in the correct starting positions, the researcher administering the test informed the athletes that the test may begin. The trial began at the first movement of the attacking athlete. This rule change was included to prevent attacking athletes from pre-planning their movement strategy, as in AF games, due to temporal limitations, athletes must make movement selections without the luxury of planning. As a result, it was less likely that the athlete would select a straight-line sprinting strategy in the trial.

4. *Attacking athletes were able to out-endure the defender.*
In the previous testing procedure, the attacking athlete was able to spend a substantial amount of time making repeated changes of direction in the hope of finding space to evade. However, in the sport of AF, if an attacking athlete were to take a large amount of time before making a movement decision, defending athletes would encroach on their space. Therefore, to better represent the temporal demands of agility in AF, a five-second time-limit was introduced. The attacking athlete was given five seconds for each trial to attempt to evade the defender. If the trial finished after five seconds, the attacking athlete received a minimum score, and the defending athlete received a maximum score.

5. *Once the attacking athlete passed the defending athlete, the defender was able to sprint after the attacker to tackle.*
In the previous version of the test, once the attacking athlete passed the defender, the defender was able to chase the attacker in an attempt to tackle. As a result, the final agility score could foreseeably be determined by the athlete’s acceleration ability, rather than their ability to evade. In the case of an AF game, if an attacking athlete is getting chased after evading the defender, it is likely that they will dispose of the ball. Therefore, the rules were changed to finish each trial once the attacking athlete has passed the defender, rather than passed the end-line.

6. **There was an uneven distribution of inter-athlete distances and angles.**

In the previously published testing procedure, repetitiveness was observed in the starting positions of the attackers and defenders. Therefore, the attacker and defender locations were changed to allow for a large variance of inter-personal distances and angles. The modifications of starting positions are presented below in Figure 4.4. The starting positions, along with inter-personal distances and angles, are documented in Appendix I.
4.2 METHODS

4.2.4 Data Analyses

4.2.4.1 Test-Retest Reliability

To measure test-retest reliability of attacking and defensive agility, typical error (TE), t-tests, and single-measure intra-class correlation coefficients (ICC) were calculated, as shown in Table 4.3. Reliability from ICC results was interpreted using qualitative descriptors suggested by (107), as shown below in Table 4.2. An ICC of 0.6 was set as the minimum acceptable threshold, as in previous research (186).

Table 4.2: Qualitative descriptors of ICC reliability (107)

<table>
<thead>
<tr>
<th>ICC</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.5</td>
<td>Poor</td>
</tr>
<tr>
<td>≥ 0.5 &lt;0.75</td>
<td>Moderate</td>
</tr>
<tr>
<td>≥ 0.75 &lt;0.9</td>
<td>Good</td>
</tr>
<tr>
<td>&gt;0.9 ≤ 1</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

Figure 4.4: Changes in starting positions and testing area

Previous Starting Positions

Updated Starting Positions
Table 4.3: 1v1 test reliability statistics

<table>
<thead>
<tr>
<th></th>
<th>ICC</th>
<th>Difference between means (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between days (test-retest)</td>
<td>0.67</td>
<td>p = 0.55</td>
</tr>
<tr>
<td>Between testers (inter-rater)</td>
<td>0.92</td>
<td>p = 0.41</td>
</tr>
<tr>
<td>Within tester (intra-rater)</td>
<td>0.97</td>
<td>p = 0.93</td>
</tr>
</tbody>
</table>

Agreement between pre-testing and post-testing results was visualised using Bland-Altman plots (18). The Bland-Altman plot assigns the mean of both testing periods on the x-axis, while the difference between the trails is assigned to the y-axis. The mean difference and 95% limits of agreement (Mean ± 1.96 SD) were plotted as dashed lines.

4.2.4.2 Inter-rater and intra-rater reliability

As the test protocol relies on the score from an assessor, a research assistant independently scored a subsection of the first 16 athletes (320 trials). The research assistant was an Exercise and Sport Science undergraduate student in their final year of study. As such, the assistant had considerable sport science experience and was familiar with video analysis from their academic studies. Prior to scoring video footage, the PhD student and the research assistant discussed the scoring protocol to eliminate any potential confusion that may arise during the data recording process. All agility scenarios were scored by the PhD student and the research assistant independently and as such ratings were not discussed or compared prior to data analysis. Inter-rater variation was
assessed using intra-class correlation coefficients as described for test-retest reliability.

As with inter-rater reliability, to assess intra-rater reliability, the primary researcher re-analysed a subsection of the first 16 participants (320 trials) after a period of more than 1-month. Following the re-scoring of the test, the results from both testing periods were compared using intra-class correlation coefficients.

4.2.4.3 Validity

Frequency distributions were formed for categorical movement variables from the 1v1 test as well as the notational analysis from chapter 3, frequencies along with percentages were reported. To determine if movement patterns used in the 1v1 test differ in their proportion to elite AF, categorical variables relating to athlete movement patterns were compared using data from 1v1 test and the notational analysis via Chi-square tests of homogeneity (57). To expose the athlete to multiple approach speeds and angles, as expected in matches, the initial starting positions of the athletes in the bounded area varied between trials, as shown in Figure 4.2. Statistical analysis was performed using R version 3.5.1 (R Foundation for Statistical Computing, Vienna, Austria) with significance set at $p < 0.05$. As with the notational analysis, Cramér’s V statistics were calculated to determine the effect sizes for all Chi-square tests of homogeneity, and are indicated by $\phi_c$ throughout. As $r = 2$ throughout this chapter Cramér’s V and Cohen’s w are
equivalent (34). Therefore, qualitative descriptors from Cohen were used to describe the magnitude of effect (34) (Table 4.4).

<table>
<thead>
<tr>
<th>Descriptor</th>
<th>Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negligible</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>Small</td>
<td>≥ 0.1 &lt; 0.3</td>
</tr>
<tr>
<td>Medium</td>
<td>≥ 0.3 &lt; 0.5</td>
</tr>
<tr>
<td>Large</td>
<td>≥ 0.5</td>
</tr>
</tbody>
</table>

4.3 RESULTS

The mean ± SD for attacking and defending agility scores were 9.16 ± 5.72 and 20.84 ± 6 respectively. Reliability and validity results are presented separately below.

4.3.1 Reliability

The test-retest, inter-rater, and intra-rater reliability statistics are summarised in Table 4.3. As attacking and defensive athletes were scored simultaneously, and the score for the defending athlete is opposite to the attacking athlete, the ICCs for attacking and defending agility are synonymous.

The test-retest reliability statistics for attacking and defensive agility are summarised in Table 4.5, and Bland-Altman plots visualising the test-retest, inter-rater, and intra-rater reliability is presented in Figure 4.5 on Page 130. Both ICC (0.67), and the Band-Altman plot demonstrated acceptable agreement between the two testing periods,
indicating moderate test-retest reliability. No significant bias was detected between pre-testing and post-testing conditions (p > 0.05).

Excellent agreement was found for inter-rater and intra-rater reliability (ICC = 0.92; ICC = 0.97). However, inspection of the Bland-Altman plots reveals that the research assistant had a small, non-significant negative bias for attacking agility, and positive bias for defending agility. That is, the research assistant tended to score attackers slightly lower than the PhD student.

| Table 4.5: Test Re-Test Reliability for Attacking and Defending Agility |
|------------------------------------------------|---------|---------|
|                             | Attacking | Defending |
| Session 1 (Mean ± SD)      | 9.36 ± 5.6 | 20.64 ± 5.6 |
| Session 2 (Mean ± SD)      | 8.28 ± 4.84 | 21.59 ± 4.84 |
| Difference between tests (p-value) | 0.55 | 0.55 |
| ICC                        | 0.67     | 0.67     |
| Typical Error              | 3.07     | 3.07     |

ICC = Intra-class Correlation Coefficient
Figure 4.5: Bland-Altman plots. (A) Attacking Agility, (B) Defending Agility
4.3.2  Validity

As mentioned earlier, the validity of the 1v1 test of attacking and defensive agility was determined by comparing attacking and defending movement patterns in the test with those in professional AF games (Table 4.6). Chi-square testing found significant differences in the proportion of specific movement patterns used by athletes in the test when compared to agility events in the AFL (p>.05). This finding indicates that the movement patterns used in the test are not identical to those used in elite AF. However, inspection of the effect sizes (\(\phi_c\)) are useful for understanding the degree of difference between the test and in-game scenarios, as discussed below.
Table 4.6: Similarity of movement patterns used in the notational analysis and the 1v1 test

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Overall Sample</th>
<th>Notational Analysis</th>
<th>Test</th>
<th>Chi-square</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>SR</td>
<td>N</td>
</tr>
<tr>
<td>Attacker Technique</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side Step</td>
<td>642</td>
<td>264</td>
<td>73.9</td>
<td>4.24</td>
</tr>
<tr>
<td>Deceleration</td>
<td>31</td>
<td>27</td>
<td>7.6</td>
<td>4.83</td>
</tr>
<tr>
<td>Crossover Cut</td>
<td>44</td>
<td>35</td>
<td>9.8</td>
<td>1.77</td>
</tr>
<tr>
<td>Acceleration</td>
<td>54</td>
<td>21</td>
<td>5.9</td>
<td>-0.9</td>
</tr>
<tr>
<td>Blind Turn</td>
<td>44</td>
<td>35</td>
<td>9.8</td>
<td>1.77</td>
</tr>
<tr>
<td>Curved Run</td>
<td>14</td>
<td>28</td>
<td>2.8</td>
<td>2.7</td>
</tr>
<tr>
<td>Attacker COD Angle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 Degrees</td>
<td>47</td>
<td>40</td>
<td>11.2</td>
<td>5.73</td>
</tr>
<tr>
<td>&gt;90 Degrees</td>
<td>125</td>
<td>118</td>
<td>33.1</td>
<td>12.15</td>
</tr>
<tr>
<td>Stride</td>
<td>435</td>
<td>167</td>
<td>46.8</td>
<td>-3.98</td>
</tr>
<tr>
<td>Sprint</td>
<td>190</td>
<td>32</td>
<td>9.0</td>
<td>-8.88</td>
</tr>
<tr>
<td>Defender Technique</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side Step</td>
<td>464</td>
<td>139</td>
<td>38.9</td>
<td>-9.94</td>
</tr>
<tr>
<td>Deceleration</td>
<td>97</td>
<td>83</td>
<td>23.2</td>
<td>8.62</td>
</tr>
<tr>
<td>Curved run</td>
<td>105</td>
<td>86</td>
<td>24.1</td>
<td>8.21</td>
</tr>
<tr>
<td>Crossover Cut</td>
<td>38</td>
<td>14</td>
<td>3.9</td>
<td>-1.01</td>
</tr>
<tr>
<td>Acceleration</td>
<td>63</td>
<td>5</td>
<td>1.4</td>
<td>-6.13</td>
</tr>
<tr>
<td>None</td>
<td>30</td>
<td>30</td>
<td>8.4</td>
<td>6.2</td>
</tr>
<tr>
<td>Defender Approach Speed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stationary</td>
<td>14</td>
<td>11</td>
<td>3.1</td>
<td>2.56</td>
</tr>
<tr>
<td>Walk/ Slow Jog</td>
<td>62</td>
<td>55</td>
<td>15.4</td>
<td>-0.96</td>
</tr>
<tr>
<td>Stride</td>
<td>488</td>
<td>225</td>
<td>63.0</td>
<td>0.94</td>
</tr>
<tr>
<td>Sprint</td>
<td>161</td>
<td>66</td>
<td>18.5</td>
<td>-1.09</td>
</tr>
<tr>
<td>Defender COD Angle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 Degrees</td>
<td>151</td>
<td>77</td>
<td>21.6</td>
<td>1.70</td>
</tr>
<tr>
<td>&gt;90 Degrees</td>
<td>347</td>
<td>151</td>
<td>42.3</td>
<td>-0.64</td>
</tr>
<tr>
<td>None</td>
<td>269</td>
<td>99</td>
<td>27.7</td>
<td>-3.24</td>
</tr>
</tbody>
</table>

$^* = p < 0.05, ** = p < 0.01, † = p < 0.001$
4.3.2.1  **Agility Technique**

As shown below in Figure 4.6, the most used technique by both attacking and defending athletes in-game and in the 1v1 test was the side-step. Further, in the notational analysis, attackers and defenders used a variety of techniques during agility events. However, a Chi-square test of homogeneity revealed significant differences in the proportion of agility techniques used between the notational analysis, and the 1v1 test, for both attacking and defending agility (Table 4.6). The magnitude of differences was small for attacking agility ($\phi_c = 0.29$), and large for defending agility ($\phi_c = 0.55$).

![Figure 4.6: Comparison of technique between the notational analysis and 1v1 test](Image)

Note: Percentages may not sum to 100 due to rounding.

4.3.2.2  **Approach Speed**

As shown in Figure 4.7, the most common approach speed for both attacking and defending athletes in both the test and the 1v1 test is a stride, indicating that the testing procedure was
successful in reducing the number of sprinting efforts. Nevertheless, sprinting occurred proportionally more often in the 1v1 test than in the notational analysis for both attacking and defending. As such, Chi-square testing of homogeneity revealed significant differences in the proportion of approach speed used for both attacking and defending athletes between the 1v1 test and notational analysis (Table 4.6). Differences between proportions were large for attacking agility ($\phi_c = 0.53$) and small for defensive agility ($\phi_c = 0.1$).

Figure 4.7: Comparison of approach speed between the notational analysis and 1v1 test

Note: Percentages may not sum to 100 due to rounding

4.3.2.3 COD Angle

As shown in Figure 4.8, a range of COD angles were used for attacking and defending athletes in the 1v1 test. Chi-square testing of homogeneity revealed small differences in the proportion of COD angles used between the test and AF matches (Table 4.6). While the results indicate differences
between the proportion of COD angles used in the test with those used in-game, effect sizes reveal that the degree of the differences is small ($\phi_c < 0.3$) indicating similarity between the test and in-game agility events.

![Figure 4.8: Comparison of COD Angle between the notational analysis and 1v1 test](image)

Note: Percentages may not sum to 100 due to rounding

### 4.4 Discussion

This study aimed to determine the reliability and validity of a new test of attacking and defending agility. The test, based on previous research (212), used a series of simulated 1v1 agility events to assess attacking and defending agility. Modifications to the previously used testing procedure were chosen to rectify limitations of the previous test. By using simulated agility events, rather than agility tests that confine athletes to pre-determined movement patterns, the test was designed to improve ecological validity compared to traditional agility tests.
4.4.1 Reliability

Results from reliability testing indicated acceptable test-retest, inter-rater, and intra-rater reliability. However, the test-retest reliability of the agility score derived from the examined testing procedure was found to be lower than in previous 1v1 agility testing research (212). This decrease in test-retest reliability and subsequent increase in between-test variation can likely be attributed to rule changes implemented in the current version of the test. The inclusion of a rule whereby the attacking athlete begins by facing away from their opponent was included to increase uncertainty in the attacking athlete. This increased uncertainty was designed to better replicate on-field playing conditions where the pre-planning of movements is uncommon due to temporal limitations. Further, the area in the examined testing procedure was reduced from previous research to limit the opportunity for attacking athletes to perform a straight-line sprint past the defender. By doing so, attacking athletes in the new test are forced to engage in more changes of direction, which may account for an increased variation. Nevertheless, as noted in the notational analysis in Chapter 3, agility scenarios in AF are characterised by high levels of variability. Therefore, the small decrease in test-retest reliability from previous testing procedures likely corresponds to an increase in ecological validity.

Results indicate excellent inter-rater and intra-rater reliability of the agility scoring protocol. This finding agrees
with previous studies which have also shown excellent inter-rater reliability of similar scoring methods (49, 212). As mentioned by Drake in previous research, the high inter-rater and intra-rater reliability are likely due to the simple scoring method used in the test, and the ability to review the score from video analysis (49). It is likely that reliability would decrease without the use of video technology.

4.4.2 Validity

As discussed previously, the majority of testing procedures described in the literature have limited ecological validity. This is due to a lack of variability in the test, along with the lack of a game-like perceptual stimulus for athletes to respond to. In the majority of testing procedures, athletes are required to perform changes of direction at a maximal intensity to predetermined angles, using pre-determined movement techniques. However, a recent review of agility in team sports suggested that practitioners should adopt more ecologically valid testing procedures (137). The results from the survey of AFL high-performance managers in Chapter 3 indicated that formal testing of agility is uncommon in elite AF environments. This may be partially due to a current lack of ecologically valid testing protocols.

To address ecological validity limitations in previous testing procedures, this test sampled a series of 1v1 agility scenarios. By doing so, the 1v1 testing procedure aimed to
replicate game conditions and required athletes to produce a variety of movement solutions in response to the agility demands of the specific scenario. Analysis of the footwork patterns, approach speeds, and COD angle revealed a large variability of movement techniques used by attacking and defending athletes. This corresponds well with game demands whereby athletes must use a range of footwork patterns, approach speeds, and COD angles depending on the given scenario.

While analysis of the 1v1 test revealed an increased variation of movement patterns used by athletes, small differences between game demands and the 1v1 test were found for the proportion of footwork patterns, defending approach speeds, and COD angles used by athletes. Similarly, large differences were found for the proportions of attacking approach speeds and defending footwork patterns. Despite increases in ecological validity in the current 1v1 testing procedure, differences in movement patterns used in the test to those used in-game likely correspond to differences in the demands of the two events. In the 1v1 test, the attacking athlete must attempt to evade the defending athlete, and move past the defender. While this rule increases the likelihood of an agility event occurring, during AF games attacking athletes may choose to not engage in a contest with an opponent, and may instead adopt a less risky option of disposing of the ball or changing direction to move away from the opposition. Similarly, in the test, the defending athlete is required to attempt to tackle the attacking opponent. While this does occur in AF games, it is
also possible that the defending athlete may choose to corral, or move to reduce the attacking athlete’s options for disposing of the ball. Therefore, the choice for a defender to not engage in an agility event with an opponent may provide a tactical advantage in-game that does not exist in the constraints of the test.

In addition to the above limitations, agility events in the 1v1 test are limited to front-on scenarios in a restricted area (11x11m). This artificial limitation is dissimilar to game demands whereby agility scenarios occur with the defender side-on or behind the attacker approximately half of the time (52.1%). As discussed in chapter 3, the location of the defender in relation to the attacker has a significant influence on the approach speed and COD angle used by athletes in agility scenarios. Further, by restricting the space in the agility event to 11x11m, the space available to athletes is restricted, and the opportunity to approach an agility event at a high-speed is reduced.

As discussed in the previous chapter, agility scenarios in the test are restricted to 1v1 events. This limits the physical and technical possibilities of the athletes in the agility scenario, and in the case of the test, the technical options of the athlete are reduced. In an AF game, some agility events occur with multiple athletes in a small area, and the resulting complexity of perceptual-cognitive demands of the athletes in the scenario are increased. Further, in 1v1 events in AF games, the athletes in the evasive scenario are in a larger full-ground match which influences the decisions by the competing athletes. For example,
an attacking athlete in a 1v1 scenario may move according to other athletes on the field to be better able to dispose of the ball to the team’s advantage. Alternative, with the presence of other team-members, an attacking athlete may use a fake-disposal to deceive their opponent. However, in the 1v1 test, deception by means of a fake disposal is rendered ineffective. Similarly, in an AF game, the defending athlete may select a movement strategy that limits the attacker’s options based on their relative position to athletes external to the agility contest. In the 1v1 test, athletes are deprived of specifying information external to the test that provides additional context. For this reason, along with the limitations discussed above, the movement patterns in the 1v1 test are not a perfect representation of 1v1 events in-game. Nevertheless, the discussed testing procedure is substantially more effective at replicating 1v1 agility game demands than previous tests and allows practitioners to assess attacking and defending agility separately. A table comparing the similarities of test procedures to AF games is provided below in Table 4.7.
Table 4.7: Similarities of agility tests to AF demands

<table>
<thead>
<tr>
<th></th>
<th>AF Game</th>
<th>Generic Stimulus RAT</th>
<th>Futsal Agility Test</th>
<th>Stop’n’Go Video Stimulus RAT</th>
<th>Human Stimulus RAT</th>
<th>1v1 Agility Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Representative Stimulus</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Simultaneous Attacking and Defending</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Multiple Footwork Patterns</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Multiple COD Angles</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Multiple Speeds</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Fake COD</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Some Variants</td>
<td>No</td>
</tr>
<tr>
<td>Fake Disposals</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Multiple COD</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Some Variants</td>
<td>No</td>
</tr>
</tbody>
</table>

While differences were found between the test and AF agility demands, some of the discrepancy may be explained by the comparison of differing populations. This study used community-level footballers while the comparison was made to elite AF athletes. The different groups may use different strategies due to their differing physical, technical, and cognitive capacities. As such, further research using elite athletes is needed to determine if the ecological validity of the test is dependent on the population.

Finally, while this study examined the ecological validity of the 1v1 test, the ability to distinguish between playing standards was not explored. Analysis of the discriminatory capacity of other agility tests has been assessed in the literature (73, 82, 124, 161, 165, 208). Further, testing protocols that include more specifying information such as human and video stimulus
are better able to discriminate between playing levels than protocols with a generic stimulus (137). This is likely due to the ability for expert performers to better detect kinematic cues to anticipate the required movement pattern and COD direction. As the 1v1 test includes an opposition athlete, it is likely that it has the sufficient qualities to distinguish playing standards. Nevertheless, the construct validity of the 1v1 testing procedure is unknown, and further research is needed in this area.

4.4.3 The Relationship Between Ecological Validity and Reliability

The above discussion of validity and reliability highlights a trade-off between test-retest reliability and ecological validity in agility testing protocols. That is, by removing confounding factors in an agility test, test-retest reliability may remain high, but only at the expense of ecological validity, and the subsequent generalisability of findings. This concept has been discussed at length in the methodological literature discussing the compromise between internal and external validity in study designs (98). In the case of the 1v1 test of attacking and defending agility, while significant increases in ecological validity were obtained, concessions of the generalisability of the design were made to allow for acceptable test-retest reliability, as discussed above. While the discussed agility test has lower test-retest reliability than the majority of other agility tests (137), the analysed test is more generalisable to 1v1 agility events that occur in AF than previous testing methodologies.
4.5 PRACTICAL APPLICATIONS

The above 1v1 testing procedure presents a viable alternative to test agility in the context of AF games. The test, although not without limitations, allows practitioners and researchers to test attacking and defending 1v1 agility in the context of a 1v1 event. Further, by testing against a live opponent, the perceptual-action stimulus that proceeds the agility manoeuvre is maintained. As such, the testing procedure provides improvements in ecological validity and is recommended for use by researchers wanting to assess the agility of Australian footballers. However, due to the moderate test-retest reliability found in this study, some caution must be applied when interpreting changes.

Attacking and defending agility are separate skills, characterised by different technical and cognitive demands (212). As such, it is possible for an athlete to excel at one skill while being deficient in the other. As the testing procedure allows for the discrimination between attacking and defending agility, researchers and practitioners may use the testing procedure to identify strengths and weaknesses in their athletes. However, if time-constraints exist, and practitioners are unable to assess both qualities, it is recommended that role of the athlete, and the athlete’s strengths and weaknesses are considered when determining which skill to assess, and when interpreting results. Further, if a subjective measure of agility is used, as is common in AF (Chapter 3), coaches should differentiate between attacking and defending agility.
While the proposed 1v1 agility test likely better represents agility as it occurs in AF, the 1v1 test is a simplification of in-game agility demands. As such, the test better assesses an athlete’s agility skill in a confined space, and in front-on scenarios. Therefore, practitioners and researchers must assess the role of their athlete prior to selecting the 1v1 test for use in assessment. For athletes who do not often engage in front-on scenarios with an opposing player, subjective assessment of the athlete’s movement capacity may be more appropriate. However, subjective assessments of agility have not been examined in the literature, and coach experience is likely beneficial to correctly identifying agility deficits.

The 1v1 test uses a series of trials to determine an aggregate score for the attacking and defending athletes in the test. The inclusion and summation of multiple trials is required to ensure adequate reliability. However, as ten trials are required to perform a singular assessment of attacking or defending agility, testing requires a significant time investment. Coaches should consider the viability of field-based agility testing when limited training time is available. However, to make efficient use of time, coaches may be able to use the training-effect from the test when planning athlete training load.

The scoring protocol used in the 1v1 test was shown to have excellent reliability. The reliability of the scoring procedure was assessed following video-review. For coaches and researchers wishing to implement the 1v1 agility test, the use of video-analysis is recommended to maintain high levels
of reliability. Nevertheless, the implementation video-review requires extensive time and resources, and the time required to implement this testing method must be considered. Coaches looking to use the proposed testing protocol should allow approximately 10 minutes for the video review of each attacking or defending testing session.

While the proposed testing procedure improves upon validity limitations of previous agility research, more research is needed in the area of agility testing. Methods for assessing more complex agility events which include more than two athletes may be assessed. Further constraint modifications of the 1v1 agility protocol could be examined for the purposes of including more agility events with the defender to the side, or behind the attacker. Finally, as coaches in the survey in Chapter 3 on page 100 reported relying on subjective assessment, the reliability of subjective agility assessments may be examined.
STUDY 3: EVALUATION OF 1 V 1 AGILITY TRAINING

5.1 INTRODUCTION

Chapter five details a study that evaluated the effectiveness of a four week, 1v1 agility training intervention to improve attacking and defending agility in Australian footballers. For the purposes of this study, 1v1 training referred to agility scenarios, similar to those used in the testing procedure, where an attacking athlete was required to attempt to evade a defender, while a defender attempted to tackle. During the training intervention, attacking athletes only trained attacking agility, while defending athletes only trained defending agility. By doing so, the study assessed the crossover between attacking and defending training. That is, does attacking-only agility training improve defending agility, and does defending-only training improve attacking agility? As previous research has indicated that attacking and defending agility are distinct skills (212), it is possible that training must be specific to attacking or defending. To assess agility, the study used the testing procedure described in the previous chapter.

This testing procedure outlined in Chapter 4 was chosen for its improved ecological validity when compared to
alternative tests in the literature. As discussed in the previous chapter, the 1v1 testing procedure has significant benefits over other agility tests for assessing AF agility. While other tests require athletes to react to a stimulus, by assessing athletes in 1v1 agility scenarios, the 1v1 test exposes athletes to more specific visual information by which to respond. Therefore, agility-specific improvements in the cognitive capacity of athletes can be assessed in the 1v1 test. In addition, the 1v1 testing procedure allows for the individual assessment of attacking and defending agility. As research has demonstrated that attacking and defending agility are distinct skills (212), the 1v1 testing method allows for the assessment of each skill individually. Finally, as discussed in the previous two chapters, the 1v1 testing procedure allows for variation of movement and cognitive demands similar to those the variation seen in AF agility events. For these reasons, the 1v1 testing procedure was selected as an appropriate method of assessing attacking and defending agility for this study.

As discussed in chapter three, the behaviour of athletes in 1v1 agility events is dependent on the context of the agility event. The context includes the sporting environment, the rules of the game, the physical and technical capacity of the individual athlete, as well as the behaviour of the opposition. The techniques used by athletes in an agility event are the result of the constraints of each specific agility scenario, and due to variation between each event, specific techniques used by athletes are unpredictable. For example, an attacking athlete wishing to evade a defender will adapt their technique based
on their proximity to the opponent, their angle of approach, their proximity to a side-line, and their movement capacities, etc. Agility training methods that use pre-determined techniques or isolated movements are likely inappropriate as they ignore the complex interaction of variables that determine agility performance.

One similar training method to 1v1 training that has been described in the literature is SSG. By performing agility scenarios in a simulated sporting environment, much of the demands between SSG and 1v1 training are likely similar. Further, one agility training study in soccer included 1v1 training in a larger SSG training intervention (28). However, as the training used in this study also included trials with more than two athletes, it is unclear if performance benefits were a result of the 1v1 training, or 2v2 or 3v3 training. In addition to this study, previous research in SSG for training agility in Australian footballers has demonstrated successful agility improvement (214). Nevertheless, as 1v1 training has not been assessed in isolation, the effectiveness of this training method is not known.

1v1 training is an attractive training method for coaches wishing to improve agility in their athletes. As 1v1 training requires athletes to change direction in response to an opponent, it is possible to simultaneously develop the physical, technical, and cognitive factors of agility. While this is also true for SSG, previous research has indicated that load management during SSG training is difficult as some athletes are exposed to substantially more agility events than others in SSG training.
interventions (40). By equating agility exposures, 1v1 training provides coaches with a viable method for addressing issues with load management while maintaining the training benefits of SSG. Nevertheless, SSG does offer some advantages to 1v1 training such as increased complexity, greater similarity to AF, the ability to practice fake disposals, and more varied inter-athlete angles.

Athletes in 1v1 training may be given specific attacking or defending roles. This presents benefits for the individualisation of training. While all athletes in AF are required to undertake attacking and defending roles, depending on the role of the athlete, the degree to which the athlete may attack or defend likely differs. Therefore, to optimally train athletes for their specific game role, biasing the athlete’s exposure to attacking or defending agility is likely beneficial. As discussed by high-performance managers in the survey presented in Chapter 3 (pg 92), an individual athlete’s strengths and weaknesses help guide agility training in elite environments. 1v1 training provides a viable method for coaches to tailor training towards an athlete’s weaknesses. Further manipulation of agility demands may be achieved by manipulating the constraints in 1v1 events. By adapting task constraints, coaches can control the specific demands of the agility scenario. This study manipulated the size and shape of the training area to provide athletes with a variable stimulus throughout the training period.
5.2 Methods

5.2.1 Participants

Prior to recruitment, an a priori power analysis was conducted using GPower 3.1.9.2 (GPower, Dusseldorf, Germany) which revealed that a sample size of 48 would result in statistical power of $1-\beta = 0.80$ for an alpha of $\alpha = 0.05$. Therefore, a sample size of 48 was proposed. However, due to recruiting challenges, the study was undertaken with 28 male, community-level footballers between the ages of 18 and 35, indicating an increased risk of type 2 error. Participants were recruited from the community via print and online advertisements, and the inclusion criteria to participate was identical to the criteria used in the reliability and validity study described in chapter 4. All athletes underwent two weeks of familiarisation, before being evenly split into three groups, an attacking training group who trained only as attackers, a defensive training group who trained only as defenders, and a control group who undertook no specific agility training. Two athletes withdrew from the study prior to completing the familiarisation phase, one due to an injury sustained outside of the study, and one due to external commitments. Therefore, 26 athletes were allocated into training groups; two training groups with nine athletes each, and one control group with eight athletes. Training commenced at the end of the regular season of AF competition.
Ethical approval for the study was granted by the Federation University Research Ethics Committee (Appendix E).

Prior to participation in the study, all athletes were given a plain language information statement which clearly outlined the details of the study (Appendix J). After the participants were informed of the study demands, informed consent was granted in the form of a signed consent form (Appendix K).

5.2.2 Procedure

The study used a 3-group parallel randomised control trial design. The study commenced with a 2-week familiarisation period to mitigate the learning effect associated with a low familiarisation of the testing procedures and to familiarise with techniques that may be used in the testing period. As the study was conducted post-season, all athletes did not participate in football training during either the familiarisation or the training period. However, athletes were instructed to maintain their usual non-football related training. Following the initial two-week familiarisation period, athletes undertook pre-testing against two standardised opponents, using identical testing procedures as outlined in study two, then a four-week training period was undertaken, followed by one week of post-testing. A training duration of four weeks was chosen as it is a typical length of a training cycle in team sports (11, 143). A timeline of the training period is shown below in Figure 5.1.
To ensure the consistency of results from pre-testing to post-testing, three research assistants acted as opponents for the test. The research assistants were required to meet identical inclusion criteria to the participants of the study, and were a similar age and had a similar level of playing experience. The research assistants underwent the familiarisation procedure with the participants of the study to minimise any learning effect. However, as the research assistants performed the test against the participants during familiarisation, the research assistants undertook a greater volume of test familiarisation than participants. To minimise fatigue, two research assistants were used for each test; one tester undertook the first five trials of the test, while the second tester undertook the second five trials. The same two testers in the same order were used for all athletes in both pre-testing and post-testing to allow the capacity to detect changes in performance.

**5.2.2.1 Familiarisation Procedures**

Over four sessions, in the familiarisation period, participants were familiarised with safe and effective agility technique, and
with the testing procedures. As the notational analysis showed side-stepping to be the most frequently used agility technique in 1v1 AF agility scenarios, the first three sessions were used to familiarise athletes with safe side-stepping technique. The familiarisation period focused on aspects of technique that may prevent injury, or improve performance, as detailed below. Further, in the third familiarisation session, athletes were introduced to the split-step technique. The split step has been shown to be an effective approach technique for attacking athletes to deceive a defender (21). It was proposed that by introducing athletes with this technique prior to training, athletes may practice the technique, in the training period. In addition to the proposed performance benefit, the split-step may reduce injury risk by reducing knee moments due to the distribution of force across both limbs during the landing phase (185). During the final familiarisation session, athletes practised the testing procedure in full to reduce the chance of a learning effect. Each familiarisation session took approximately 30 minutes.

Aspects of the side-step deemed to be safe and effective that guided the familiarisation sessions were:

- Minimal hip flexion during the stance phase:
  Excessive hip flexion during the stance phase of side-stepping has been associated with high knee abduction moments and subsequent injury risk (106, 121). Therefore, to not place athletes at undue risk of injury, athletes were instructed to maintain an upright torso.
when excessive hip flexion was observed during the familiarisation period.

- **Feet point forward during the stance phase:** Internal rotation of the hip, and a subsequent external foot progression angle during the stance phase of the side-step is associated with increased knee abduction moments (121, 169, 170). Therefore, to reduce the risk of traumatic knee injury, athletes were instructed to point their foot forward during side-stepping throughout the familiarisation period.

- **Reduce valgus movement of knee:** Knee valgus load is strongly associated with non-contact ACL injuries (121, 168). As such, if excessive valgus movement of the knee was observed in the familiarisation period, athletes were instructed to focus on keeping their knee tracking over their toes to promote a safe knee posture.

- **Land on the forefoot rather than mid-foot or heel:** Forefoot landing during side-stepping has been demonstrated to reduce the risk of ACL injury (46, 108, 202). Further, athletes who land on their forefoot show greater ankle plantarflexion (46), resulting in improved COD performance (75, 119). Therefore, athletes were cued throughout the familiarisation period to land on their forefoot during side-stepping.
• Laterally flex and rotate the torso in the direction of intended travel:

Laterally flexion and rotation in the direction of travel has been demonstrated to reduce ACL injury risk by reducing knee abduction during planned and unplanned side-stepping (44, 45, 94, 125). Further, lateral trunk flexion away from the intended direction of travel has been observed during non-contact ACL injury (84). In addition to a reduced injury risk, flexion and rotation in the direction of travel have been shown to improve CODS cutting times (58, 75). For this reason, athletes were instructed to lean towards the intended direction of travel when side-stepping throughout the familiarisation period.

5.2.2.2 Training Procedures

The training intervention consisted of two training sessions per week, separated by a minimum of one day, for four weeks. Each session took approximately 30 minutes to complete. All training was conducted at a single indoor facility in the university’s sport science department on the same surface as Study 2 (Chapter 4). During each session, athletes in the attacking-only agility group undertook 20 1v1 trials as the attacker. Ten of the trials were performed against one opponent and then, following a 2-minute rest period, ten more trials were performed against an alternate opponent. The alternative opponent was included to expose athletes to varied opposition strategies to allow athletes to attune to a wider range of affordances. Athletes in the defending-
only agility group undertook the same procedure but assumed
the role of the defender. Following the first 20 trials, athletes
undertook five additional trials from their own chosen starting
position. The extra trials provided allowed athletes to guide
their own learning based on perceived weaknesses (129). The
rules of each agility scenario were identical to those described
in the test. Therefore, the goal of the attacking athlete was to
evade and travel past the defender, while the defender’s goal
was to move to position to simulate a tackle.

During each training session, task constraints were
manipulated by modifying the size and shape of the training
area to increase variability. By modifying the size and shape of
the training area, the inter-athlete distance and
inter-athlete-angles were modified. The size and shape of the
training area for each session are shown below in Table 5.1.

<table>
<thead>
<tr>
<th>Session</th>
<th>Width (m)</th>
<th>Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>5</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>6</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>7</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>8</td>
<td>11</td>
<td>9</td>
</tr>
</tbody>
</table>

The standardised starting positions for the first 20
scenarios for each session are shown below in Table 5.2. By
varying the starting positions along with the size and shape of
the testing area for each session, the speed and angle of
approach varied from trial to trial. A detailed list of the subsequent inter-athlete distances and angles is provided in Appendix L.

<table>
<thead>
<tr>
<th>Attacker Position</th>
<th>Defender Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 A1</td>
<td>A4</td>
</tr>
<tr>
<td>2 E1</td>
<td>E4</td>
</tr>
<tr>
<td>3 C1</td>
<td>C4</td>
</tr>
<tr>
<td>4 A1</td>
<td>C4</td>
</tr>
<tr>
<td>5 E1</td>
<td>C3</td>
</tr>
<tr>
<td>6 C2</td>
<td>C4</td>
</tr>
<tr>
<td>7 B2</td>
<td>C4</td>
</tr>
<tr>
<td>8 C2</td>
<td>B3</td>
</tr>
<tr>
<td>9 C2</td>
<td>B4</td>
</tr>
<tr>
<td>10 C2</td>
<td>D4</td>
</tr>
<tr>
<td>11 D2</td>
<td>C4</td>
</tr>
<tr>
<td>12 A1</td>
<td>B5</td>
</tr>
<tr>
<td>13 E1</td>
<td>D5</td>
</tr>
<tr>
<td>14 A1</td>
<td>B4</td>
</tr>
<tr>
<td>15 B1</td>
<td>A4</td>
</tr>
<tr>
<td>16 B1</td>
<td>A5</td>
</tr>
<tr>
<td>17 D1</td>
<td>E5</td>
</tr>
<tr>
<td>18 D1</td>
<td>E4</td>
</tr>
<tr>
<td>19 C2</td>
<td>D3</td>
</tr>
<tr>
<td>20 A1</td>
<td>D5</td>
</tr>
</tbody>
</table>

5.2.3 Data Analyses

To compare attacking and defending agility between groups (attacking-only training and defending-only training vs control), one-way analyses of covariance (ANCOVAs) were employed using pre-test values as the covariate. A comparison between
the control group and the attacking-only and defensive-only training groups’ agility scores were inspected to determine if 1v1 training is effective for improving attacking and defensive agility. Partial eta-squared ($\eta^2_p$) effect sizes were calculated for the main effect and post-hoc analyses. As $\eta^2$ is analogous to $r^2$, the magnitude of effect sizes were derived from Hopkins (87) as shown below in Table 5.3

<table>
<thead>
<tr>
<th>Partial eta-squared ($\eta^2_p$)</th>
<th>Descriptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>$&lt; 0.01$</td>
<td>Trivial</td>
</tr>
<tr>
<td>$\geq 0.01 &lt; 0.09$</td>
<td>Small</td>
</tr>
<tr>
<td>$\geq 0.09 &lt; 0.25$</td>
<td>Moderate</td>
</tr>
<tr>
<td>$\geq 0.25 &lt; 0.49$</td>
<td>Large</td>
</tr>
<tr>
<td>$\geq 0.49 &lt; 0.81$</td>
<td>Very Large</td>
</tr>
<tr>
<td>$\geq 0.81 &lt; 1$</td>
<td>Nearly Perfect</td>
</tr>
<tr>
<td>$1$</td>
<td>Perfect</td>
</tr>
</tbody>
</table>

Statistical analysis was performed using R version 3.5.1 (R Foundation for Statistical Computing, Vienna, Austria) with significance set at $p < 0.05$.

5.3 Results

A summary of the results from the training intervention is detailed below in Table 5.4. Results for attacking and defending agility are discussed separately below.
Table 5.4: Training study summary results

<table>
<thead>
<tr>
<th></th>
<th>Attacking Agility</th>
<th></th>
<th>Defending Agility</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre  Post Adj. Post</td>
<td></td>
<td>Pre  Post Adj. Post</td>
<td></td>
</tr>
<tr>
<td>Defending Group</td>
<td>10 ± 6.95 10.1 ± 7.46 11.4</td>
<td></td>
<td>18.7 ± 5.96 20.3 ± 5.15 20.8</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>14 ± 4.24 8.5 ± 5.18 6.24</td>
<td></td>
<td>19.3 ± 5.28 19.9 ± 7.51 20.1</td>
<td></td>
</tr>
</tbody>
</table>

Note: Adjustments based on pre-test mean for attacking agility = 11.5, defending agility = 20

5.3.1 Attacking Agility

Prior to ANCOVA testing, the assumptions of an ANCOVA were assessed. Visual assessment of a scatter-plot which compared pre-test scores to post-test scores for all groups was used to confirm the assumption of linearity. The homogeneity of regression slopes was confirmed using a type 2 ANOVA ($F(2,20) = 0.4$, $p = 0.68$). Normality of residuals was confirmed from Shapiro Wilk testing ($p > 0.05$), while a Levene’s test was used to determine the homogeneity of the residual variances for all groups ($p > 0.05$). No outliers were found in the data, as assessed by the number of cases with standardised residuals greater than 3.

After adjusting for pre-test scores, an ANCOVA revealed a very large, significant difference in post-test scores between groups ($F(2,22) = 12.37$, $p < 0.001$, $\eta^2_p = 0.53$). Pairwise comparisons between groups were undertaken to determine if attacking-only, or defending-only groups differed from control using estimated marginal means with a Bonferroni correction applied to minimise the risk of increased type I error. After
adjusting for pre-test scores, post-test results for both the attacking-only, and defending-only training groups were significantly higher than control ($p < 0.001; p = 0.02$), with a very large effect found for the attacking group ($\eta^2_p = 0.53$), and a large effect found for the defending group ($\eta^2_p = 0.29$). A moderate, non-significant difference was found between the adjusted means of the attacking-only group and the defending-only group ($p = 0.17$, $\eta^2_p = 0.16$). Changes in attacking agility are visualised in Figure 5.2.

![Attacking Agility](image)

**Figure 5.2**: Changes in Attacking Agility. Bars = mean ± 95% CI.

### 5.3.2 Defending Agility

Visual assessment of a scatter-plot comparing the pre-test scores to the post-test scores for all groups was used to confirm the assumption of linearity between the dependent variable and the covariate. The homogeneity of regression slopes was confirmed by assessing the interaction term using a type 2 ANOVA ($F(2,20)$...
= 0.44, p = 0.65). Normality of residuals was confirmed from Shapiro Wilk testing (p>0.05), while a Levene’s test was used to determine the homogeneity of the residual variances for all groups (p > 0.05). One outlier from the control group was found with a pre-test score of 4, and a post-test score of 17. An ANCOVA revealed no significant differences in post-test scores between groups after controlling for pre-test scores (F(2,22) = 0.11, p = 0.9, \( \eta^2_p = 0.01 \)). Results for the ANCOVA were confirmed by reanalysis following the removal of the outlier (F(2,22) = 0.28, p = 0.76). Pairwise comparisons revealed trivial effects when the attacking and defending training groups were compared to control (\( \eta^2_p < 0.01, p > 0.05 \)). Results for defending agility are visualised in Figure 5.3.

![Defending Agility](image)

Figure 5.3: Changes in Defending Agility. Bars = mean ± 95% CI.
5.4 DISCUSSION

As previously mentioned, this chapter presents the first 1v1 training study in agility and therefore expands upon research in open training methods such as SSG for improving agility performance. In addition, previous studies which have assessed the effect of SSG on agility performance have assessed only defending agility (28, 214). This study expands upon previous research by assessing attacking and defending agility separately by use of a new field-based testing procedure.

Results of the training study indicate that 1v1 training is a viable training method for improving attacking agility, especially for attacking athletes. However, neither the attacking-only group nor the defending-only group improved more than the control for defending agility, indicating that 1v1 training may not be effective in improving defending agility. While the defending-only training group improved defending agility by 8.9%, when pre-test scores were adjusted, a trivial non-significant difference to control was found. This indicates that the raw improvements in defending agility were likely a result of the defending-only group’s lower baseline defending agility.

The improvement in attacking agility for both the attacking-only and defending-only training groups when compared to control is due, in part, to a decrease in performance by the control-group. This decrease in performance may be due to an unintended training effect experienced by the standardised testers. It is possible that the
research assistants, by repeatedly performing the testing protocol during pre-testing, improved attacking agility to a greater extent than the control group who were only exposed to the testing protocol during familiarisation, pre-testing, and post-testing. Alternatively, due to the repeated demands imposed upon the research assistants during the familiarisation week, it is possible that the research assistants were fatigued during the pre-testing week, and returned in post-testing without fatigue. Both scenarios would result in an apparent decrease in agility for the control group. As, the decrease in agility performance for the control group may not have been an actual decrease in agility, but rather, an unintended by-product of the testing procedure, future research that uses the 1v1 testing may need to use a larger number of testers to account for the training effect of the test. While the results do not confirm this speculation, if the decrease in agility experienced by the control group is a result of an improvement in the standardised testers, the improvements in attacking agility are particularly large.

When compared to control, improvement in attacking agility was greater for the attacking-only training group than for the defending-only training group. Indeed, inspection of the effect sizes indicates a very large improvement for attacking agility and a large improvement for defending agility. This indicates some specificity of training effect for attacking agility. This finding agrees with previous literature that has described the specific needs of agility training, and the distinction between attacking and defending agility (207, 212). The need
for specificity of training between attacking and defending agility reinforces findings from the previous two chapters of this thesis which have highlighted differences between these skills. In AF agility scenarios, the specificity of attacking and defending agility extends to differences in movement technique, speeds, and cognitive demands. By training in the specific environment, athletes are able to attune to the perceptual information contained in agility events. Further, highly-skilled athletes likely require a more specific stimulus (91). Therefore, while improvements in attacking agility for the defending-only training group were observed in the current study, the crossover effect may not remain in an elite environment.

While improvements in agility were observed for attacking-agility, no significant changes were seen for any group for defending-agility. This suggests that 1v1 training may be an ineffective stimulus for improving defending agility. However, this may be a result of the training volume of 8 sessions of 25 trials used in this study. As the defending-only training group improved defending agility by 8.9% from this stimulus, it may be possible that a larger training volume or duration may improve defending agility to a significant degree, but more research is needed to assess this hypothesis. Indeed, previous research which has demonstrated improvements in defending agility following SSG interventions has used larger volumes and durations in the studies (28, 214). Future research using 1v1 training interventions may be required to determine if an increased training volume may improve defending agility performance.
Some of the improvements in attacking agility performance may be due to the physical training effect of 1v1 training. During the plant phase of agility manoeuvres, athletes are required to absorb an eccentric load in the lower extremities and make a subsequent concentric contraction. This movement may have a plyometric training effect which may explain the training effect for attacking agility performance. As shown in the previous chapter, attacking athletes perform the 1v1 test at faster speeds than defending athletes. In the test, the attacking athlete often approaches at high speed prior to performing an evasive technique, while the defending athlete takes smaller steps to get into position to attempt to tackle. Therefore, any increases in reactive strength as the result of 1v1 training may be detected by the attacking portion of the test. However, reactive strength was not assessed in this investigation, but this result may provide impetus for future research in the area.

The plyometric training effect proposed above may partly explain the increased improvements in attacking agility for the attacking-only group when compared to the defending-only group. As the 1v1 training stimulus is similar to the test, the attacking-only athletes are exposed to more high-speed agility scenarios than the defending-only group. This increased momentum likely provides an increased plyometric training demand as a result of increased load on the lower extremities. This may produce an increase in reactive strength that is greater for the attacking group than the defending group, leading to an increased attacking agility score. In addition to physical improvements, it is likely that the attacking training improved
the attacking-specific technical and cognitive capacities to a greater degree than the defending training. By exposing attacking athletes to scenarios where they must respond to the cues of defenders, it is possible that attacking athletes became attuned to the specifying visual information in attacking agility scenarios. As the defending-only athletes did not train attacking agility, their learning effects are likely limited.

5.4.1 Limitations

Some limitations to this study were observed which guided its interpretation. The sample size obtained for the study was low, and insufficient to detect small changes in attacking and defending agility. It therefore, may be possible that small changes that could not be observed in this study may be detected in a study with a larger sample size. The low sample size was primarily due to insufficient recruitment of participants due to the placement of the study in the calendar year. To reduce confounding factors and the risks of injury, the study was conducted following the playing season. While this reduced the overall load experienced by athletes in the training period, some athletes who may have participated in-season declined to participate, opting to take a break from football-related activities in their off-season. Further, as many participants were undergraduate university students, the late training period fell immediately prior to the exam period, so it is possible that some athletes did not participate due to the
academically stressful timing of the study. Future research with larger sample sizes is needed, and research in the playing season should be considered to aid in recruitment.

In addition to sample-size limitations, fatigue, and an unintended learning effect for the research assistants presented challenges. To limit exposure to agility events, three research assistants were used in the testing periods, and testers were limited to five consecutive trials before swapping. Nevertheless, the testing period did amount to a substantial volume of 1v1 scenarios for research assistants. As a result, the performance of testers may have decreased throughout the testing week due to fatigue. Further, as limited recovery was given between the familiarisation week and the testing week, some residual fatigue from the familiarisation week may have carried into the pre-testing period. As testers began the post-testing period fully-rested, it is possible that tester performance may have been higher in the post-testing period than the pre-testing period, resulting in a reduction in agility for the participants. In addition to fatigue, by experiencing a large volume of 1v1 agility scenarios in testing, the testing period may have resulted in an unintended learning effect for the research assistants. This may have further contributed to an increase in agility for testers used in the study. Both fatigue and unintended learning by the research assistants may partially explain the apparent decrease in attacking agility for the control group. To limit fatigue in future research, it is recommended that a larger number of research assistants are used, and a resting period is provided between familiarisation and the pre-testing period.
5.5 PRACTICAL APPLICATIONS

Results of the training intervention indicate that 1v1 training is a suitable training intervention for developing attacking agility. Coaches wishing to develop this quality in their athletes should consider 1v1 training as an efficient method for improving the technical and cognitive aspects of agility simultaneously. By training agility in a manner similar to how agility presents in-game, coaches can likely expect increased transfer to on-field performance.

While 1v1 training is likely appropriate for developing attacking agility, the results indicate that four weeks of 1v1 training is insufficient for improving defending agility. While it is possible that a longer training intervention or more volume may elicit a training response, it is likely that defending agility is a difficult quality to train. More research is needed to understand how to best develop defending agility.

Agility training methods that do not consider the role of the athlete are likely inefficient and the results of the training study indicate that training specific to the athlete’s role likely elicits an improved training response. Therefore, coaches looking to improve attacking or defending agility should train using the corresponding skill. It is recommended that coaches consider the athlete’s needs as well as their tactical role in the team prior to prescribing 1v1 training.

By manipulating task-constraints to reduce athlete numbers to 1v1, the training presented in this study presents a
simplified version of traditional SSG. The decreased player numbers in 1v1 training reduces the context by which an athlete may train, and for this reason, it is recommended that 1v1 training be prescribed in addition to SSG activities with larger player numbers. Nevertheless, 1v1 training does offer advantages over SSG, and its prescription should be considered. In SSG, the management of load between athletes is difficult, and some athletes may be exposed to a large number of agility events, while other athletes may be exposed to compatibly few. 1v1 training offers a method for managing load, as an exact number of 1v1 events may be prescribed by coaches.

In SSG, while athletes may be exposed to attacking and defending scenarios, some athletes may be limited a disproportionate exposure to attacking or defending due to their individual affordances. For example, an athlete who possesses good pattern recognition abilities as a defender may play a role in SSG that exposes themselves to their strength as a defender, at the neglect of attacking exposures. For this reason, coaches should consider 1v1 training as a method to allow for greater control of exposure to attacking or defending scenarios. A summary of strengths and weaknesses of closed CODS activities, 1v1 training, and SSG is provided below in Table 5.5 to assist practitioners in selection of an appropriate training method.
Table 5.5: Comparison between CODS, 1v1, and SSG training indicating proposed advantages and disadvantages

<table>
<thead>
<tr>
<th></th>
<th>CODS</th>
<th>1v1</th>
<th>SSG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposes athletes to attacking and defending</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Allows coaches to the manipulate the volume of attacking and defending exposures</td>
<td>No</td>
<td>Yes</td>
<td>Limited</td>
</tr>
<tr>
<td>Develops physical capacity</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Develops technical capacity</td>
<td>Limited</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Develops cognitive capacity</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Allows athletes to practise deception</td>
<td>No</td>
<td>Limited</td>
<td>Yes</td>
</tr>
<tr>
<td>Allows for disposals of the ball</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Exposes athletes to multiple athletes in each event</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Controls for uneven exposure between athletes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

The training intervention in this study used an identical program for all athletes. However, in a sporting environment, coaches should consider constraint manipulations that influence the athlete’s affordances depending on their needs or the needs of the team. While no research exists that describes the effects of individual constraint manipulations in 1v1 events for agility,
172 study 3

some speculative effects may be inferred as provided below in

Table 5.6: Speculative effects of constraint manipulations in 1v1 training

<table>
<thead>
<tr>
<th>Constraint Manipulation</th>
<th>Hypothesised Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Task constraints</strong></td>
<td></td>
</tr>
<tr>
<td>↑ training area size</td>
<td>Increased speed of agility</td>
</tr>
<tr>
<td>↓ training area size</td>
<td>Decreased speed of agility events</td>
</tr>
<tr>
<td>Manipulate field shape</td>
<td>The shape of the training area shape may be manipulated to influence the inter-athlete angle or to direct the 1v1 contest</td>
</tr>
<tr>
<td>↑ time for attacker to evade</td>
<td>Increased evasive attempts by the attacker</td>
</tr>
<tr>
<td>↓ time for the attacker to evade</td>
<td>Evasive attempts from sub-optimal positions</td>
</tr>
<tr>
<td>Inclusion of ‘zones’</td>
<td>Zones may be used to direct agility events, e.g. if attackers have a zone that the defender cannot enter, attackers may be able to approach defenders at a higher speed</td>
</tr>
<tr>
<td><strong>Environmental constraints</strong></td>
<td></td>
</tr>
<tr>
<td>Rain</td>
<td>Decreased surface friction, and subsequent difficulty producing powerful changes of direction</td>
</tr>
<tr>
<td>Low light conditions</td>
<td>Reduced visual input and subsequent need to make decisions with limited information</td>
</tr>
<tr>
<td><strong>Athlete constraints</strong></td>
<td></td>
</tr>
<tr>
<td>Fatigue</td>
<td>Limited physical capacity and subsequent need to find movement solutions with decreased explosiveness</td>
</tr>
</tbody>
</table>
CONCLUSION

The purpose of this thesis was to explore 1v1 agility training and testing for AF. The first study was designed to determine the physical and cognitive characteristics of agility events by describing 1v1 agility events that occur in AF. To determine how agility is trained and tested in elite environments, a survey was sent to high-performance managers of the AFL. The findings from the notational analysis and the survey were used to inform the creation of an ecologically valid 1v1 agility test. The test was designed to determine the attacking and defending agility of athletes in simulated 1v1 agility scenarios. The validity of this testing procedure was assessed using results from the notational analysis to determine how well the test represented 1v1 agility events in AF. Finally, Study 3 assessed the use of 1v1 training for improving attacking and defending agility in Australian footballers.

The notational analysis found that the side-step was the preferred footwork technique for attacking and defending athletes in 1v1 agility scenarios. This corresponded well with the survey which showed that the side-step is the most trained agility manoeuvre in AFL clubs. Nevertheless, the notational analysis showed that a range of movement techniques are used by athletes in elite AF, and movements are not restricted to the
side-step. Further, the use of the side-step was less common for defending athletes than attacking athletes. It was recommended that coaches wishing to train and test agility account for variation in movement technique. Much of the literature in agility has forced athletes into using pre-determined techniques and COD angles (55, 73, 83, 132). The notational analysis contradicts this reductionist approach and suggests that training and testing in an open environment that allows for movement variability may be more appropriate. The thesis presented proposed alternatives to closed COD training and testing in chapters 4 and 5.

Results of the notational analysis showed that athletes rarely approach agility events at a sprint. Rather, slower approaches that allow athletes more time to select a movement technique are preferred. As time is the primary scoring criteria for the majority of agility tests presented in the literature, most agility research has constrained athletes to maximal intensity testing. It was suggested that coaches explore field-based testing alternatives which allow athletes to self-select movement speeds appropriate for the given situation. While slower approach speeds are more common than sprinting approaches, stationary approach speeds were generally unsuccessful for attacking athletes. This may be because athletes who are stationary at the commencement of an agility event are usually in high-pressure, space-restricted situations. For this reason, it was proposed that coaches should prescribe some training in space-restricted environments to train for these scenarios.
While changes of direction in 1v1 events in elite AF most commonly occur at angles of less than 90 degrees, a range of COD angles are used. This reinforces the sport-specific nature of agility and suggests that previous research in rugby union which showed that shallow COD angles (<90 degrees) are common, may not be generalisable to AF. It was recommended that AF coaches should allow athletes to perform changes of direction at a range of angles in training and that practitioners should look to move away from testing methods that restrict athletes to a set COD angle.e.g.45-degrees.

The cognitive demands of agility have been recognised throughout recent agility literature (157, 166, 205). As such, a primary aim of the first study of the thesis was to understand the cognitive demands of agility events in AF by exploring inter-athlete angles and deceptive manoeuvres used in agility events. The location of an athlete’s opponent in 1v1 events directly influences the athlete’s visual field, and as such, their cognitive demands. The notational analysis found that front-on scenarios accounted for less than 50% of 1v1 agility events. The large number of side-on and chasing scenarios are likely a result of the 360-degree nature of AF. As AF does not have an offside rule, opposition pressure can come from any angle. This differs from other sports such as rugby codes and further reinforces the need for practitioners to consider the specific demands of their sport. The notational analysis found that the location of the opposition in agility events served as a constraint that influenced the movement strategy used by athletes. It was, therefore, suggested that coaches should expose
athletes to opponents from a variety of angles when designing agility training and testing.

Athletes in agility events use deceptive manoeuvres to mislead opponents to move in the incorrect direction, or to increase their opponent’s temporal demands. Findings from the notational analysis showed that deceptive techniques in AF are both common and effective. Due to the effectiveness of deceptive manoeuvres, it was recommended that practitioners wishing to train agility should allow for deception to be practised. By doing so, attacking athletes can learn to better deceive opponents, while defending athletes can learn to better detect deceptive movements from their opposition. SSG and 1v1 training and testing environments are likely suitable to allow athletes to use deceptive manoeuvres.

In addition to the sport-specificity of agility discussed previously, the notational analysis found differences between attacking and defending athletes for their technique, approach speeds, and COD angles in 1v1 agility events. As the role of the athlete in agility events influences the technique used, training and testing methods effective for one role, may not be effective for the other. Therefore, it was recommended that coaches should consider the development of both attacking and defending agility separately. Ideally, coaches will use agility training methods effective at improving both qualities but should consider the role of the athlete when biasing development towards either skill. Further, when testing agility, assessment of attacking and defending agility should be performed separately.
The survey of high-performance managers in the AFL revealed that the formal assessment of agility is uncommon in elite AF. Rather, coaches frequently adopt subjective assessment, sometimes augmented with the use of accelerometry. This testing strategy allows for the assessment of agility in training and games, and therefore assesses agility in a representative environment; nevertheless, the reliability of this testing method is uncertain. The thesis explored 1v1 testing as an alternative agility testing strategy that may be suitable for use by coaches in AF.

A key finding of study 2 was that the test-retest reliability of 1v1 agility testing was acceptable, but was lower than other testing methods. The lower test-retest reliability was proposed to be due to the variable nature of the agility scenarios that occur in the test. The variation, although a desired quality of an externally valid agility test, results in a subsequent decrease in reliability. Therefore, practitioners should consider the trade-off between test-retest reliability and external validity when selecting an agility test. Nevertheless, inter-rater and intra-rater reliability were found to be almost perfect, indicating that the scoring protocol was reliable. The excellent inter-rater and intra-rater reliability were likely due to the simple scoring method, and the ability to use video to review scoring.

By comparing the demands of the 1v1 agility test to the notational analysis, the test was demonstrated to have improved ecological validity compared to previous testing methods. Further, the test successfully allowed for the individual assessment of attacking and defending agility.
Nevertheless, while closer to the agility demands of AF, differences were found between movement patterns used in the test and AFL games. While the 1v1 test is recommended as an improvement to previous testing methodologies, some practical limitations exist for coaches. Standardised testers are required to serve as opponents to compare results between athletes, and due to the need to perform multiple trials, the test requires a significant time commitment. For this reason, it was recommended that coaches consider the resources available if deciding to use the testing procedure in the field.

Results from the survey of high-performance managers revealed that open training methods such as SSG and 1v1 training are common in the AFL. Nevertheless, research on the effects of 1v1 training is absent in the literature. The final study of this thesis assessed the effect of 1v1 training on agility performance by using the 1v1 agility test discussed above. The 1v1 training intervention was successful in improving attacking agility, but not defensive agility following a 4-week training block. It was hypothesised that a larger training volume might be necessary for the improvement of defending agility. Further, larger improvements in attacking agility were observed when athletes trained only as attackers throughout the training period. This finding indicates a need for agility training to be specific to the role of the athlete. As such, coaches are encouraged to consider the needs of the athlete prior to undertaking attacking or defending agility training. Unexpectedly, a decrease in attacking agility was observed in the control group. It was suggested that the decrease in
attacking agility might represent an undesired improvement in attacking agility for the standardised testers used in the study. Therefore, it was recommended that more testers be used in further research to minimise the exposure to a training stimulus from repeated testing.

6.1 RECOMMENDATIONS FOR FUTURE RESEARCH

This thesis examined 1v1 training and testing for AF, and identified gaps for future research. Suitable future research in agility testing and training is individually discussed below.

6.1.1 Testing

- **Assessment of the discriminant validity of the 1v1 agility test**
  While the ecological validity of the 1v1 testing procedure was examined in this thesis, the capacity of the test to distinguish between playing groups has not been analysed. Future research using athletes of different playing standards could be used to assess this quality.

- **Reliability analysis of subjective agility assessments**
  Results from the survey of high-performance managers in the AFL showed that subjective analysis of agility performance is common in elite environments. Subjective analysis offers substantial benefits for assessing agility as it may allow for testing of agility in-game and in other training activities. However, the reliability of subjective
analysis is unexplored in the literature and requires assessment to determine its usefulness. The use of technology, such as accelerometry or video analysis, may be useful in improving reliability when using these testing methods. Further, subjective agility assessment during SSG interventions may increase athletes’ exposure to agility events, and may better facilitate reliability.

- **The suitability of 2D athlete tracking**

While the 1v1 testing procedure used in this thesis benefited from a simple scoring criterion, the discrete nature of the scoring method limits the resolution of results. Direct observation of athlete position via 2D athlete tracking may allow for more accurate recording of inter-athlete distances and inter-athlete angles. Research into dyadic systems has shown that video-based 2D player tracking may be suitable for this application, and could be explored (80, 134, 135).

### 6.1.2 Training

- **The mechanisms of 1v1 agility development**

While the 1v1 training study aimed to determine the effect of 1v1 training on attacking and defending agility, the mechanisms for change are unknown. However, proposed mechanisms have been discussed in the thesis, and more research needs to be undertaken to understand the mechanisms of agility development further. To
develop a greater understanding of changes in visual search strategy following agility training interventions results from eye-tracking may be insightful. Further, it was proposed that 1v1 training may have a plyometric benefit, particularly for attacking athletes. Therefore, it is possible that reactive strength will develop throughout a 1v1 training intervention. For this reason, the recording of reactive strength may be insightful for understanding physical mechanisms for agility development.

- **Research into the effects of constraint manipulations**

  As 1v1 agility training research is in its infancy, the precise effect of individual constraint manipulations is unknown. Therefore, more research into the effects of specific constraint manipulations needed. A constraint manipulation that may be effective in improving agility performance is the use of visual occlusion. By intermittently blinding athletes in 1v1 training scenarios, athletes must rely on limited visual input. Therefore, athletes are forced to anticipate the movements of their opposition from less information. This constraint may promote further development of the athlete’s anticipatory skill in agility events. Nevertheless, the use of visual occlusion in 1v1 agility training is unresearched.

- **Increased training volume and duration in 1v1 training**

  The 1v1 training intervention used in this study found improvements in attacking agility but not defending agility. It was hypothesised that an increased training
volume or duration might be necessary to elicit significant improvements in defending agility. Therefore, further research with increased training density is needed to evaluate this hypothesis.

- **The injury implications of 1v1 training**  
  Due to the severe nature of knee injuries that arise from side-stepping, an understanding of the injury implications of 1v1 training is needed. It is possible that by attuning athletes to the affordances of their playing environment, athletes may be better able to select safe agility movement strategies following 1v1 training. However, no research has evaluated the effects of 1v1 training on movement strategy. 3D motion analysis during the 1v1 agility test may be useful for determining biomechanical changes in movement technique.
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Part II

APPENDICES
NOTATIONAL ANALYSIS FORM

1. Who is recording data?

2. Game no?

3. Quarter
   a) One
   b) Two
   c) Three
   d) Four

4. Time left in quarter:

5. Did the agility event result in a turnover?
   a) Yes
   b) No

6. Attacking team:

7. Attacking jumper number:

8. Did the defending athlete simultaneously place 2 hands on the attacking athlete?
   a) Yes
   b) No
9. Attacker speed of approach
   a) Stationary
   b) Walk/ Slow Jog
   c) Striding
   d) Sprinting

10. Attacker angle of COD
    a) 0-90 Degrees
    b) More than 90 Degrees
    c) Acceleration/ Deceleration only

11. Attacker deceptive technique
    a) Fake disposal
    b) Fake COD (deceptive movement in unintended direction of travel)
    c) None

12. Did the attacker attempt to fend off the opponent?
    a) Yes
    b) No

13. Did the attacker attempt to fend off the opponent?
    a) Side Step (outside foot)
    b) Crossover Cut
    c) Acceleration
    d) Deceleration
    e) Spin (Blind turn)
f) Other

14. Where does the stimulus occur?
   a) In front
   b) Behind
   c) Side

15. Did the attacker attempt a disposal?
   a) Yes
   b) No

16. Was the disposal successful?
   a) Yes
   b) No

17. Defender jumper number:

18. Defender speed of approach
   a) Stationary
   b) Walk/ Slow Jog
   c) Striding
   d) Sprinting

19. Change in defender’s gait
   a) Shortened
   b) Normal
   c) Lengthened

20. Did the defender successfully tackle?
a) Yes

b) No
The ethical approval document from the Federation University human research ethics committee, along with the final report to the ethics committee, is presented in full on the following pages.
Principal Researcher: Dr Warren Young

Other/Student Researcher/s: Dr Scott Talpey
                         Mr Russell Rayner

School/Section: School of Exercise Sciences and Physiology

Project Number: B17-025

Project Title: Comparison of attacking and defending agility in AF: Current coaching practices.

For the period: 09/05/2017 to 23/10/2019

Quote the Project No: A17-049 in all correspondence regarding this application.

Please note: Ethics Approval is contingent upon the submission of annual Progress reports when applicable and a Final report upon completion of the project. It is the responsibility of researchers to make a note of the following dates and submit these reports in a timely manner, as reminders may not be sent out. Failure to submit reports will result in your ethics approval lapsing.

REPORTS TO HREC:

An annual report for this project must be submitted to the Ethics Officer by:
9 May 2018

A final report for this project must be submitted to the Ethics Officer by:
23 November 2017

Report templates can be found at:

Fiona Koop
Ethics Officer
9 May 2017

Please see attached ‘Conditions of Approval’.
CONDITIONS OF APPROVAL

1. The project must be conducted in accordance with the approved application, including any conditions and amendments that have been approved. You must comply with all of the conditions imposed by the HREC, and any subsequent conditions that the HREC may require.

2. You must report immediately anything which might affect ethical acceptance of your project, including:
   - Adverse effects on participants;
   - Significant unforeseen events;
   - Other matters that might affect continued ethical acceptability of the project.

3. Where approval has been given subject to the submission of copies of documents such as letters of support or approvals from third parties, these must be provided to the Ethics Office before the research may commence at each relevant location.

4. Proposed changes or amendments to the research must be applied for, using a ‘Request for Amendments’ form, and approved by the HREC before these may be implemented.

5. If an extension is required beyond the approved end date of the project, a ‘Request for Extension’ should be submitted, allowing sufficient time for its consideration by the committee. Extensions cannot be granted retrospectively.

6. If changes are to be made to the project’s personnel, a ‘Changes to Personnel’ form should be submitted for approval.

7. An ‘Annual Report’ must be provided by the due date specified each year for the project to have continuing approval.

8. A ‘Final Report’ must be provided at the conclusion of the project.

9. If, for any reason, the project does not proceed or is discontinued, you must advise the committee in writing, using a ‘Final Report’ form.

10. You must advise the HREC immediately, in writing, if any complaint is made about the conduct of the project.

11. You must notify the Ethics Office of any changes in contact details including address, phone number and email address.

12. The HREC may conduct random audits and / or require additional reports concerning the research project.

Failure to comply with the National Statement on Ethical Conduct in Human Research (2007) and with the conditions of approval will result in suspension or withdrawal of approval.
Please indicate the type of report:  
- [ ] Annual Report *(Omit 3b & 5b)*  
- [x] Final Report

**Project No:** B17-025

**Project Name:** Comparison of attacking and defending agility in AF: Current coaching practices

**Principal Researcher:** Dr Warren Young

**Other Researchers:** Dr Scott Talpey  
Mr Russell Rayner

**Date of Original Approval:** 09 May 2017

**School / Section:** School of Exercise Sciences and Physiology

**Phone:** 0416 472 141

**Email:** rayner.russell.j@gmail.com

---

**Please note:** For HDR candidates, this Ethics annual report is a separate requirement, in addition to your HDR Candidature annual report, which is submitted mid-year to research.degrees@federation.edu.au.

---

### 1) Please indicate the current status of the project:

| 1a) Yet to start |  
| 1b) Continuing |  
| 1c) Data collection completed |  
| 1d) Abandoned / Withdrawn: | [x] |

**1e) If the approval was subject to certain conditions, have these conditions been met? (If not, please give details in the comments box below)**  
- [x] Yes  
- [ ] No

**Comments:**

| 1f) Data Analysis |  
| 1g) Have ethical problems been encountered in any of the following areas: |

- [ ] Study Design  
- [x] Recruitment of Subjects

| [ ] Not yet commenced | [ ] Proceeding | [x] Complete | [ ] None | [ ] Yes | [x] No |
Finance

Facilities, Equipment

(If yes, please give details in the comments box below)

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
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</table>

Comments:

2a) Have amendments been made to the originally approved project?

☐ No  ☐ Yes

2b) If yes, was HREC approval granted for these changes?

☐ Yes

Provide detail:

☐ Yes Application for Amendment to an Existing Project
☐ Yes Change of Personnel
☐ Yes Extension Request

☐ No If you have made changes, but not had HREC approval, provide detail as to why this has not yet occurred:

2c) Do you need to submit any amendments now?

☐ No

☐ Yes Application for Amendment to an Existing Project
☐ Yes Change of Personnel
☐ Yes Extension Request

* NB: If ‘Yes’, download & submit the appropriate request to the HREC for approval:
Please note: Extensions will not be granted retrospectively. Apply well prior to the project end date, to ensure continuity of HRE approval.

3a) Please indicate where you are storing the data collected during the course of this project: (Australian code for the Responsible conduct of Research Ch 2.2.2, 2.5 – 2.7)

The data is stored on the PhD student’s password protected laptop located in the School of Health and Life Sciences

3b) Final Reports: Advise when & how stored data will be destroyed
(Australian code for the Responsible conduct of Research Ch 2.1.1)

The data will be destroyed in five years following submission of the PhD thesis
4) Have there been any events that might have had an adverse effect on the research participants OR unforeseen events that might affect continued ethical acceptability of the project?

☑ No    ☐ Yes  * NB: If ‘yes’, please provide details in the comments box below:

Comments:

5a) Please provide a short summary of results of the project so far (no attachments please):

The project investigated the agility training and testing practices used in elite Australian football by means of a survey. The results indicated that a range of agility training and testing practices were used between clubs, and that subjective agility assessment was preferred to formal agility testing.

5b) Final Reports: Provide details about how the aims of the project, as stated in the application for approval, were achieved (or not achieved).

(Australian code for the Responsible conduct of Research 4.4.1)

The aims of the project were met as the survey revealed the agility training and testing practices that are used in elite Australian football

6) Publications: Provide details of research dissemination outcomes for the previous year resulting from this project: eg: Community seminars; Conference attendance; Government reports and/or research publications

NA

7) The HREC welcomes any feedback on:
- Difficulties experienced with carrying out the research project; or
- Appropriate suggestions which might lead to improvements in ethical clearance and monitoring of research.
8) Signatures

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<thead>
<tr>
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Submit to the Ethics Officer, Mt Helen campus, by the due date: research.ethics@federation.edu.au
HIGH PERFORMANCE MANAGER SURVEY

Rating Scale:

1. Never
2. Rarely
3. Sometimes
4. Often

1. Please respond by checking the appropriate box to indicate how often you see the following methods in your training:

   1 v 1 evasion (could include tackling) 0 1 2 3
   Small-sided games that encourage evasive skill 0 1 2 3
   Full ground match play 0 1 2 3
   1v1 with agility belts 0 1 2 3
   COD drills with lines, poles, or cones 0 1 2 3
   COD drills with ladders 0 1 2 3

2. What footwork manoeuvres do you coach to enhance agility:

   Split-step 0 1 2 3
   Side-step 0 1 2 3
   Crossover-cut 0 1 2 3
   Blind-turn (spin) 0 1 2 3
3. Based on your responses above, please elaborate on your preferred training activities.

4. How do you assess agility and/or CODS?

5. How much value you place on the results of the AFL Planned Agility Test used in the AFL Draft Combine? Is there an alternative agility test that you would like to see implemented?

6. Are there any questions you have regarding the training and testing of agility and/or CODS that you will like to see addressed with research?

7. Do you have any additional comments relating to agility training and testing? Please elaborate
SURVEY RESPONSES

1. Please respond by checking the appropriate box to indicate how often you see the following methods in your training

<table>
<thead>
<tr>
<th>Sub Question</th>
<th>Never</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Often</th>
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</thead>
<tbody>
<tr>
<td>1 v 1 evasion (could include tackling)</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>8</td>
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<tr>
<td>Small-sided games that encourage evasive skill</td>
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<td>0</td>
<td>1</td>
<td>9</td>
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<tr>
<td>Full ground match play</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>9</td>
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<tr>
<td>1v1 with agility belts</td>
<td>7</td>
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<td>COD drills with lines, poles, or cones</td>
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<tr>
<td>COD drills with ladders</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>1</td>
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2. What footwork manoeuvres do you coach to enhance agility

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</thead>
<tbody>
<tr>
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<td>2</td>
<td>1</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Side-step</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Crossover-cut</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Blind-turn (spin)</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td>0</td>
</tr>
</tbody>
</table>

3. Based on your responses above, please elaborate on your preferred training activities:

- We do a combination of COD drills for foot speed and coordination, and then train it in footy specific
small sided games, with lots of rule, numbers and size of game alterations to challenge players.

- We undertake most of our agility training via small sided games and other competitive drills that include opponents and a football. We will however identify those that are poor and spend extra time with these players in improving their fundamental foot patterning (e.g. ladders), COD movements (e.g. poles), and agility drills (adding in a reaction stimulus - e.g. ball, opponents, sound or visual cue).

- Foot patterning coordination & conditioning Reactive agility - position specific Small sided games with and without contact

- These activities change depending on the time of the year, in season v pre season, days turn around, position requirements of the player and strengths and deficiencies of the player.

- Basic COD activities occur early in warm ups. However, our focus is on game specific agility activities such as tackling drills and small sided games. Many of our key position players have specific footwork training during pre-season.

- We acknowledge that the inside foot and outside foot play a role in different situations (i.e we don’t bias just inside or outside foot training) We use some techniques picked up off Bill Knowles (posture/arms/legs/stiffness) Frans Bosch and Dean
Benton all leaders in my mind in the area being discussed.

- We spend the majority of our training time in context driven drills. Rarely COD drills with poles etc. Maybe only during warm up as a change up

- We start the day with an injury prevention piece that includes cutting and COD movements at relatively low speed. Our warm-up on main training days then includes reactive agility and COD training at high speed. Our biggest challenge is preparing players for the force involved in a sharp cut during high speed running due to the high levels of deceleration and high forces involved. A lot of our non-game based agility training focuses on deceleration.

- Footwork technique - teaching correct movement patterns consciously so they become habit unconsciously

- Gym-based lateral force absorption and application SSG with varied chaos elements Footwork coaching in football contexts

4. How do you assess agility and/or CODS?

- Game based observation

- Both the coaching group and conditioning staff will make subjective assessments.

- 505, T - Test Coach expertise
• Predominantly subjectively with the assistance of some accelerometer data.

• No formal assessment used.

• We don’t use any formal tests besides filming our players from front on, on their ability to decel and change direction. We use that as a teaching tool and to identify issues in R.O.M / Strength / Technique.

• Qualitative analysis in general. We will video each player in frontal and sagittal view for unanticipated cutting at periods in preseason to inform our programming/coaching

• Mostly just through subjective appraisal of movement and ability to decelerate. We try and get a feel for volume of COD through GPS accelerometry (although we aren’t convinced in the validity) and the amount of change in speed per minute that a player does. We currently use no objective test of agility or COD with our whole list. When players arrive at the club we record a change of direction test using Fitlights in a random sequence that we file away in case a player gets injured and then we can use it as a return to play assessment in specific cases.

• using the eye / video. no testing

• Using vision No specific, isolated testing

5. How much value you place on the results of the AFL Planned Agility Test used in the AFL Draft Combine? Is
there an alternative agility test that you would like to see implemented?

- A very small amount. It tells us that they are powerful and can produce force quickly whilst changing direction.

- I personally do not place a great deal of value in it. I don’t believe it would change a draft spot. That said, it is a “nice to know”. If there was a more reactive based test, then this would be more relative. However I would still be more likely to take on board what our recruiters report on each player re their agility.

- No importance. COD assessment for capacity - 505 Left & Right v 10m speed test

- Would like to see a "response to a stimulus" test rather than a COD test.

- Low priority. Prefer to see how they move in game.

- We don’t use that test. I see agility as a really difficult thing to test. It would need have an reactive component to it, I’m yet to see anything that is standardised that also ticks that box.

- very little.

- We place very little value but I wouldn’t go as far as to say it is useless. If a player can perform well on this test it is generally a good sign that they are a capable mover. I would not have an alternative test in mind. Most tests that I have seen have major limitations.
• a little but not much maybe some of the NFL type tests =- 5-10-5

• Little value

6. Are there any questions you have regarding the training and testing of agility and/or CODS that you will like to see addressed with research?

• Interaction of SL Strength (bounding) / COD / Agility

• The measurement of the differentiation between a player who reads the cues of an activity/stimulus v’s the player who is athletically gifted and can make up for poor anticipation. The combination of these factors explored.

• No.

• Importance of Flexibility? Inside leg vs Outside leg? NFL crossover step relevance to AFL?

• worthwhile training interventions utilising cueing?

• My biggest concern is preparing players to manage deceleration and the high forces that are created when cutting at high velocities - particularly in unplanned situations.

• turning - inside leg or outside leg emphasis. always a lot of debate on this.

7. Do you have any additional comments relating to agility training and testing? Please elaborate
• Tough one to measure in context when we look at all of the variables that are potentially in play at various stages of the game.

• Just interested in hearing alternatives to the AFL draft camp agility test?

• Although we do not place a large emphasis on training agility this is something we can do better. The more information we can glean from you work in this area will always be of interest for us

• In a small sided game in a grid we get a high frequency of change of directions but low forces in each change of direction because the grid-size restricts the velocities that our players can get up to. In a bigger space we get a much lower frequency of change of direction and it is harder to manipulate unplanned situations. Developing drills that can train players at higher velocities but also in a chaotic and unplanned environment is an area that I think has a large scope for research and development.

• Much of agility skill relates to pattern recognition and cognitive skills IN CONTEXT. Much agility training is not in context.
STUDIES 2 & 3 ETHICAL APPROVAL

The ethical approval document from the Federation University human research ethics committee, along with the final ethics report, is presented in full on the following pages.
Principal Researcher: Dr Warren Young

Other/Student Researcher/s: Dr Scott Talpey  
Mr Russell Rayner

School/Section: School of Exercise Sciences and Psychology

Project Number: A17-112

Project Title: Training and testing attaching and defending agility in Australian football

For the period: 15/08/2017 to 01/03/2019

Quote the Project No: A17-112 in all correspondence regarding this application.

Approval has been granted to undertake this project in accordance with the proposal submitted for the period listed above.

Please note: It is the responsibility of the Principal Researcher to ensure the Ethics Office is contacted immediately regarding any proposed change or any serious or unexpected adverse effect on participants during the life of this project.

In Addition: Maintaining Ethics Approval is contingent upon adherence to all Standard Conditions of Approval as listed on the final page of this notification.

COMPLIANCE REPORTING DATES TO HREC:

Annual project report: 15/08/2018
Final project report: 01/04/2019

The combined annual/final report template is available at:

Irene Hall
Ethics Officer
15 August 2017

Please note the standard conditions of approval on Page 2:
STANDARD CONDITIONS OF APPROVAL

1. Conduct the project strictly in accordance with the proposal submitted and granted ethics approval, including any amendments made to the proposal required by the HREC.

2. Advise (email: research.ethics@federation.edu.au) immediately of any complaints or other issues in relation to the project which may warrant review of the ethical approval of the project.

3. Where approval has been given subject to the submission of copies of documents such as letters of support or approvals from third parties, these are to be provided to the Ethics Office prior to research commencing at each relevant location.

4. Submission for approval of amendments to the approved project before implementing such changes. A combined amendment template covering the following is available on the HRE website: http://federation.edu.au/research/research-support/ethics/human-ethics/human-ethics3

   - Request for Amendments
   - Request for Extension. Note: Extensions cannot be granted retrospectively.
   - Changes to Personnel

5. Annual Progress reports on the anniversary of the approval date and a Final report within a month of completion of the project are to be submitted by the due date each year for the project to have continuing approval.

6. If, for any reason, the project does not proceed or is discontinued, advise the committee by completing the Final report form.

7. Notify the Ethics Office of any changes in contact details including address, phone number and email address for any member of the research team.

8. The HREC may conduct random audits and / or require additional reports concerning the research project as part of the requirements for monitoring, as set out in the National statement on Ethical Conduct in Human Research.

Failure to comply with the National Statement on Ethical Conduct in Human Research (2007) and with the conditions of approval will result in suspension or withdrawal of approval.
Please indicate the type of report:  
- [ ] Annual Report (Omit 3b & 5b)  
- [x] Final Report

**Project No:** A17-112

**Project Name:** Training and testing attacking and defending agility in Australian football

**Principal Researcher:** Dr Warren Young

**Other Researchers:** Dr Scott Talpey, Mr Russell Rayner

**Date of Original Approval:** 15 August 2017

**School / Section:** School of Exercise Sciences and Psychology

**Phone:** 0416 472 141

**Email:** rayner.russell.j@gmail.com

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Please note: For HDR candidates, this Ethics annual report is a separate requirement, in addition to your HDR Candidature annual report, which is submitted mid-year to research.degrees@federation.edu.au.

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1) Please indicate the current status of the project:

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1e) If the approval was subject to certain conditions, have these conditions been met? (If not, please give details in the comments box below)

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Comments:

1f) Data Analysis

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<td>[x]</td>
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1g) Have ethical problems been encountered in any of the following areas:

- Study Design
  - [ ] Yes  
  - [x] No

- Recruitment of Subjects
  - [ ] Yes  
  - [x] No
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<th>Finance</th>
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<td>Facilities, Equipment</td>
<td>Yes</td>
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<td>(If yes, please give details in the comments box below)</td>
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**Comments:**

2a) **Have amendments been made to the originally approved project?**

- ☑ No
- ☐ Yes

2b) **If yes, was HREC approval granted for these changes?**

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- ☑ No

If you have made changes, but not had HREC approval, provide detail as to why this has not yet occurred:

2c) **Do you need to submit any amendments now?**

- ☑ No
- ☐ Yes

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3a) **Please indicate where you are storing the data collected during the course of this project:** (Australian code for the Responsible conduct of Research Ch 2.2.2, 2.5 – 2.7)

The data is stored on the PhD student’s password protected laptop located in the School of Health and Life Sciences

3b) **Final Reports:** Advise when & how stored data will be destroyed (Australian code for the Responsible conduct of Research Ch 2.1.1)

The data will be destroyed in five years following submission of the PhD thesis
4) Have there been any events that might have had an adverse effect on the research participants OR unforeseen events that might affect continued ethical acceptability of the project?

☐ No  ☐ Yes  * NB: If ‘yes’, please provide details in the comments box below:

Comments:

5a) Please provide a short summary of results of the project so far (no attachments please):

The study investigated the reliability and validity of an agility test and found excellent inter-rater and intra-rater reliability, and moderate test-retest reliability. Comparison to game demands showed improved validity when compared to previous testing protocols; however, some differences between the test and game demands were observed.

The test was then used to assess four weeks of agility training, and revealed improvements in attacking agility, but not defending agility following the intervention.

5b) Final Reports: Provide details about how the aims of the project, as stated in the application for approval, were achieved (or not achieved).

(Australian code for the Responsible conduct of Research 4.4.1)

The study met the proposed research aims by determining the reliability and validity of field-based attacking and defending agility tests, and using the test to determine the effectiveness of 1v1 agility training by means of a training study. Finally, the study found poor transfer from attacking training to defending agility, and defending training to attacking agility.

6) Publications: Provide details of research dissemination outcomes for the previous year resulting from this project: eg: Community seminars; Conference attendance; Government reports and/or research publications

NA
7) The HREC welcomes any feedback on:
- Difficulties experienced with carrying out the research project; or
- Appropriate suggestions which might lead to improvements in ethical clearance and monitoring of research.

8) Signatures

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| | …………………………………… | Date: | 08/01/2020 |
| Print name: Mr Russell Rayner |

Submit to the Ethics Officer, Mt Helen campus, by the due date: research.ethics@federation.edu.au
The Plain Language Information Statement from the reliability and validity study is presented in full on the following two pages.
You are invited to participate in the above research project, which is being conducted by Dr Warren Young (principle supervisor), Dr Scott Talpey (associate supervisor) and Mr Russell Rayner (PhD student) of the Faculty of Health at Federation University. The supervisors of this project have experience in conducting agility testing for academic use.

The aim of this study is to investigate the reliability and validity of a field based test of agility. This data will be compared to agility events performed in-game to determine if movement patterns during the test are similar to on field. Should you agree to participate, you would be asked to complete one familiarisation and two testing sessions, one week apart, undertaken at the Mt Helen campus at Federation University. During testing you will be required to perform 10 simulated 1v1 agility scenarios, each lasting approximately five seconds. We estimate that the time commitment required of you would approximate 30 minutes per session.

During participation of the study, you will be video-recorded for the purposes of data collection. As such, it is impossible for the researchers to maintain anonymity. However, we intend to protect your anonymity and the confidentiality of your responses to the fullest possible extent, within the limits of the law. Your name and contact details will be kept in a separate, password-protected computer file from any data collected from the study. This will only be able to be linked to your results by the researchers. In the final report, you will be referred to by a pseudonym. We will remove any references to personal information that might allow someone to know your identity.

Once the publication arising from this research has been completed, a brief summary of the findings will be made available by researchers upon request. It is also possible that the results will be presented at academic conferences. The data will be kept securely in the Faculty of Heath for five years from the date of publication, before being destroyed.
Plain Language Information Statement

Please be advised that your participation in this study is completely voluntary. Should you wish to withdraw at any stage, or to withdraw any unprocessed data you have supplied, you are free to do so without prejudice. This research has been approved by the Federation University Human Research Ethics Committee. Your decision to participate or not, or to withdraw, will be completely independent of your relationship with the researchers. Therefore, your participation will not affect ongoing assessment, grades, management or treatment by researchers. However, if consent is withdrawn after data has been aggregated and processed it will not be possible to withdraw non-identifiable data, although consent can still be withdrawn.

As the study is physical in nature, participation poses a small risk of discomfort and injury. All foreseeable measures to mitigate injury risk will be undertaken, but in the event of injury, immediate first aid will be available from trained individuals. Further, if any psychological discomfort arises during participation of the study, please seek assistance from lifeline on 13 11 14 or the university counselling service on (03) 5827 9470. Please note, the Federation University counselling service is available only to Federation University students.

If you have any further questions about the research project, please contact the principal researcher using the contact details provided below.

If you have any questions, or you would like further information regarding the project titled reliability & validity of field tests of attacking & defending agility, please contact the Principal Researcher, Dr Warren Young of the School of sport science and psychology:

EMAIL: w.young@federation.edu.au
PH: 03 5327 9685

Should you (i.e. the participant) have any concerns about the ethical conduct of this research project, please contact the Federation University Ethics Officers, Research Services, Federation University Australia, P O Box 663 Mt Helen Vic 3353 or Northways Rd, Churchill Vic 3842.
Telephone: (03) 5327 9765, (03) 5122 6446
Email: research.ethics@federation.edu.au

CRICOS Provider Number 00103D
The consent form from the reliability and validity study is presented in full on the following page.
Consent Form
Human Research Ethics Committee

<table>
<thead>
<tr>
<th>PROJECT TITLE:</th>
<th>Reliability &amp; validity of field tests of attacking &amp; defending agility</th>
</tr>
</thead>
<tbody>
<tr>
<td>RESEARCHERS:</td>
<td>Dr Warren Young, Dr Scott Talpey, Mr Russell Rayner</td>
</tr>
</tbody>
</table>

Consent – Please complete the following information:

I ________________________________ of ________________________________ hereby consent to participate as a subject in the above research study.

The research program in which I am being asked to participate has been explained fully to me, verbally and in writing, and any matters on which I have sought information have been answered to my satisfaction.

I understand that: all information I provide (including questionnaires) will be treated with the strictest confidence and data will be stored separately from any listing that includes my name and address.

- Aggregated results will be used for research purposes and may be reported in scientific and academic journals.
- All sessions will be video-taped for research purposes
- As the number of people involved in the study may be small, it is possible that someone may be able to identify you
- Anonymity and confidentiality will be kept to the fullest possible extent, within the limits of the law
- I am free to withdraw my consent at any time during the study in which event my participation in the research study will immediately cease and information/data obtained from it will not be used.
- I understand the exception to this is if I withdraw after information has been aggregated - it is unable to be individually identified - so from this point it is not possible to withdraw my information/data, although I may still withdraw my consent to participate.
- Need to add that players will be video-taped, limits to confidentiality and small sample sizes.

SIGNATURE:___________________________________  DATE: ____________________.
WARM-UP PROTOCOL

AEROBIC WARM-UP

• Jog 6 laps of perimeter of testing area (approximately 450m)

DYNAMIC STRETCHES – APPROX. 30M EACH

• Butt kicks

• High Knees

• Skip for height

• Skip for distance

• Zig Zag sidestep

• Side-to-side

• Carioca

• Sprint and turn back sharp at increasing intensities
  - 50%
  - 75%
  - 90%
  - 100%

• 5 trials each of small evasive efforts from 2-metres apart
# Test Starting Positions

<table>
<thead>
<tr>
<th>Trial No.</th>
<th>Attacker position</th>
<th>Defender position</th>
<th>Inter-athlete distance (m)</th>
<th>Inter-athlete angle</th>
<th>Position of defender in relation to attacker</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A1</td>
<td>B5</td>
<td>11.34</td>
<td>14.04°</td>
<td>Left</td>
</tr>
<tr>
<td>2</td>
<td>B1</td>
<td>B4</td>
<td>8.25</td>
<td>0°</td>
<td>In Front</td>
</tr>
<tr>
<td>3</td>
<td>C1</td>
<td>C4</td>
<td>8.25</td>
<td>0°</td>
<td>In Front</td>
</tr>
<tr>
<td>4</td>
<td>B2</td>
<td>B3</td>
<td>2.75</td>
<td>0°</td>
<td>In Front</td>
</tr>
<tr>
<td>5</td>
<td>C2</td>
<td>D4</td>
<td>6.15</td>
<td>26.57°</td>
<td>Left</td>
</tr>
<tr>
<td>6</td>
<td>D2</td>
<td>B5</td>
<td>9.92</td>
<td>33.69°</td>
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</tr>
<tr>
<td>7</td>
<td>D2</td>
<td>D4</td>
<td>5.5</td>
<td>0°</td>
<td>In Front</td>
</tr>
<tr>
<td>8</td>
<td>E2</td>
<td>D5</td>
<td>8.7</td>
<td>18.43°</td>
<td>Right</td>
</tr>
<tr>
<td>9</td>
<td>B3</td>
<td>C4</td>
<td>3.89</td>
<td>45°</td>
<td>Left</td>
</tr>
<tr>
<td>10</td>
<td>D3</td>
<td>C5</td>
<td>6.15</td>
<td>26.57°</td>
<td>Right</td>
</tr>
</tbody>
</table>
The Plain Language Information Statement from the training study is presented in full on the following two pages.
SCHOOL OF EXERCISE SCIENCES AND PHYSIOLOGY  
FACULTY OF HEALTH  

<table>
<thead>
<tr>
<th>PROJECT TITLE:</th>
<th>Evaluation of 1 v 1 agility training</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRINCIPAL RESEARCHER:</td>
<td>Dr Warren Young – Associate Professor (Exercise and Sport Sciences)</td>
</tr>
</tbody>
</table>
| OTHER/STUDENT RESEARCHERS: | Dr Scott Talpey – Lecturer (Exercise and Sport Sciences)  
Mr Russell Rayner – PhD Student (Exercise and Sport Sciences) |

You are invited to participate in the above research project, which is being conducted by Dr Warren Young (principle supervisor), Dr Scott Talpey (associate supervisor) and Mr Russell Rayner (PhD student) of the Faculty of Health at Federation University. The supervisors of this project both have experience in conducting agility testing and training for academic use.

The aim of this study is to investigate the suitability of 1v1 training for improving agility. This data will be used to inform future agility training practice in Australian football. Should you agree to participate, you would be asked to complete one familiarisation, two testing sessions, as well as 4 weeks of bi-weekly agility training, undertaken at the Mt Helen campus at Federation University. We estimate that the time commitment required of you would approximate 30 minutes per session. The testing procedures will require you to perform 10 simulated 1v1 agility scenarios, each lasting approximately five seconds. The training program will require you to perform 20 1v1 scenarios, identical to the test, followed by 5 trials from your own chosen starting position.

During participation of the study, you will be video-recorded for the purposes of data collection. As such, it is impossible for the researchers to maintain anonymity. However, we intend to protect your anonymity and the confidentiality of your responses to the fullest possible extent, within the limits of the law. Your name and contact details will be kept in a separate, password-protected computer file from any data collected from the study. This will only be able to be linked to your results by the researchers. In the final report, you will be referred to by a pseudonym. We will remove any references to personal information that might allow someone to know your identity.

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As the study is physical in nature, participation poses a small risk of discomfort and injury. All foreseeable measures to mitigate injury risk will be undertaken but in the event of injury, immediate first aid will be available from trained individuals. Further, if any psychological discomfort arises during participation of the study, please seek assistance from lifeline on 13 11 14 or the university counselling service on (03) 5827 9470.

If you have any further questions about the research project, please contact the principal researcher using the contact details provided below.

If you have any questions, or you would like further information regarding the project titled reliability & validity of field tests of attacking & defending agility, please contact the Principal Researcher, Dr Warren Young of the School of sport science and psychology:

EMAIL: w.young@federation.edu.au
PH: 03 5327 9685

Should you (i.e. the participant) have any concerns about the ethical conduct of this research project, please contact the Federation University Ethics Officers, Research Services, Federation University Australia, P O Box 663 Mt Helen Vic 3353 or Northways Rd, Churchill Vic 3842.
Telephone: (03) 5327 9765, (03) 5122 6446
Email: research.ethics@federation.edu.au
The consent form from the training study is presented in full on the following page.
Consent Form
Human Research Ethics Committee

<table>
<thead>
<tr>
<th>PROJECT TITLE:</th>
<th>Evaluation of 1v1 agility training</th>
</tr>
</thead>
<tbody>
<tr>
<td>RESEARCHERS:</td>
<td>Dr Warren Young, Dr Scott Talpey, Mr Russell Rayner</td>
</tr>
</tbody>
</table>

Consent – Please complete the following information:

I _______________________________________________ of
__________________________________________________+

hereby consent to participate as a subject in the above research study.

The research program in which I am being asked to participate has been explained fully to me, verbally and in writing, and any matters on which I have sought information have been answered to my satisfaction.

I understand that: all information I provide (including questionnaires) will be treated with the strictest confidence and data will be stored separately from any listing that includes my name and address.

▪ Aggregated results will be used for research purposes and may be reported in scientific and academic journals.
▪ All sessions will be video-taped for research purposes
▪ As the number of people involved in the study may be small, it is possible that someone may be able to identify you
▪ Anonymity and confidentiality will be kept to the fullest possible extent, within the limits of the law
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▪ I understand the exception to this is if I withdraw after information has been aggregated - it is unable to be individually identified - so from this point it is not possible to withdraw my information/data, although I may still withdraw my consent to participate.
▪ Need to add that players will be video-taped, limits to confidentiality and small sample sizes.

SIGNATURE: __________________________________ DATE: ____________________.
TRAINING STUDY STARTING POSITIONS

L.1 SESSION 1

Testing Area: 15m wide x 15m long

<table>
<thead>
<tr>
<th>Attacker Position</th>
<th>Defender Position</th>
<th>Inter-athlete Distance (m)</th>
<th>Inter-athlete Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 A1</td>
<td>A4</td>
<td>11.25</td>
<td>0°</td>
</tr>
<tr>
<td>2 E1</td>
<td>E4</td>
<td>11.25</td>
<td>0°</td>
</tr>
<tr>
<td>3 C1</td>
<td>C4</td>
<td>11.25</td>
<td>0°</td>
</tr>
<tr>
<td>4 A1</td>
<td>C4</td>
<td>13.53</td>
<td>33.69°</td>
</tr>
<tr>
<td>5 E1</td>
<td>C3</td>
<td>10.61</td>
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<td>6 C2</td>
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<td>C4</td>
<td>8.39</td>
<td>26.57°</td>
</tr>
<tr>
<td>8 C2</td>
<td>B3</td>
<td>5.30</td>
<td>45°</td>
</tr>
<tr>
<td>9 C2</td>
<td>B4</td>
<td>8.39</td>
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<td>13 E1</td>
<td>D5</td>
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<td>14.04°</td>
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<tr>
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<tr>
<td>15 B1</td>
<td>A4</td>
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<tr>
<td>18 D1</td>
<td>E4</td>
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<tr>
<td>19 C2</td>
<td>D3</td>
<td>5.30</td>
<td>45°</td>
</tr>
<tr>
<td>20 A1</td>
<td>D5</td>
<td>18.75</td>
<td>36.87°</td>
</tr>
</tbody>
</table>
L.2 SESSION 2

Testing Area: 11m wide x 15m long

<table>
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<th>Attacker Position</th>
<th>Defender Position</th>
<th>Inter-athlete Distance (m)</th>
<th>Inter-athlete Angle</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>2 E1</td>
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<td>0°</td>
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<tr>
<td>3 C1</td>
<td>C4</td>
<td>11.25</td>
<td>0°</td>
</tr>
<tr>
<td>4 A1</td>
<td>C4</td>
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<td>26.05°</td>
</tr>
<tr>
<td>5 E1</td>
<td>C3</td>
<td>9.30</td>
<td>36.25°</td>
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<tr>
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<td>C4</td>
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<td>C4</td>
<td>7.99</td>
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</tr>
<tr>
<td>8 C2</td>
<td>B3</td>
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</tr>
<tr>
<td>9 C2</td>
<td>B4</td>
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<td>C4</td>
<td>7.99</td>
<td>20.14°</td>
</tr>
<tr>
<td>12 A1</td>
<td>B5</td>
<td>15.25</td>
<td>10.39°</td>
</tr>
<tr>
<td>13 E1</td>
<td>D5</td>
<td>15.25</td>
<td>10.39°</td>
</tr>
<tr>
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<td>B4</td>
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<td>13.74°</td>
</tr>
<tr>
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<td>A4</td>
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<td>13.74°</td>
</tr>
<tr>
<td>16 B1</td>
<td>A5</td>
<td>15.25</td>
<td>10.39°</td>
</tr>
<tr>
<td>17 D1</td>
<td>E5</td>
<td>15.25</td>
<td>10.39°</td>
</tr>
<tr>
<td>18 D1</td>
<td>E4</td>
<td>11.58</td>
<td>13.74°</td>
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<tr>
<td>19 C2</td>
<td>D3</td>
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</table>
### L3 Session 3

Testing Area: 13m wide x 13m long

<table>
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<tr>
<th></th>
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<th>Defender Position</th>
<th>Inter-athlete Distance (m)</th>
<th>Inter-athlete Angle</th>
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</thead>
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<td>1</td>
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<td>0°</td>
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<tr>
<td>2</td>
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</tr>
<tr>
<td>3</td>
<td>C1</td>
<td>C4</td>
<td>9.75</td>
<td>0°</td>
</tr>
<tr>
<td>4</td>
<td>A1</td>
<td>C4</td>
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<td>33.69°</td>
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<tr>
<td>5</td>
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<td>C3</td>
<td>9.19</td>
<td>45°</td>
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<tr>
<td>6</td>
<td>C2</td>
<td>C4</td>
<td>6.50</td>
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<td>7</td>
<td>B2</td>
<td>C4</td>
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<td>26.57°</td>
</tr>
<tr>
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<td>C2</td>
<td>B3</td>
<td>4.60</td>
<td>45°</td>
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<tr>
<td>9</td>
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<td>C2</td>
<td>D4</td>
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<td>26.57°</td>
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<tr>
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<td>D2</td>
<td>C4</td>
<td>7.27</td>
<td>26.57°</td>
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<tr>
<td>12</td>
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<td>13</td>
<td>E1</td>
<td>D5</td>
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<td>14.04°</td>
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<tr>
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<td>A1</td>
<td>B4</td>
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<td>18.43°</td>
</tr>
<tr>
<td>15</td>
<td>B1</td>
<td>A4</td>
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<td>18.43°</td>
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<td>B1</td>
<td>A5</td>
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<td>14.04°</td>
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<tr>
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<td>D1</td>
<td>E5</td>
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<tr>
<td>18</td>
<td>D1</td>
<td>E4</td>
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<td>18.43°</td>
</tr>
<tr>
<td>19</td>
<td>C2</td>
<td>D3</td>
<td>4.60</td>
<td>45°</td>
</tr>
<tr>
<td>20</td>
<td>A1</td>
<td>D5</td>
<td>16.25</td>
<td>36.87°</td>
</tr>
</tbody>
</table>
L.4  SESSION 4

Testing Area: 15m wide x 11m long

<table>
<thead>
<tr>
<th>Attacker Position</th>
<th>Defender Position</th>
<th>Inter-athlete Distance (m)</th>
<th>Inter-athlete Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 A1</td>
<td>A4</td>
<td>8.25</td>
<td>0°</td>
</tr>
<tr>
<td>2 E1</td>
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</tr>
<tr>
<td>3 C1</td>
<td>C4</td>
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<tr>
<td>4 A1</td>
<td>C4</td>
<td>11.15</td>
<td>42.27°</td>
</tr>
<tr>
<td>5 E1</td>
<td>C3</td>
<td>9.3</td>
<td>53.75°</td>
</tr>
<tr>
<td>6 C2</td>
<td>C4</td>
<td>5.5</td>
<td>0°</td>
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<tr>
<td>7 B2</td>
<td>C4</td>
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L5  Session 5

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### L6 Session 6

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Testing Area: 9m wide x 9m long

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### L.8 Session 8

Testing Area: 11m wide x 9m long

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