THE RELATIONSHIP OF REPEATED
AGILITY TO STRENGTH, POWER AND
REPEATED SPRINTS
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Abstract

Agility is one of a number of crucial factors which influence sporting performance. The performance of agility and particularly repeated agility however has received limited research in comparison with other physiological determinants of performance such as repeated sprint ability, power or strength. The purpose of the present study was to determine if repeated sprint ability, power or strength significantly affect repeated agility performance. Twelve male, university standard rugby players performed, in a randomised order, a repeated sprint test, a 1 repetition maximum half squat test, a power test and a repeated agility test. Mean values for the repeated sprint test, the power test and the peak 1 repetition maximum half squat were correlated against mean values for the repeated agility test. The mean reactive change of direction presented no significant correlation with any of the other performance variables (-0.406 < r < 0.418). Mean total agility time found to correlate with mean reactive strength index, \( r = -0.623, P = 0.03 \), mean 30m sprint time \( r = 0.638, P = 0.026 \) and mean total sprint time \( r = 0.595, P = 0.041 \). Mean initial acceleration of the agility protocol also showed correlations with mean reactive strength index \( r = -0.602, P = 0.038 \), mean 30m sprint time \( r = 0.688, P = 0.013 \) and mean total sprint time \( r = 0.658, P = 0.02 \). The low correlations of the mean reactive change of direction in particular suggest that repeated agility is a distinct physiological variable which needs significant concentration within training if players are to improve.
CHAPTER I

INTRODUCTION
1.0 Introduction

The physiology of sports performance is an area which has a vast background of research. Indeed, an extensive amount of studies have been performed assessing the strength, power and sprinting capabilities of various groups of athletes (Dawson et al., 1993; Fitzsimmons et al., 1993; Harrison et al., 2004; Kotzamanidis et al., 2005; Stone et al., 2006; Holtermann et al., 2007b). It is generally accepted that these factors have a large bearing on the success of athletes, particularly within games sports. It is also understood that knowledge of an athlete’s ability to perform these various components can aid their training by allowing sport specific goals for improvement. Agility, however, has a limited research background with few studies concentrating on this area (Young et al., 2002; Brown and Vescovi 2003; Craig, 2004; Farrow et al., 2005; Sheppard and Young, 2006 and Young and Farrow, 2006). There are also a number of limiting factors in existing studies such as the definition of agility, assessment methods and the terms speed and agility have been used interchangeably. Additionally, the area of repeated agility activity - as an athlete may expect to undertake during a game activity - appears to have been particularly neglected.

Games activities are characterised by repeated bouts of varying intensity activities (Bishop and Edge, 2006; Deutsch et al., 2007; Duthie et al., 2003; Gamble, 2004; Spencer et al., 2004). Many studies have been performed to examine the movement characteristics of games athletes and there seems a general consensus that work to rest ratios are, on average, between 1:4 to 1:8 with slight variations between sports (Deutsch et al., 2007; Fitzsimons et al., 1993; Spencer et al., 2004). Dawson et al. (1993) states that athletic performance should be assessed by measuring the
athletes’ ability to regularly reproduce sport specific actions at the highest intensity that they would expect to find in a game, rather than a one off maximal effort. Studies into the movement patterns of games sports have highlighted components such as sprints and repeated sprints as essential actions for performance, whilst strength and power capabilities were noted as integral to contact sports.

Stone et al. (2006) describes strength as the ability to produce force and as such is vital to games players. Cronin et al. (2007) concur, stating that strength is essential for sporting performance and resultanty, many athletes include resistance training to improve the force capability of their muscles. Cronin et al. (2007) also found that enhancements of strength via resistance training resulted in positive improvements of sprint performance. Kotzamanidis et al. (2005) supported this argument, determining that combined high resistance training and sprint training in the same sessions were most beneficial. Many tests have also indicated that strength has links with power and the rate of force development (Mirkov et al., 2004; Andersen and Aagaard, 2006; Holtermann et al., 2007a; and Holtermann et al., 2007b). It therefore appears that strength is vital for not just as a single component within sporting performance but for the impact it has upon other crucial factors within sport (Tsitskaris et al., 2003).

Due to the intermittent nature of high intensity activity observed during games sports, a number of studies have been performed into the repeated sprint ability of athletes. Spencer et al. (2005) contested that the ability to perform repeated sprint bouts with minimal recovery between, is an important aspect of team sports. As such, studies, such as Dawson et al. (1993), have focused upon repeated sprint
ability, finding that repeated sprint ability was closely correlated to performance measures of anaerobic power and work capacity. In addition, a number of studies have been performed to assess the validity of repeated sprint test protocols and their use for assessing sport specific fitness. Wragg et al. (2000) performed one such study by assessing a sport specific field test against an anaerobic laboratory test in order to find a sport specific measure of repeated sprint ability. In addition, studies such as that performed by Bishop and Edge (2006) into the determinants of repeated sprint performance have provided insight into the physiological factors that underpin repeated sprints.

Power is an important aspect of any games athlete as it gives them the ability to win contact situations, contest for possession and can give an added dimension to an athlete’s performance. Saez Saez de Villarreal (2007) stated that muscle power and explosiveness had been shown to be a major factor in successful sports performance. As such, studies such as Andersen and Aagaard (2006) have focused on athletes’ power and the ‘explosiveness’ of their muscle contraction. Andersen and Aagaard’s study used the term ‘rate of force development’ to explain the explosive muscle strength and the muscle’s ability to rapidly produce muscular force. This term has been the basis of a number of studies assessing the ability of an athlete to produce muscular force quickly; which by definition is a power movement (Mirkov et al., 2004; Holtermann et al., 2007a and Holtermann et al., 2007b). Another crucial term used throughout the literature is the stretch-shortening cycle, which is the eccentric to concentric contractions of the leg extensor muscles (Hennessy and Kilty, 2001). Hennessy and Kilty (2001) explain that the stretch-shortening cycle results in a more powerful concentric contraction compared with
concentric contraction performed without prior eccentric movement. Both the stretch-shortening cycle and the rate of force development characteristics of athletes’ muscles have been widely researched and have also been linked with agility, strength and sprinting performance (Hennessy and Kilty, 2001; Young et al., 2001; Young et al., 2002; Brown and Vescovi, 2003; Harrison et al., 2004; Mirkov et al., 2004; Andersen and Aagaard, 2006).

Agility is an important factor within sports performance, which can often be overlooked and has not yet been extensively researched (Young and Farrow, 2006). The ability to change the body’s position quickly and effectively in a response to a stimulus is crucial in almost all sports (Craig, 2004). Current studies into agility have been flawed in many ways such as the athlete’s ability to predict the next move (Craig, 2004) or the combination of sprinting and agility activities (Wragg et al., 2000). Sheppard and Young (2006) contested that agility is a rapid whole body action with a change in direction and velocity in response to an external stimulus. Investigations should therefore take all these factors into consideration when designing test protocols. In addition, Sheppard and Young (2006) suggested that previous studies may have been flawed due to the number of different theories and definitions of agility. It has also been contested that due to the complexity of some theories, confusion about their true meaning could have caused test protocols to have inherent confusion and flaws. As a result, Sheppard and Young (2006) concluded that a new agility protocol should be designed to account for physical performance measures and perceptual factors.
With the abundance of studies investigating the other physiological components which influence sporting performance, it appears that agility has been somewhat neglected. Research into this area could provide vital information so coaches can be advised if there is a gap within training, which may affect games athletes’ performance. Therefore the purpose of this study was to a) correlate performance measures of repeated agility with measures of repeated sprint ability, power and strength and b) assess if repeated sprint ability, power and strength significantly affect agility performance.

It is hypothesised that power will display the highest correlations with repeated agility whereas repeated sprints will produce the lowest.
CHAPTER II

CRITICAL REVIEW OF LITERATURE
2.0 Critical Review of Literature

2.1. Muscular Strength

Muscular strength can be described as the ability to produce force (Mirkov et al., 2004 and Stone et al., 2006). Stone et al. (2006) went on to suggest that the measurement of strength is effectively a measure of a skill or ability. Furthermore, Stone et al. (2006) contests that because force is a vector quantity, it should have a direction and magnitude. In addition, Berg (2006) states that as force provides the impetus to accelerate the mass of the body, an implement or a limb, muscular strength is necessary for all sports. Berg (2006) also contests that the need for muscular strength varies between sports as the masses that need to be moved or accelerated also vary.

2.1.1 Types of muscular strength

Stone et al. (2007) suggest that there are 4 main types of muscular contraction, concentric, eccentric, isometric or isokinetic. Concentric muscle contraction allows shortening of the muscle as the force produced by the muscle is greater than the load acting upon it (Baechle and Earle, 2000). Alternatively, force produced by the muscle during eccentric contraction is not enough to raise the resistance and as such the muscle lengthens (Stone et al., 2007). The concentric and eccentric muscle actions are often used in combination where an eccentric contraction is used to store energy to maximise the subsequent concentric movement. This eccentric-concentric movement is termed the stretch-shortening cycle (Hennessy and Kilty, 2001). As the stretch-shortening cycle requires a dynamic movement in order to utilise the stored energy and maximise force production it is often used within power based literature.
(Hennessy and Kilty, 2001 and Harrison et al., 2004). In contrast, isometric muscle contraction refers to the muscle maintaining a constant length and producing just enough force to hold the resistance statically (Stone et al., 2007). Fleck and Kraemer (2004) explain that maximal isometric force is greater than maximal concentric force but less than maximal eccentric force. Isokinetic muscular contraction explains the application of force at a constant velocity. In addition, Stone et al. (2006) explains that further elements of strength include relative strength and absolute strength. Relative strength is the ability of an athlete to produce force as a percentage of their body weight. Absolute strength is the pure ability of an athlete to produce a magnitude of force.

2.1.2 Factors Affecting Force Production

The ability of an athlete to produce force is dependant upon a number of factors such as muscle fiber type, muscle cross sectional area and neural drive to the muscles (Andersen and Aagaard, 2006). Folland and Williams (2007) explain that the muscle fiber type is a key component in force production as more type 2 fibres allows for a greater force to be applied in the same amount of time. This view is supported by Cissik (2004) who suggests that an athlete with a greater percentage of fast twitch muscle fibers has the potential to produce greater amounts of force more quickly than athletes with a greater percentage of slow twitch fibers. Further, Stone et al. (2006) contests that muscle size or cross sectional area has an affect on force production as an increased cross sectional area allows fewer motor units to be recruited at the same force output, hence a greater force can be produced when the same amount of muscle units are utilised. Neural drive to the muscles affects motor unit recruitment and discharge rate and as such has a significant affect on force production.
production (Holtermann et al., 2007). In addition, Holtermann et al. (2007) argued that an athlete who has an increased net excitatory synaptic input or motorneuron excitability will increase the maximum voluntary contraction that athlete is able to produce.

2.1.3 Muscular Strength Assessment

Assessment of muscular strength is commonplace within strength and conditioning literature (Berg, 2006; Stone et al., 2006; Cronin et al., 2007) and a variety of different methods have been used. Berg (2006) states that the most common test for muscular strength is a 1 repetition maximum test. Berg (2006) however, contests that 1 repetition maximum tests may not be valid for every muscle group, as it may be more specific to test the strength endurance capabilities of the lower back, rather than maximum strength. In addition, Cronin et al. (2007) states that most studies use a squat test as their measure of maximal strength. Squat tests can be said to be specific for most sports as most sports have a large contribution from leg muscles. Although 1 repetition maximum tests are commonplace, the methods of assessment vary significantly. Mirkov et al. (2004) used a system which gave digital feedback from the test, rather than using Olympic lifting techniques. Digital data allows more detailed feedback about the movement to be given, however this limits the sports specific movements that can be produced. This is true of the study by Mirkov et al. (2004) as the participants performed their tests from a rigid chair. Further, testing by Andersen and Aagaard (2006) had participants performing leg extensions from a seated position, a movement which is uncommon within sporting performance. Limitations of Olympic lifting techniques however are that lifting to maximum can
become dangerous, particularly with untrained individuals as well as the limited data found compared with digital feedback.

2.2. Speed

Baechle and Earle (2000) describe speed as the maximum horizontal velocity an athlete can reach and is the product of stride length and stride frequency. Further, Fleck and Kraemer (2004) argued that sprint performance is determined by the ability to accelerate to maximum velocity and the ability to maintain velocity against the onset of fatigue. Baechle and Earle (2000) went on to explain that stride length and stride frequency are important in the initial phases of acceleration but as the athlete reaches near maximum velocity, stride frequency becomes more important and is concurrently more important in deciding final velocity. In addition, Young et al. (2001a) state that sprinting at maximum or near maximum speed over a variety of different differences is crucial within most sports.

2.2.1 Speed and Agility

Young et al. (2001b) contests that sprint speed and agility are different factors entirely. Young et al. (2001b) went on to say that training for multidirectional speed as found in agility activity does not transfer to unidirectional straight speed and equally, straight speed does not transfer to high speed agility activity. This view is supported by Young and Farrow (2006) who state that although many strength and conditioning professionals believe straight line speed and agility performance are strongly correlated, no evidence has been found to support this view, with low correlations found throughout the literature. Young and Farrow (2006) furthered this
by arguing that the more changes of direction, the less that straight speed can be transferred.

2.2.2 Factors Affecting Speed

Cissik (2004) stated that the most crucial determinants of speed are the structure and make up of an athlete’s muscles, technique, stride length and stride frequency with flexibility and fatigue also playing a role. Cissik (2004) suggests that a high percentage of fast twitch muscle fibers allow for fast and large force production and as such are advantageous for sprint performance. Young et al. (2001a) adds that speed strength or explosive force production of the muscles is also a significant factor in sprint performance. Young et al. (2001a) also suggests that as maximum speed is reach and eccentric loads are high, the stretch-shortening cycle and reactive strength properties of the muscles have an impact on sprint speed. Kumagi et al. (2000) found that fascicle lengths influenced sprint performance, with faster sprinters exhibiting greater fascicle lengths and increasing shortening velocity by almost 22%. As sprinting speed can be said to be a product of stride length and stride frequency (Beachle and Earle 2000), it is important to understand what affects both factors. Flexibility is important in allowing a fluid movement, through the full range of motion, allowing an optimum stride length and increasing efficiency (Cissik, 2004). Technique is a limiting factor as is will significantly affect stride length and frequency (Cissik, 2004). Sheppard and Young (2007) suggest that the best technique for sprinting is upright, with a high centre of mass. Fatigue will influence sprinting performance as the muscle’s ability to shorten quickly and to utilise muscle units effectively, interfering with technique and maximum sprint speed (Cissik, 2004). Spencer et al. (2005) argued that energy metabolism during
sprints of less than 10 seconds, which is predominantly what is found in team games, is primarily supplied by both phosphocreatine degradation and anaerobic glycolysis. The evidence for significant anaerobic glycolysis contribution to short duration sprints are in the only partially depleted stores of phosphocreatine.

### 2.2.3 Repeated Sprint Activity

It has been well documented that repeated sprint performance is an important indicator of sporting performance, particularly within team sports (Dawson et al., 1993; Fitzsimmons et al., 1993; Spencer et al., 2005; Bishop and Edge, 2006). The importance of repeated sprint activity is in that of game specificity, as most team sports involve repetitions of high intensity work periods with intermittent rest periods (Dawson et al., 1993). Spencer et al. (2005) suggested that although repeated sprint activity only contributes a small proportion of the whole game activity, it may be critical to the result of a game. Spencer et al. (2004) performed game analysis on field hockey players and found that repeated sprints of 4 seconds duration, with active recovery of approximately 20 seconds, if repeated six to seven times would represent an intense but realistic period of game activity for the purposes of performance assessment. Further, Spencer et al. (2004) stated that the protocol described could be adapted for other team sports such as rugby or football to allow for the specific requirements of each game. Metabolically, Dawson et al. (1993) states that the phosphagen energy system is the primary energy source for sprint starts and short maximal efforts with the glycolytic energy system having increased importance during longer sprints. Dawson et al. (1993) explains that the glycolytic system has particular significance when sprint efforts must be repeated with insufficient recovery time for complete phosphagen repletion. Further, Dawson
et al. (1993) contest that although the aerobic energy system has a very limited contribution to a maximal short sprint, it plays a key role in the repletion of intramuscular ATP, PCr and myoglobin stores during the recovery period. This is supported by Spencer et al. (2005) who explains that the physical requirements for single sprints remain but, although the energy system requirements to replenish ATP are initially dependant upon anaerobic glycolysis, this is reduced during the performance of subsequent sprints, and an increase in aerobic metabolism is seen. Energy metabolism however is largely dependant upon the sprint duration (Spencer et al., 2005).

2.2.4 Assessment of Speed

Due to the variety of different sprints within sports, from as little as 5 metres up to and possibly beyond 100 metres, as well as the issues of repeated sprints, a large volume of speed and sprinting tests have been performed (Fitzsimmons et al., 1993; Wragg et al., 2000; Spencer et al., 2004 and Bishop and Edge 2006). Single sprint testing was performed by Gabbett (2002) who used electronic timing gates for sprints of 10, 20, 30 and 40 metres. The use of electronic timing gates allows accurate data to be gathered, with speed being measured to 0.01s in the study by Gabbett (2002). Hennessy and Kilty (2001) also performed tests of single sprints, testing 30, 100 and 300 m distances, again using electronic timing gates for high accuracy. A limitation of the study by Hennessy and Kilty (2001) however is that the 100 and 300m tests were performed outdoors and the 30m test indoors. The change of conditions, both ambient and track could have caused errors within the data collected.
Repeated sprint ability is an area which has been extensively researched. Wragg et al. (2000) states that the Fitzsimmons et al. (1993) first introduced the term repeated sprint ability. Fitzsimmons et al. (1993) performed test of both cycling and running test of repeated sprint ability. Although the tests were novel at the time and significantly stressed the systems necessary for repeated sprint ability, the lack of a standardised protocol for between sprint rest may have affected the results of the test. Subsequent tests have addressed this issue with Wragg et al. (2000) imposing a standardised active recovery for their participants between sprints. Much debate has surrounded the area of recovery with some studies opting for passive rest (Bishop and Edge, 2006) while others employed an active rest period (Wragg et al., 2000). The argument for active rest is that during games, athletes often have periods of walking or jogging recovery (Duthie et al., 2003) while passive recovery protocols contest that activity between sprints may affect the results of further sprints.

2.3 Power

Stone et al. (2007) states that power is the product of the force produced and the velocity it is produced with. Further, Stone et al. (2007) contests that a primary factor in determining sports performances is power output. The combination of speed and strength which is found in power movements is often termed the rate of force development. The rate of force development of a muscle is explained by Andersen and Aagaard (2006) as the ability to rapidly develop muscular force, and as such it can be deemed a power movement. Explosive force production is also used throughout the literature (Mirkov et al., 2004; Andersen and Aagaard, 2006) to describe power based movements. The stretch-shortening cycle is a term which is also present in a number of power based studies. The stretch-shortening cycle
describes the eccentric to concentric contraction of muscles, which results in a more forceful concentric contraction (Hennessy and Kilty, 2001). Harrison et al. (2004) stated that utilising a stretch immediately before a concentric contraction has been shown to increase force production and power output. The ability of an athlete to produce power is crucial within most team sports as jumping or sprinting actions are predominant throughout (Kotzamanidis et al., 2005; Saez Saez de Villarreal et al., 2007).

2.3.1 Factors Affecting Power Production

Harrison et al. (2004) contests that as power is a product of force and velocity, muscle power should be proportional to muscle volume. Mirkov et al. (2004) partially reinforces this view by suggesting that the rate of force development and explosive force production of the muscles could be related to muscle force or, indirectly, muscle size. Further, Andersen and Aagaard (2006) state that maximal muscle strength and muscle size influence rate of force development.

As power is the product of force and velocity however, as Harrison et al. (2004) highlighted, the force-velocity relationship has a significant influence upon power production. Baechle and Earle (2000) state that force production is inversely related to velocity of shortening during concentric actions. The inverse relationship of force and velocity means that during faster movements, less force production is possible and during slower movements, a higher force output is achievable. Most sports require a combination of both velocity of movement and force production in order to optimise performance (Berg, 2006). Stone et al. (2007) suggested that with untrained subjects, heavy weight training could cause a rightward shift across the
entire force-velocity curve, resulting in increased power output across a wide range of velocities. Stone et al. (2007) however, indicated that trained athletes need to concentrate on high velocity actions to make alterations in the high-velocity end of the force-velocity curve.

A factor which links with the force-velocity curve is explosive strength and explosive strength deficit. Zatsiorsky (1995) describes explosive strength as the ability to exert maximal forces in minimal time. This definition of explosive strength displays links with power, as power is a product of force and velocity (Harrison et al., 2004). Explosive strength deficit links with explosive strength and describes the percentage of an athlete’s maximal force which cannot be utilised as the time available for force development is short (Zatsiorsky, 1995). It is advantageous for an athlete to assess their explosive strength deficit for a given action as it can allow significant improvements in explosive movements. Zatsiorsky (1995) contests that to decrease explosive strength deficit an athlete can either increase their maximal force or their movement velocity. Zatsiorsky (1995) suggests that an increase in maximal strength only brings good results when the explosive strength deficit is substantially below 50%. Athlete’s who have a high explosive strength deficit should concentrate on specialised training to increase their movement velocity (Zatsiorsky, 1995)

The rate of force development properties of an athlete’s muscles is another factor which affects power production (Mirkov et al., 2004). Stone et al. (2007) suggests that rate of force development is linked with strength but more specifically, high rate of force development with explosive strength and therefore power. Stone
et al. (2007) concludes that dynamic exercises resulting in a high rate of force development and high power outputs are crucial for athletes in a variety of sports. Further Zatsiorsky (1995) states that as the time available to produce force in athletic performance is typically less than the time required to produce maximal force, rate of force development is more crucial than absolute force. Andersen and Aagaard (2006) highlight a number of factors which influence rate of force development but suggested that the two main physiological parameters are muscle strength and the intrinsic contractile properties of the muscle. Further, Holtermann et al. (2007b) contests that rate of force development can be influenced by muscle cross-sectional area, muscle fiber type and properties of the muscle-tendon system. In addition, Holtermann et al. (2007b) found that resistance training significantly increased rate of force development due to the neural training hypothesis.

### 2.3.2 Assessment of Power Production

As power is a crucial aspect of sporting performance Gabbett (2002) tested it’s influence upon selection. The methods used by Gabbett (2002) however was extremely limited as the protocol involved making a chalk mark on the wall and measuring the distance from that mark to the height of their arm extended above their head when their feet were flat on the floor. This type of protocol is not very accurate and as such is not common in the literature. Hennessy and Kilty (2001) used a far more accurate assessment method in the form of an electronic contact matt. In both studies, countermovement jumps were used as methods of power assessment. In contrast, a number of studies have assessed rate of force development as a measure of power (Mirkov et al., 2004; Andersen and Aagaard, 2006; Holtermann et al., 2007a and Holtermann et al., 2007b). The volume of data needed
to assess rate of force development means electronic systems were needed with
digital feedback. As a result, the participants were forced to be seated and use
movements that aren’t specific to sport.

2.4 Agility

Agility can be described as the ability to quickly and effectively change the motion
of the body in a response to a stimulus (Young and Farrow, 2006). Sheppard and
Young (2006) contest that motion analysis studies have shown that the ability to
repeatedly change direction while sprinting is a determinant of sports performance
for both field and court sports. Sheppard and Young (2006) also suggest however
that there is some confusion within the literature as to the true definition of agility.
The terms cutting and quickness have added confusion to the problem which can
often be used as substitutes for agility within the literature (Sheppard and Young,
2006). It is however accepted that agility comprises of both perceptual mechanisms,
taking into account action of the central nervous system as well as physical factors
such as physiological qualities of the athlete or technique (Young et al., 2002; Craig,
2004; Sheppard and Young, 2006 and Young and Farrow, 2006). Figure 1 shows
one model which helps to explain the multidimensional nature of agility, proposed
by Young et al. (2002).
Although the model by Young et al. (2002) takes perceptual and physiological factors into consideration, research by Young and Farrow (2006) suggested that there was no correlation between change of direction speed and straight sprinting speed. Young and Farrow (2006) went on to say that straight sprinting speed is clearly a different movement pattern from agility and cannot be expected to transfer. This research is supported by (Young et al., 2001b) and from these studies it can be concluded that model by Young et al. (2002) is flawed although it does take into account the perceptual and physiological factors which make up agility activity.

**Figure 1.** Model of Agility by Young *et al.* (2002)
The confusion of straight line speed with agility is not confined to the model by Young et al. (2002), many studies include a straight speed component within their tests which can confuse their findings. One such example is Wragg et al. (2000) who used a sprint test with an agility component. Wragg et al. (2000) was attempting to recreate the specific demands of the sport by incorporating a multidirectional component to a sprint test. By including a reactive agility component to a sprint protocol, Wragg et al. (2000) confuses the variables of agility and speed and as such the validity and reliability of the test came into question.

2.4.1 Factors Affecting Agility

From the model of Young et al. (2002) the two main factors which affect agility movement is change of direction speed and perceptual and decision making factors. The two major factors can then be split into their relative components for further analysis. Change of direction speed is governed mainly by physiological components such as leg muscle qualities and technique. Young and Farrow (2006) suggest that strength and power can have an influence upon agility performance and particularly the stretch-shortening cycle. This view is supported by Brown and Vescovi (2003) who state that agility requires the development of the stretch shortening cycle for significant improvements. Sheppard and Young (2006) however suggests that although strength and power may have an influence upon agility activity, there is some contradiction in the literature and the correlations found were often low and non-significant. Sheppard and Young (2006) also stated that concentric muscle power is a poor predictor of change of direction speed but the stretch shortening cycle and reactive strength involvement may be a better predictor, or at least have a stronger relationship. In addition, Young et al. (2002) suggest that
as the foot is planted in agility movements, leg extensor muscles will initially lengthen, storing energy before an active push off via the shortening of the same muscles would produce extra force. Young et al. (2002) went on to say that as such, a good change of direction speed is associated with the extra force and power movement provided by the stretch shortening cycle of the leg extensors. It appears then that the power and reactive strength of the muscles, particularly in the leg extensors play a crucial role in change of direction speed.

Sheppard and Young (2006) suggest that a forward lean and low centre of gravity would be an optimum technique for agility running. It was suggested that this technique would allow optimal conditions for acceleration and deceleration as well as increasing the stability of the movement. In addition, Sheppard and Young (2006) and Young et al. (2002) contest that a lower centre of gravity allows for more rapid changes of direction, which are indicative of agility activity. Young and Farrow (2006) however suggests that there is no research supporting a singular optimum technical model of how an athlete should utilise body position and limbs to change direction. Brown and Vescovi (2003) oppose this view, suggesting that an optimum technique and specifically arm movement can be found. Brown and Vescovi (2003) concluded that athletes often swing their arms further away from their bodies than is desired, increasing the forces resisting movement and decreasing the efficiency of the movement. Brown and Vescovi (2003) proposed that rapid, compact arm actions are essential to quicker changes of direction.
Young et al. (2002) states that the ability of an athlete to react to an external stimulus and the nature of the stimulus influences performance in agility tasks. As a result, Young et al. (2002) deduce that perceptual factors are significant for agility performance. This view is echoed by Farrow et al. (2005) who found that a distinct differences between highly skilled and club players ability to react to a stimulus, with an increased decision making time for the club players. As a result, Farrow et al. (2005) concluded that perceptual factors play a large role in agility performance.

2.4.2 Repeated Agility Activity
Repeated agility activity is an area which has been largely overlooked within performance analysis. Repeated agility activity will include all the perceptual and physical factors which are highlighted by the model by Young et al. (2002) for single agility activity but it will be affected by metabolic processes and fatigue. The metabolism of repeated agility activity will be extremely similar to repeated sprint activity and the fatigue experienced will affect agility performance in a similar way as described in section 2.4.

2.4.3 Assessment of Agility
Research shows that agility activity requires both a perceptual and physical component (Wragg et al., 2000; Young et al., 2002; Craig, 2004 and Sheppard and Young, 2006). Farrow et al. (2005) contested that planned tests of agility with no perceptual factors included do not provide a true indication of an athlete’s performance within team sports where many agility activities are in reaction to an opponent. This view is supported by Young and Farrow (2006) who states that skilled performers use anticipatory information more successfully than less skilled
performers and as such, agility testing and training should include this factor. Young et al. (2002) however presented no perceptual element to their testing as the participants were informed of the action they were to perform prior to testing. Young et al. (2002) are clearly ignoring a crucial factor of their model and as such their findings may be flawed. Farrow et al. (2005) employed both a planned and a reactive test in order to assess the relative success of perceptual factors, concluding that perceptual factors significantly distinguished the highly skilled players from the less skilled. The methods employed by Farrow et al. (2005) were highly successful, including sport specific movements as well as visual images which the participants reacted to, simulating a game situation effectively. A limitation of the testing however is that upon repetition of the testing, the images were played in the same order, allowing for anticipation from memory the order of the stimuli. The testing by Wragg et al. (2000) demonstrated a different problem, by linking a test for speed with an agility movement. Although the test includes a change of direction and a perceptual factor, the length of the sprint before and after the agility movement causes neither factor to be tested successfully.
CHAPTER III

METHODOLOGY
3.0 Method

3.1 Subjects
Twelve male, university standard rugby players (age 20.5 ± 1.6yr, height 1.86m ± 0.06m, body mass 92.5 ± 9.1kg) volunteered to participate in the current study. All subjects had been using resistance training, plyometrics and sprint training for at least 2 years prior to the experiment. All participants were free from injury and illness and had completed the informed consent approved by the University of Wales Institute, Cardiff Ethics Committee. The subjects were informed of the procedures, purpose and possible risks of the experiment prior to commencement.

3.2 Experimental Protocol
The study was conducted by using repeated sprints, a 1RM half squat, a 5 bounce jump protocol and a repeated agility test. The tests were randomised for each subject to avoid systematic error. Data collection was split into four sessions over 2 weeks, allowing each subject to perform all of the tests once. Each participant undertook a familiarisation session the week prior to data collection so that they were comfortable with each test and no learning effect would interfere with the data collection. Uniform encouragement was given to all participants throughout the study. Prior to each testing session, the participants performed their own warm up and were fully prepared. The participants were advised not to exercise or drink alcohol within 24hrs of the testing session. In addition, eating on the day of testing was recommended, however not within 2 hours of the experiment. Hydration was also encouraged prior to and throughout testing.
3.3 Repeated Sprint Protocol

The repeated sprint protocol was adapted from research by Fitzsimmons et al. (1993) and Spencer et al. (2004) in accordance with research by Deutsch et al. (2007) and Duthie et al. (2003) to add specificity for the participants. Repeated sprint ability evaluation comprised of 10 x 40 metre sprints commencing every 30 seconds. The 40m sprints were timed using electronic timing gates (Fusion Sport, Brisbane, Australia). The timing gates were placed at 10 and 40m on an indoor track in order to standardise conditions for each participant and prevent environmental conditions, such as adverse weather, affecting the results. The participants began each sprint with a verbal command from the test administrator. On the command, the participant would sprint 40m as fast as possible. The participant was required to make his way back to the starting point within 30 seconds of the commencement of the previous test. As the participant was required to jog or walk to recover to the starting position, their recovery was active, simulating the active recovery within a game situation. The participant was required to complete 10 repetitions of the 40 metre sprints. The chosen performance measures of repeated sprint ability were the mean 10m sprint time, the mean sprint time between 10m and 40m and the mean total sprint time. Figure 2 shows a diagram of the repeated sprint protocol.
Figure 2. Diagram of Repeated Sprint Protocol. a, start; b, first timing gates (0m); c, second timing gates (10m); d, third timing gates (40m); dashed line, recovery jog/walk to start position; solid arrow, direction of sprint.

3.4 1RM Half Squat Protocol

Each participant was familiar with the half squat technique from prior training. The bar was supported upon the shoulders and firmly grasped with both hands for balance. The participants kept a straight back position and bent their knees until they reached the 90° limit. Once the 90° position was reached, the participant raised himself to the upright position with the legs completely extended. To test the participants’ one repetition maximum, each participant started at a load they knew they were capable of and increased the load until they were unable to complete the movement unaided. For safety purposes, there were 3 ‘spotters’ for each squat, one on either side of the bar and one behind the participant to aid the completion of the movement if necessary.
3.5 **5 Bounce Jump Protocol**

To test the participants’ power, a 5 bounce jump routine using a jump matt (Fusion Sport, Brisbane, Australia) was used. To begin the test, the participants stood on the jump matt and were instructed to perform a countermovement jump, followed by 4 consecutive vertical jumps. The participants were instructed to jump as quickly and as high as possible. The jump matt automatically calculated jump height, contact time, flight time, impulse, power and the reactive strength index of the jump.

3.6 **Repeated Agility Protocol**

As there has been little research into the area of reactive agility, a new protocol was devised. Following personal correspondence with Dr Jon Oliver who recently performed reliability testing on an agility protocol and from piloting a number of tests, the following protocol was devised. The protocol takes account of the reactive nature of agility, change of direction speed and does not confuse agility with speed which is a limitation of many previous studies into agility. The agility protocol begins with a 5m acceleration to a timing gate (Fusion Sport, Brisbane, Australia), initiated by a solid green light emitted by the timing gate. The timing gate emits a flashing light once the test administrator triggers it and has a 1-5 second delay before the solid green light is emitted. This therefore simulates a reactional start as a player may make in a game, as they cannot anticipate the starting trigger and must react to the stimulus. Once the timing gate has been reached it triggers one of two timing gates positioned 3 metres either side of the first gate and 4 metres forward. The gate which is triggered will flash instantly, indicating to the participant to cut to that gate. Cutting back to a central gate, 3 metres to the centre and 4 metres forward from the second set of gates completes the test. Participants complete 10 repetitions of this
activity and must run a total of 15 metres each repetition. From piloting and taking into account the 4:1 ratio of work to rest, participants are given 20 seconds to complete the test and recover to the starting position for the next repetition. The chosen performance measures of repeated agility were the mean time to the first timing gate, the mean time to the second timing gate and the mean total agility time. In order to isolate the specific agility cutting action, the time between the first gate and the second gate was also calculated and used as a measure of agility. Figure 3 shows a diagram of the repeated agility protocol.

![Diagram of the Repeated Agility Protocol](image)

**Figure 3.** Diagram of the Repeated Agility Protocol. a, start; b, first timing gates; c, second timing gates; d, final timing gates; dashed line, recovery jog/walk to start position; solid arrow, direction of sprint.
3.7 Statistical Analysis

A Pearson's two-tailed correlation was used to compare measures of repeated agility against squats, repeated sprints and power. The agility measures were correlated against 1RM squat, the mean 10m sprint time, the mean sprint time between 10m and 40m and the mean total sprint time as well as all six measures of power calculated by the force matt. The levels of significance were set to $P \leq 0.05$. The Statistical Package for Social Sciences 12.0 (SPSS, Chicago, Illinois) was used to analyse the data. All tables and graphs were composed using Microsoft Excel (Microsoft Corporation, USA).
CHAPTER IV

RESULTS
4.0 Results

Table 4.1 shows the mean split times of the agility protocol for each of the participants. Correlations performed on the data showed that the mean first split and total agility time significantly correlated with the mean reactive strength index ($r = -0.623$, $P = 0.03$) and ($r = -0.602$, $P = 0.038$) respectively. Figure 4 demonstrates the negative correlation between the mean reactive strength index and the mean time to the first agility timing gate. The correlation performed between reactive strength index and the mean second split for agility found a high but non-significant correlation ($r = -0.556$, $P = 0.06$). The statistical analysis of the remaining performance variables of power found no correlation to the mean agility data.

Table 1. The Mean Split Times of the Agility Protocol for Each Player.

<table>
<thead>
<tr>
<th>PLAYER 1</th>
<th>Agility Split 1 (s)</th>
<th>Agility Split 2 (s)</th>
<th>Agility Split 1-2 (s)</th>
<th>Agility Total (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLAYER 2</td>
<td>2.11</td>
<td>3.74</td>
<td>1.63</td>
<td>4.97</td>
</tr>
<tr>
<td>PLAYER 3</td>
<td>1.88</td>
<td>3.3</td>
<td>1.42</td>
<td>4.61</td>
</tr>
<tr>
<td>PLAYER 4</td>
<td>1.91</td>
<td>3.48</td>
<td>1.58</td>
<td>4.65</td>
</tr>
<tr>
<td>PLAYER 5</td>
<td>1.85</td>
<td>3.35</td>
<td>1.5</td>
<td>4.54</td>
</tr>
<tr>
<td>PLAYER 6</td>
<td>2.02</td>
<td>3.59</td>
<td>1.57</td>
<td>4.74</td>
</tr>
<tr>
<td>PLAYER 7</td>
<td>1.79</td>
<td>3.32</td>
<td>1.53</td>
<td>4.5</td>
</tr>
<tr>
<td>PLAYER 8</td>
<td>1.73</td>
<td>3.19</td>
<td>1.46</td>
<td>4.33</td>
</tr>
<tr>
<td>PLAYER 9</td>
<td>1.93</td>
<td>3.47</td>
<td>1.53</td>
<td>4.81</td>
</tr>
<tr>
<td>PLAYER 10</td>
<td>1.77</td>
<td>3.37</td>
<td>1.6</td>
<td>4.54</td>
</tr>
<tr>
<td>PLAYER 11</td>
<td>1.66</td>
<td>3</td>
<td>1.34</td>
<td>4.18</td>
</tr>
<tr>
<td>PLAYER 12</td>
<td>1.65</td>
<td>2.96</td>
<td>1.31</td>
<td>4.09</td>
</tr>
</tbody>
</table>

29
Significant correlations were found between the mean time between 10m and 40m during the sprint and the time to the first agility timing gate ($r = 0.688$, $P = 0.013$) as well as the mean time to the second agility timing gate ($r = 0.600$, $P = 0.039$) and the mean total time for the agility protocol ($r = 0.638$, $P = 0.026$). Figure 4.2 shows the positive relationship between the mean 10m-40m sprint time and the mean total agility time.
When analysed, the mean total sprint time was found to significantly correlate with the mean time to the first agility timing gate \( r = 0.658, P = 0.02 \) and the mean total time for the agility protocol \( r = 0.595, P = 0.041 \). High but non-significant correlations were also found between the mean total sprint time and the time to the second agility timing gate \( r = 0.565, P = 0.056 \).

The data from the 1RM half squat displayed high but non-significant correlations with all three agility variables. The highest correlation was with the mean time to the first agility timing gate \( r = -0.573, P = 0.051 \), then the mean total time \( r = -0.524, P = 0.080 \) and finally the mean time to the second timing gate \( r = -0.523, P = 0.081 \).
Additionally, high but non-significant correlations were found between the mean 10m time during the sprint protocol and the mean time to the first agility timing gate \((r = 0.513, P = 0.088)\). Table 2 shows the repeated sprint and squat data for each of the players.

### Table 2. Mean Repeated Sprint Data and Squat Data for Each Player

<table>
<thead>
<tr>
<th></th>
<th>RS 10m (s)</th>
<th>RS 10-40 (s)</th>
<th>RS total (s)</th>
<th>Squats (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PLAYER 1</strong></td>
<td>2.41</td>
<td>5.33</td>
<td>7.74</td>
<td>222.5</td>
</tr>
<tr>
<td><strong>PLAYER 2</strong></td>
<td>2.08</td>
<td>4.39</td>
<td>6.46</td>
<td>215</td>
</tr>
<tr>
<td><strong>PLAYER 3</strong></td>
<td>1.95</td>
<td>4.04</td>
<td>6</td>
<td>200</td>
</tr>
<tr>
<td><strong>PLAYER 4</strong></td>
<td>1.99</td>
<td>4.31</td>
<td>6.3</td>
<td>220</td>
</tr>
<tr>
<td><strong>PLAYER 5</strong></td>
<td>2.16</td>
<td>4.52</td>
<td>6.68</td>
<td>177.5</td>
</tr>
<tr>
<td><strong>PLAYER 6</strong></td>
<td>1.96</td>
<td>4.12</td>
<td>6.07</td>
<td>215</td>
</tr>
<tr>
<td><strong>PLAYER 7</strong></td>
<td>2.24</td>
<td>4.25</td>
<td>6.49</td>
<td>237.5</td>
</tr>
<tr>
<td><strong>PLAYER 8</strong></td>
<td>2.19</td>
<td>4.8</td>
<td>6.99</td>
<td>192.5</td>
</tr>
<tr>
<td><strong>PLAYER 9</strong></td>
<td>2.04</td>
<td>4.42</td>
<td>6.46</td>
<td>230</td>
</tr>
<tr>
<td><strong>PLAYER 10</strong></td>
<td>2.06</td>
<td>4.31</td>
<td>6.38</td>
<td>232.5</td>
</tr>
<tr>
<td><strong>PLAYER 11</strong></td>
<td>1.96</td>
<td>4.01</td>
<td>5.97</td>
<td>210</td>
</tr>
<tr>
<td><strong>PLAYER 12</strong></td>
<td>2.05</td>
<td>4.41</td>
<td>6.47</td>
<td>192.5</td>
</tr>
</tbody>
</table>

The analysis performed on the specific agility cutting movement between gate 1 and gate 2 of the agility protocol showed low and non-significant correlations throughout \((-0.406 < r < 0.418)\), with a low average correlation \((r = 0.300)\) and significance \((P = 0.37)\).
CHAPTER V

DISCUSSION
5.0 Discussion

The aim of the study was to a) correlate performance measures of repeated agility with measures of repeated sprint ability, power and strength and b) assess if repeated sprint ability, power and strength significantly affect agility performance. It was proposed that the area of agility and specifically repeated agility has been neglected within games research and that information regarding what influences agility would be of benefit to strength and conditioning professionals. To the author’s knowledge, this is the first study to directly compare repeated agility with other physiological measures of performance.

The major findings of the study show that although correlations were found between repeated agility variables and reactive strength index as well as between repeated agility variables and repeated sprint variables, no correlation was found with the specific reactive change of direction data. The finding that reactive change of direction, which underpins agility performance, shows no correlation with other physiological measures of performance is in agreement with other studies, including Young et al. (2002), Young and Farrow (2006), Sheppard and Young (2006). Indeed, Sheppard and Young (2006) concluded that agility is a distinct physical quality, independent of straight line speed, whilst Young et al. (2002) stated that the importance of leg power to agility was unclear.

The underpinning mechanisms to explain such findings are subject to speculation, as in this study physiological variables were not collected and analysed alongside performance variables. After examining prior research however, it is possible to derive answers on a theoretical level. Agility activity is primarily
different from sprinting and other activities due to the optimum body position used for agility. Brown and Vescovi (2003) suggest that the arm movement particularly varies for agility with rapid, compact arm movements. Furthermore, Sheppard and Young contest that a low centre of gravity and forward lean is the optimum position for agility performance. This is in particular contrast to sprint activity, and power and strength movements, which tend to be initiated from a more neutral, anatomical position. The reactive nature of agility may also make comparisons with other physiological components difficult. Agility is reactive and the participant must therefore respond to a stimulus before movement is initiated and an unplanned movement is consequently performed. Farrow et al. (2005) suggests that significant differences in decision making time are found between highly skilled players and novices, suggesting that this is a key factor in agility performance. The unplanned nature of agility is different from sprinting, power and strength where decision making is not a significant factor and as such may have caused the results to be significantly different.

It has been suggested that reactive strength may be a predictor of agility, due to the use of the stretch-shortening cycle which could be beneficial for cutting movements (Young et al., 2002; Sheppard and Young, 2006; Young and Farrow, 2006). This view is in contrast to the findings of the current study, however the testing procedures were significantly different and this may account for the different results. It was expected however, that the reactive strength index calculated by the force matt would accurately indicate the reactive strength capabilities of the participants. In previous studies, a drop jump test has been used to determine reactive strength, increasing eccentric loading and utilising the stretch-shortening
cycle (Young et al., 2002). The current study however maintained sport specificity by initiating the test from a ground start. In addition agility tests, which found significant links with reactive strength in this study, did not contain a perceptual component which could subsequently have affected the statistical analysis.

The present study found correlations between 30m sprint times, between the 10m and 40m sprint gates, and the remaining agility variables. Total sprint time was also found to be statistically related to total agility time and the acceleration to the first agility timing gate. There are a number of possible reasons that correlations occurred between these variables and not with the specific agility cutting movement. One of the reasons could be that the remaining agility variables take into account a straight speed component from the acceleration to the first timing gate. This added component of straight speed acceleration is more similar to the running technique of the repeated sprint test and as such may have contributed to the correlations found. In addition, the cutting movement from the second set of timing gates to the third and final gates had no reactive component. The participants therefore would be able to plan their movement to cut back and sprint to finish. The cutting movement from the second timing gate to the final gate can consequently be said to be more like sprinting as it is a predicted acceleration as opposed to the reactive change of direction of agility.

This study found links between strength and the total agility time, time to the first agility timing gate and time to the first agility timing gate. However these links were not found to be significant. Sheppard and Young (2006) explained this relationship by contesting that strength measures have links with changes of
direction over short distances, due to the eccentric loading of the muscles. Furthermore, Young et al. (2002) suggested that leg strength and particularly reactive strength can be linked with changes of direction due to the similarity in the push off mechanism used to change direction. These studies however, did not involve a perceptual factor within their agility test which may have caused the results of the current study to display lower correlation values. Craig et al. (2004) suggest that if an athlete can anticipate the next move, they are able to recruit muscles more easily. Therefore if a perceptual factor is added, the central nervous system has less time to react and as such, fewer motor units may be recruited. If fewer motor units were recruited, it could explain the non-significant correlation values found, as the maximum strength of the participants would not be able to be utilised. Craig et al. (2004) stated that an athlete who is able to recognise cues from the opposition and react to them in advance of the movement will be able to recruit more muscle fibers and as such produce a quicker and more powerful change of direction.

Unsurprisingly, a link between 10m sprint and 5m agility time was found, although it was statistically non-significant. Cissik et al. (2004) suggests that acceleration is when an athlete increases their velocity and stride length. Both 10m sprint time and 5m agility time are therefore measures of acceleration and the consequent link between the two is obvious. Even though the two variables are both measuring the acceleration of the participants’, they are not statistically significant which may be expected. A cause of this could be the reactive start of the agility protocol and that reaction time’s differed between participants. Alternatively, some of the subjects may have felt they needed more time to react to and perform the agility movement and consequently slowed before they reached the first timing gate.
From observing the results it is evident that the time to the first timing gate and the time to the final timing gate have higher correlations than the time to the second timing gate. The exact reasons for this are unclear, however, suggestions can be derived from previous literature to help explain this phenomenon. Although the time to the second timing gate takes into account the initial acceleration, which is linked with straight line speed, it also includes the reactive change of direction. As discussed, reactive change of direction is not correlated with any of the measured physiological variables and therefore could explain the absence of a link with the time to the first timing gate. As a result, the correlations performed on the time to the second timing gate displayed lower $r$ values than that of the initial acceleration to the first timing gate or the total time. Young et al. (2001b) performed tests with varying cutting degrees, including a straight sprint. The findings of this study suggest that the greater the cutting angle, the slower the movement and the less it can link with straight line speed. The lack of a cutting movement in the initial acceleration therefore can help explain why it produced higher correlations than the time to the second timing gates. Additionally, the time to the first timing gate was more highly correlated than the total time. This may have been due to the affect of the reactive agility component within the total time. Farrow et al. (2005) stated that the reactive element of agility is the crucial factor which makes it unique from other physiological components and provides a true indication of agility performance. The initial acceleration to the first timing gate was the only variable without a reactive cutting element which may explain why it displays the highest correlations.
It was hypothesised that power would have the highest correlations with repeated agility and that repeated sprint would have the lowest. The results however show that with the exception of reactive strength index, the power variables calculated by the force matt displayed no statistical relationship with any of the agility data. This result is in contrast with the study of Young et al. (2002) who suggested there may be a link between power and agility. Furthermore, Sheppard and Young (2006) suggest that although straight line speed and agility are two distinct variables, independent of each other, power may have an influence on change of direction speed. It is interesting therefore that stronger correlations were found between agility and speed variables as opposed to agility and power. Due to the lack of physiological data, the underlying mechanisms for these findings are unclear. However, this could be a result of the participants involved having exceptional agility or because the investigation did not adequately test power in relation to agility. The link between the sprint and agility data could be due to the repeated nature of both elements. As repeated agility is a unique variable which has no prior testing, the previous research combining sprints and agility would not have included this data. It is possible that the physiological can metabolic mechanisms that facilitate repeated sprints also facilitate repeated agility and may be the cause of the link between the data.

When all the correlations are assessed together an overall trend can be observed. The correlations performed on the reactive cutting movement between timing gate 1 and 2 found no statistical links at all, however, the other agility variables found significant correlations. The implications of these findings are that although, speed, power and strength variables do not significantly influence the
specific reactive cutting motion of agility, it influences the acceleration into and out of the agility motion. This means that an athlete who is looking to improve agility will need to concentrate specifically on whole body changes of direction in response to a stimulus. Farrow et al. (2005) agree with this statement, stating that a key finding from their research was that reactional changes of direction were the only true reflection of an athlete’s agility performance. Concentration on agility however should not be at the expense of other performance variables such as straight line speed or power, which have shown a significant influence to the overall agility movement. This view is supported by Young et al. (2002) who stated that a holistic approach to agility and performance development that would include all the muscle strength qualities, technique and perceptual factors should be fruitful. As a result, specific agility training has its part to play in a training programme aiming to improve, all areas of performance. Yet in order to experience significant gains agility must be broken down to its component parts rather than being used within straight line speed or power work. Young et al. (2001b) concur, concluding that particularly speed and agility are separate components, and that methods to train both should be incorporated into a training programme according to the specific demands of each sport.

5.1 Practical Applications

The implications from the current study suggest that the performance of agility and repeated agility are distinct performance variables, separate from outside influence. The unique combination of physical and neural components which make up agility mean it is different from other physiological components. That is not to say that factors such as power, strength or speed have no influence on agility performance,
rather that the neural components of agility have not previously been accounted for and must be in the future. Craig (2004) suggested that neural adaptations are required to improve agility performance, therefore significant time must be spend concentrating on this. This author added that the biggest problem with current training is that the athlete is able to predict the next move, decreasing the coordination between the central nervous system and proprioceptive feedback which improves agility performance. Practically, this information could be of use to a conditioning coach who is attempting to improve the agility performance of their players. The results suggest that the improvement of agility performance should take the form of specific agility movements involving a whole body change of direction in response to a stimulus. The stimulus response in particular is a crucial aspect of training as the decision making and reaction time capabilities of an athlete significantly influence agility performance. Sheppard and Young (2006) concur, stating that highly specific training which also includes cognitive challenges and perceptual factors is necessary. Additionally, Young and Farrow (2006) contest that activities which make the athlete pay attention to the specific movement kinematics of an opponent can help them to recognise cues. Recognising cues can allow an athlete to react quicker and training this can develop a greater link with the correct response, decreasing an athlete’s reaction time. The results further suggest that attempting to improve agility performance by improving straight line speed, power or strength would not produce significant benefits. The author however suggests that a training regime that looked to combine specific agility movements in conjunction with the performance of speed, strength and power work would offer the greatest benefits.
5.2 Limitations

There are limitations associated with the current study which affect the results of the study and the conclusions that can be made. The lack of physiological variables taken during the testing means that only performance data could be collected and assessed. As a result, the underlying mechanisms explaining the results can only be speculated on and definitive conclusions cannot be made. The time delay start of the agility test meant that the rest period for the athletes was not standardised, with a possible 4 second difference from one test to another. As a result, the repeated agility data may have been affected, however, the time delay did produce a reactive start which was deemed an important, sport specific element. Comparisons between the repeated agility protocol and repeated sprint protocol may have errors associated due to the recovery period. Although the time taken to complete the protocols were comparable, the distance the participants needed to cover during the repeated sprint protocol was significantly further than that of the repeated agility test. As a result, the average speed, and therefore effort, necessary to recover to the starting position for the repeated sprint test was higher. The increased effort in recovery may have affected subsequent sprints more adversely than in the repeated agility protocol, resulting in a greater drop off in performance. Limitations of the strength test are that technique may have affected the maximum weight lifted, whereas a mechanical device such as a dynamometer would be able to give more exact values of strength. The movements used during a squat however more accurately compare with the actions carried out during sport and as such, this was deemed an acceptable limitation.
5.3 Implications for Future research

The author suggests that future research into agility and repeated agility should concentrate on taking more physiological variables, such as electromyography of the muscles. Data collected could provide information about the recruitment patterns of the muscles. Once physiological data had been collected it could be collated with the performance data previously collected and with physiological data from other tests, such as power or straight line speed tests. This collated data could inform sports scientists about what influences agility, allowing training to concentrate on this area and permitting training to mimic the muscle recruitment patterns of agility. In addition, significant research is required to assess the decision making abilities and reaction time associated with agility performance. Unless extensive research is undertaken into these two areas, it is the author’s view that agility performance will not be fully understood.

5.4 Conclusion

In conclusion, the present findings indicate that strength, speed and power have no affect on repeated agility performance. The correlations performed on the reactive cutting action which embodies agility displayed no significant links with any other variables. Other agility measures however demonstrated statistical links with some of the speed and power data, with some high but non-significant correlations found with the strength data. These findings suggest that although the reactive cutting action may be an independent value, the acceleration into and out of the agility movement may be affected by other performance variables. As such, speed, power and strength variables should not be ignored within agility performance but specific changes of direction in response to a cue should be more prevalent in agility training.
This is in accordance with the research by Sheppard and Young (2006) and Farrow et al. (2005) who suggest that agility training must involve highly specific changes of direction which reflect the demands of the sport. Discrepancies with the findings of previous research are mainly due to differences in experimental protocols, with many studies ignoring the perceptual component of agility within their testing procedures. Additionally, previous studies have used varying tests of power, strength and speed which makes comparisons difficult to make. However, it should be emphasised that this investigation was unique in its experimental procedure, as the repeated nature of agility within team sports has not been previously studied. In order to verify the findings of the present study, additional research should aim to take physiological variables such as electromyography or muscle biopsy, to fully understand the underlying mechanisms of repeated agility performance.


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APPENDIX A
Physical Activity Readiness Questionnaire (PAR-Q)

Please circle the answers to the following questions:

1. Has your doctor ever said you have heart condition and that you should only do physical activity recommended by a doctor?  Yes / No

2. Do you feel pains in the chest when you do physical activity?  Yes / No

3. In the past month have you had chest pain when you were not doing physical activity?  Yes / No

4. Do you lose your balance because of dizziness or do you ever lose consciousness?  Yes / No

5. Do you have a bone or joint problem that could be made worse by physical activity, jumping actions or cutting actions?  Yes / No

6. Is your doctor currently prescribing drugs for blood pressure or a heart condition?  Yes / No

7. Do you know of any other reason why you should not do physical activity?  Yes / No

If you have answered yes to any of these questions, please add details below. Similarly, if there are any situations which will prevent you from exercising write them here.

Signed………………………………………………….

Date…………………………………………………….

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APPENDIX B
Informed Consent

I am an undergraduate student at the University of Wales Cardiff undertaking research for my dissertation in the area of physiology. The title of my study is “Physiological Correlations of Repeat Agility Activity”. The study is designed to test anaerobic physiological components against repeated agility. This may interest you as it has applications within a number of games sports, such as rugby union.

As a participant, you will be required to take part in a repeated sprint test, repeated agility test, a vertical jump test and a 1RM squat test. These tests are designed to test your anaerobic system and as such you may become fatigued. If you have any concerns, the study administrator will answer any questions you have prior to and during testing.

Any personal data collected for the purposes of testing will be kept confidential and the study administrators are the only people with access to this data.

Participant:

I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

I understand the risk involved, that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.

I understand that relevant sections of any of research notes and data collected during the study may be looked at by the study administrators. I give permission for these individuals to have access to my records.

I agree to take part in the study of Mr D. Fulling.

Signature of Participant : …………………………………………………………

Date : …………………………….