SPORT-SPECIFIC VIDEO-BASED REACTIVE AGILITY TRAINING IN RUGBY UNION PLAYERS

BY

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DECLARATION

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SUMMARY

In rugby union the players are constantly faced with a changing environment and successful play requires the players to correctly interpret and respond to these changing situations. Reactive agility (RA) is an open and complex motor skill that has the ability to distinguish between higher and lesser skilled athletes. Evasive RA manoeuvres are most likely to lead to successful tackle breaks and advancing beyond the advantage line.

The current study investigated the effectiveness of a sport-specific video-based RA training program for rugby union players. The video-based training (VT) was compared to field-based training (FT) to determine if it could be a possible alternative method in RA conditioning.

Twenty six male rugby union players (aged 18 to 24 years) volunteered to participate in the study. They were divided into forwards and backs and then randomly divided into VT (n = 10), FT (n =9) or control (C) (n =7). Players in VT and FT completed a six week intervention program of two sessions per week. All the players were tested pre and post intervention and six weeks after the completion of the intervention. The tests included anthropometrical measurements (height, body mass, % BF, % LBM), sprint speed, change of direction speed (CODS), RA, anaerobic capacity (repeated sprint) and aerobic endurance (multistage shuttle run).

The results showed that sprint speed was not influenced by any of the training interventions ($p > 0.05$). VT resulted in improvements in CODS and VT performed significantly better than FT ($p < 0.05$). However, these improvements were not maintained after the intervention period. RA improved significantly in both VT and FT groups ($p < 0.05$). The improvement in RA was also significantly better than the changes in C ($p < 0.05$). The training effect was possibly more beneficial in FT than VT to improve RA (3.0 $\pm$ 4.4%). Following the retention

period VT and FT only dropped their RA performance slightly (0.8 ± 7.7% and 1.2 ± 4.6%, respectively), with no clear benefit or disadvantage for any of the training groups.

Both VT and FT produced significant improvements in RA performance of intermediate rugby union players, and these changes were significantly greater than with rugby training alone (C). Therefore, VT is an effective alternative conditioning method or add-on to improve RA in rugby union.

OPSOMMING

In rugby unie word spelers voortdurend uitgedaag met veranderinge in die omgewing en suksesvolle spel vereis dat die spelers die veranderende situasies korrek interpreteer en daarop reageer. Reaktiewe ratsheid (RA) is 'n oop en komplekse motoriese vaardigheid wat die vermoë het om te onderskei tussen atlete met verskillende vlakke van vaardigheid. Ontwykende RA maneuvres dra die meeste by tot die vermoë van spelers om tot oor die voordeel lyn te vorder.

Die huidige studie ondersoek die effektiwiteit van 'n sport spesifieke video-gebaseerde RA oefenprogram vir rugby unie spelers. Die video-gebaseerde oefenprogram (VT) is vergelyk met 'n veld gebaseerde oefenprogram (FT) om te bepaal of dit 'n moontlike alternatiewe kondisioneringsmetode vir RA kan wees.

Sewe en twintig manlike rugby unie spelers (ouderdom 18 tot 24 jaar) het vrywillig aan die studie deelgeneem. Die groep is eers verdeel tussen voorspelers en agterspelers en daarna ewekansig toegedeel in drie groepe, naamlik VT (n = 10), FT (n = 9) en kontrole (C) (n = 7). Die spelers in die VT en FT groepe het 'n ses weke intervensieprogram van twee sessies per week gevolg. Al die spelers is voor en na die intervensie, asook ses weke na voltooing van die intervensie getoets. Toetsing het die volgende ingesluit; antropometriese metings (lengte, liggaamsmassa, % liggaamsvet, % vet vrye massa), spoed, spoed van rigting verandering (CODS), RA, anaërobiese kapasiteit ("repeated sprint") en aërobiese uithouvermoë ("multistage shuttle run").

Die resultate het getoon dat spoed nie beïnvloed is deur enige van die intervensie programme nie ($p > 0.05$). CODS het verbeter in VT en die verbetering was beduidend beter

as dié van FT ($p < 0.05$). Die verbeteringe het egter nie hierna behoue gebly na ‘n verdere ses weke nie. RA het statisties beduidend verbeter in beide VT en FT groepe ($p < 0.05$). Die verbeteringe in RA was ook beduidend beter as die veranderinge waargeneem in C ($p < 0.05$). FT is moontlik beter as VT om RA te verbeter (3.0 $\pm$ 4.4%). RA in VT en FT het minimaal verander in die ses weke na die intervensie voltooi is (0.8 $\pm$ 7.7% and 1.2 $\pm$ 4.6%, onderskeidelik), met geen duidelike voordeel of nadeel vir enige van die intervensie groepe nie.

VT and FT het beide die RA prestasie van intermediêre rugby unie spelers beduidend verbeter, en die verbeteringe was beduidend meer as wat waargeneem is met rugbyoefening (C) alleen. Die afleiding kan dus gemaak word dat VT ‘n effektiewe alternatiewe kondisioneringsmetode, of byvoeging tot ‘n program is om RA in rugby unie te verbeter.

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"Between stimulus and response there is a space. In that space is our power to choose our response. In our response lie our growth and freedom." - Viktor E. Frankl

LIST OF ABBREVIATIONS AND ACRONYMS

Δ	:	Change
^{0}	:	Degrees
$^0.s^{-1}$	:	Degrees per second
µA	:	Micro ampere
%	:	Percentage
% BF	:	Percentage body fat
% LBM	:	Percentage lean body mass
3 - Cone	:	Three-cone drill test
AIS	:	Australian Institute of Sport
ATP-PC	:	Adenosine triphosphate phosphocreatine
beats.min^{-1}	:	beats per minute
BIA	:	Bio-electrical impedance analysis
BW	:	Backward locomotion
C	:	Control
cm	:	Centimeter
cm/s	:	Centimeter per second
CMJ	:	Countermovement jump
COD	:	Change of direction
CODS	:	Change of direction speed
CT	:	Tennis-specific plyometric programme
DJ	:	Drop jump
EL	:	Explicit learning
EMG	:	Electromyography

ES	:	Effect size
FT	:	Field training
FW	:	Forward locomotion
i.e.	:	For example
IL	:	Implicit learning
ILC	:	Implicit learning control
kg	:	Kilogram
kHz	:	kilohertz
L	:	Left
LED	:	Light-emitting diode
m	:	meter
M1	:	Primary motor cortex
MEP	:	motor evoked potentials
$ml.min^{-1}.kg^{-1}$	:	milliliters per minute per kilogram body weight
$mmol.l^{-1}$	:	millimol per litre
ms	:	millisecond
n	:	sample size
N-SC	:	Non-stressed control
p	:	Probability
PC	:	Programmed conditioning
PMT	:	Pre-motor time
PT	:	Plyometric training
r	:	Pearson correlation
R	:	Right
RA	:	Reactive agility

RAT	:	Reactive agility test
RC	:	Random conditioning
RCT	:	Reactivity coefficient
RIDS	:	Randomized intermittent dynamic and skilled movement type Sport
RS	:	Repeated sprint
s	:	Second
SAQ	:	Speed, agility, quickness
SC	:	Stressed control
SD	:	Standard deviation
ShuttleSDT	:	Sport-specific shuttle sprint and dribble test
SlalomSDT	:	Sport-specific slalom sprint and dribble test
Sprint90	:	20 meter sprint with three 90 degree changes of direction
Sprint90 bounce	:	20 meter sprint with three 90 degree changes of direction while carrying a ball and performing two bounces
SSC	:	Stretch shortening cycle
SWC	:	Smallest worthwhile change
t1/2/3/4/5	:	time period of occluded video clip 1 - 5
TLD	:	tennis-specific lateral program
TMS	:	Transcranial magnetic stimulation
VIS	:	Victorian Institute of Sport
VMRT	:	Visuo-motor related time
VO_{2max}	:	Maximal aerobic capacity
vs.	:	versus
VT	:	Video training

LIST OF KEY TERMINOLOGY

Anticipation	:	The ability to predict what will occur when preparing to perform skill or tactic.
Decision-making	:	The thought process of selecting a logical choice from the available options.
Elite	:	Someone who competes on a provincial, national or international level in a particular sport.
Experienced	:	Have skill or knowledge in a particular field gained over a period of time.
Expert	:	Having or showing great skill and competing at a high level.
Game sense	:	The ability to use understanding of the rules, or strategies; of tactics and most importantly of oneself to solve the problems posed by the game or by one's opponents.
Intermediate	:	Some degree of specialization in the sport and a high level of performance at a recreational level.
Novice	:	New or inexperienced in a field or activity, a beginner.
Pattern recognition	:	The ability to identify objects, movements and running lines.
Perceptual skills	:	Perception is a series of processes in which you gather information from the environment around you as well as from within your own body in order to understand the situation in which you find yourself
Visual scanning	:	The process by which the individual actively, selectively and sequentially acquires information from the visual environment by successive eye movements.
Visual search	:	A type of perceptual task requiring attention that typically involves an active scan of the visual environment for a particular object
Visual tracking	:	The ability of the eyes to follow the movement of an object in motion.

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CHAPTER ONE

INTRODUCTION

Rugby union is a sport with many different facets. It is classified as an invasive type sport and also described as a collision sport. Rugby union contains frequent bouts of high intensity activity (Duthie *et al*., 2003; Hughes and Bartlett, 2002). A rugby pitch is 100m long between try-lines and 70m wide between touchlines. A rugby union game typically lasts 80 minutes, which is divided into two 40 minute halves. Notational analysis revealed that of the total game time the ball is only in play for approximately 30 minutes (Eaves *et al*., 2005; Williams *et al*., 2005; McLean, 1992). A team consists of 15 players: eight forwards and seven backs.

Rugby union is all about possession. For example, the attacking team obtains possession through a line-out or scrum, or turn over ball when the opposition makes a mistake. The ultimate aim of the game is to score more points than the opposition. It is therefore very important for players to be able to advance beyond the advantage line and defend effectively. Pool (2006) named rhythm, handling, communication, correct positioning, playing under pressure, vision and decision-making as the key components for superior attacking ability. Some of these components will be developed when training reactive agility (RA), especially if training stays true to the game. Sport-specific RA training may develop the players' ability to see the gaps in the defense and travel across the advantage line, and improve their ability to recognize advance kinematic cues that would enhance their defensive abilities.

In a competitive match there is a fair amount of unpredictability in the multiple interactions between team-mates and their opponents. Therefore, players constantly need to react to the changing environment and it is expected that those reactions are quick and effective. In rugby union a change of direction occurs to advance beyond the opponents' defence line when attacking, to pursue and place pressure on opponents when defending, or to react to a moving ball. It has been suggested that these responses to the various stimuli are a component of agility (Sheppard and Young, 2006; Chelladurai, 1976).

Duthie *et al*. (2006) analyzed 17 rugby union players of an elite Australian rugby team during actual games and found that 16% of the total sprints analyzed involved a change of direction (COD). There was a significant difference in the number of sprints with a COD for forwards (15%) and for backs (22%) ($p < 0.05$). Sayers and Washington-King (2005) analyzed 48 games in the 2003 Super 12 rugby season, which included 90 players representing six different teams. They found that the most effective way to advance beyond the advantage line is through evasive movement patterns. It was shown that players who received the ball at high speeds and who used evasive side-stepping manoeuvres were more likely to be successful at tackle breaks and advancing beyond the advantage line, furthermore, these plays also lead to positive phase outcomes, i.e. scoring a try. They concluded that maintaining forward momentum, effective running and evasive agility patterns are crucial for effective ball carries. Wheeler *et al*. (2010) found through notational analysis that 37% of the ball carries involved side-stepping manoevres and 5% involved crossover stepping. 72% of successful tackle breaks were due to evasive side-stepping manoevres, thus, finding similar results than Sayers and Washington-King (2005). Wheeler *et al*. (2010) found that team success strongly relates to tackle breaks and that the most effective tackle breaks in rugby union involve evasive side-stepping manoeuvres with 20 - 60^0 changes in direction.

Agility is an open and complex skill, that involves movement in multiple directions and varying velocities (Draper and Lancaster, 1985; Baley, 1977). Agility is defined as many skills including the ability to rapidly change direction, explosively start, and stop, decelerate, change direction and accelerate again, while maintaining dynamic balance (Young and Farrow, 2006; Little and Williams, 2005; Baechle and Earle, 2000; Chelladurai, 1976). Agility performance is, however, initiated by a certain stimulus and therefore, influenced by perceptual and decision-making skills. Thus, agility is also defined as a rapid whole-body change of direction in reaction to a stimulus (Sheppard and Young. 2006).

Agility, especially RA may be the determining factor to ensure success in sport (Graham, 2005). It has been shown that RA has the ability to separate higher-skilled from lesser-skilled athletes (Young and Wiley, 2010; Gabbett and Benton, 2009; Farrow *et al*., 2005; Helsen and Pauwels, 1993). RA's ability to do this is particularly due to improved perceptual and decision-making ability, i.e. the higher-skilled athletes' ability to read, interpret and produce the appropriate responses to sport-specific situations (Gabbett and Benton, 2009; Sheppard *et al*., 2006).

Players in rugby union who possess good perceptual and decision-making skills together with effective RA skills will be able to prevent opponents from penetrating the advantage line and outmanoeuvre their opponents when on attack. The ability to react to situations presented during match-play and then make the correct decision are indeed trainable (Serpell *et al*., 2011; Abernethy *et al*., 1999).

Many different training methods exist to improve agility, however, most focus solely on developing planned agility without considering the perceptual aspects of agility performance. Some of the methods that do incorporate the perceptual and decision-making components linked to RA include game-based conditioning and video-based training (Serpell *et al*., 2011; Gabbett, 2008a; Reily and White, 2004; Turner and Martinek, 1999). These methods focus on developing RA performance in a sport-specific context to ensure the best transfer to match-play situations. RA training seeks to improve the athlete's ability to pick-up advanced visual cues, to improve their anticipation and decision-making accuracy, as well as COD movement time, to produce overall faster responses and ensure the players are able to make the proper movement adjustments in the shortest possible time.

Video-based training was developed so that training could occur in a sport-specific manner. It is believed that more learning would take place, and that there would be greater transfer when training resembles the specific sport. In rugby union, for instance, the environment is constantly changing and it requires the players to quickly and effectively react to the unpredictable stimulus. Players would; therefore greatly benefit from sport-specific training. Video-based training is mostly used to develop visual skills and perceptual and decision-making ability. It has been shown that video-based training is a sufficient method to improve anticipation and decision-making ability (Serpell *et al*., 2011; Farrow *et al*., 1998; Helsen and Pauwels, 1993). Players are able to develop their perceptual ability when participating in video-based training, and are able to recognize visual cues through video footage (Jackson *et al*., 2006; Farrow and Abernethey, 2002). Video-based training has also been shown to improve RA in rugby league players (Serpell *et al*., 2011). This may therefore be an effective method to develop RA in a sport-specific manner, help players to better predict opponents' moves and teach players to make the correct decisions in terms of their reactions to the changing environment in rugby union.

CHAPTER TWO

REACTIVE AGILITY

A. INTRODUCTION

Agility is a complex skill that involves the ability to rapidly change whole-body movements in multiple directions and at different velocities (Sheppard and Young, 2006; Baley, 1977*).* Agility also requires a combination of interacting mechanisms that comprise physiological capacities, biomechanical abilities and perceptual skills (Young *et al*., 2001; Young *et al*., 1996). In team field sports, rapid changes of direction occur more frequently than straight line running, thus agility is a crucial component for success (Sayers, 1999). For instance, rugby union is an invasive style team sport where players need to evade opponents during attack, place pressure on others during defense or react to the unpredictable bounce of the ball, whilst also performing repeated bouts of high-intensity activity (Duthie *et al.*, 2003; Hughes and Bartlett, 2002). High levels of success in rugby union are thus dependent on a player's ability to outmanoeuvre opponents through the use of agility skills. It can; therefore be concluded that agility is an essential skill for rugby union players.

B. DEFINITIONS

Agility is defined in many ways, of which the most common and basic definition is that it describes the ability to rapidly change direction (Sheppard and Young, 2006; Chelladurai, 1976). To accurately change direction was later included in this definition (Barrow and McGee, 1971) and it was even further refined when Draper and Lancaster (1985) referred to rapid whole-body change of direction and the rapid change of directions of the limbs.

Baechle and Earle (2000) defined agility as the ability to stop explosively, change direction, and then accelerate into a new direction. To start and stop quickly is another common definition (Young and Farrow, 2006; Little and Williams, 2005; Gambetta, 1996). When compared to straight sprinting, agility places a greater emphasis on deceleration and the ability to reactively accelerate (Beachle and Earle, 2000). Being a multiple-directional skill, agility performance relies heavily on the manipulation of velocity. These definitions may, however, be confused with the term quickness. Quickness is described as a multi-plantar skill that includes acceleration, explosiveness and reactive abilities (Moreno, 1995). Quickness does not, however, include changing direction or deceleration.

Chelladurai (1976) noted all the different existing definitions for agility and concluded that they did not recognize perceptual and decision-making factors inherent in agility performance. He proposed that the specific agility requirement for a certain activity is dependent on the stimulus with which the individual is presented and thus outlined a generalized agility classification system based on differing movement patterns and environmental components (*Table 2.1*). In this classification, temporal variations represent changes in the timing in which a stimulus is presented and which would initiate a preplanned movement pattern, while the spatial variation represents changes in the environment that controls the type of movement pattern required. Using this classification system it is clear that agility in rugby union is a complex skill, as it involves many temporal and spatial uncertainties. These uncertainties lead to unrehearsed responses, which implies that agility performance in rugby union is also an open skill. Simple agility, on the other hand, is a closed skill that involves limited amount of uncertainty and automated responses.

Table 2.1. Classifications of agility (adapted from Chelladurai, 1976).

Agility Classification	Definition	Example
Simple	No temporal or spatial uncertainty	High jumping: pre-planned activity in known environment
Complex		
• Temporal	Temporal uncertainty, spatial confidence	Swimming sprint start: pre-planned activity in response to a stimulus, uncertain when stimulus will occur.
• Spatial	Spatial uncertainty, temporal confidence	Tennis serve: know when to move, but uncertainty exists about the direction.
• Universal	Temporal and spatial uncertainty	Rugby union: players do not know with 100% certainty when and where opposing players will move to.

The agility classification system of Chelladurai (1976) thus considers the change of direction as well as the perceptual and decision-making factors of agility performance, since agility is often in response to a stimulus such as an opponent's actions (Sheppard and Young, 2006; Young *et al*., 2002). To this end, Sheppard and Young (2006) constructed a new definition of agility, namely "a rapid whole-body movement with change of velocity or direction in response to a stimulus."

Young *et al*. (2002) divided agility into planned agility, also termed change of direction speed (CODS), and reactive agility. Planned agility is used to describe an automated movement pattern where at least one change of direction occurs. When the movement pattern is unknown and determined by a reaction to an external stimulus it's defined as reactive agility (Gabbett *et al*., 2008c; Young *et al*., 2002). Reactive agility is; therefore influenced by an athlete's decision-making ability.

According to Young *et al.* (2002) the perceptual and decision making factors distinguishes reactive agility from CODS, mainly due to the lack of a reaction to an external stimulus in a planned agility movement. It has been shown that having to react to a stimulus, such as having to pursue an opponent on the field, affects the way the agility skill is performed and; therefore perceptual skills play a role in agility performance (Wheeler and Sayers, 2010; Chelladurai, 1976). On the other hand, Wheeler (2009) contends that CODS and reactive agility should not be seen as two separate skills but rather as separate components that classify agility. Thus, the requirement of agility is changed by decision-making, but should not be re-classified as a skill on its own.

The most common definition of agility, i.e. the ability to rapidly change direction, has been termed as CODS or planned agility (Gabbett *et al.*, 2008c; Sheppard and Young, 2006; Farrow *et al*., 2005; Draper *et al.*, 1985). Planned agility will be classified as a closed skill as the exact movement pattern is known, whereas a rapid change of direction in response to a stimulus has been redefined as reactive agility and referred to as an open skill (Young *et al*., 2002).

Agility performance is also influenced by environmental factors and consists of various movement patterns. Wheeler (2009) contends that definitions for agility should consider these factors and be specific for a sport. Since rugby union requires running-based agility with lateral movement patterns, Wheeler (2009) proposed a sport-specific definition for rugby union, namely "a rapid multi-directional movement involving predominant lateral side-stepping manoeuvres observed during running based locomotion patterns".

It can thus be concluded that agility is influenced by many factors, including perceptual, environmental and decision-making skills (Sheppard and Young, 2006; Young *et al*., 2002).

This is probably the reason for the lack of a single, universally accepted definition. An all-inclusive definition would also need to incorporate the physical demands, cognitive processes and technical skills involved in the specific activity and should; therefore be sport-specific. Fact is, the manner in which agility is defined determines how this performance parameter is measured and evaluated in different sports, as well as the manner in which proper training methods is constructed in an effort to improve agility performance for a specific sport.

In this study agility is defined as CODS for planned agility where no stimulus is present and the movement pattern is known. The term reactive agility (RA) is used to describe agility where perceptual factors will influence the performance.

C. FACTORS THAT INFLUENCE AGILITY

Young *et al.* (2002) proposed a model of the potential factors that may influence agility and which should be included when measuring agility skill execution (*Figure 2.1*). The pivotal components that determine agility performance have been identified as the functional capacities related to speed and cognitive skills. This model of Young *et al*. (2002) was later modified by Sheppard and Young (2006) who added anthropometry as a factor that may affect agility (*Figure 2.2*). Both models, however, have CODS and perceptual skills as the key determinants of agility performance.

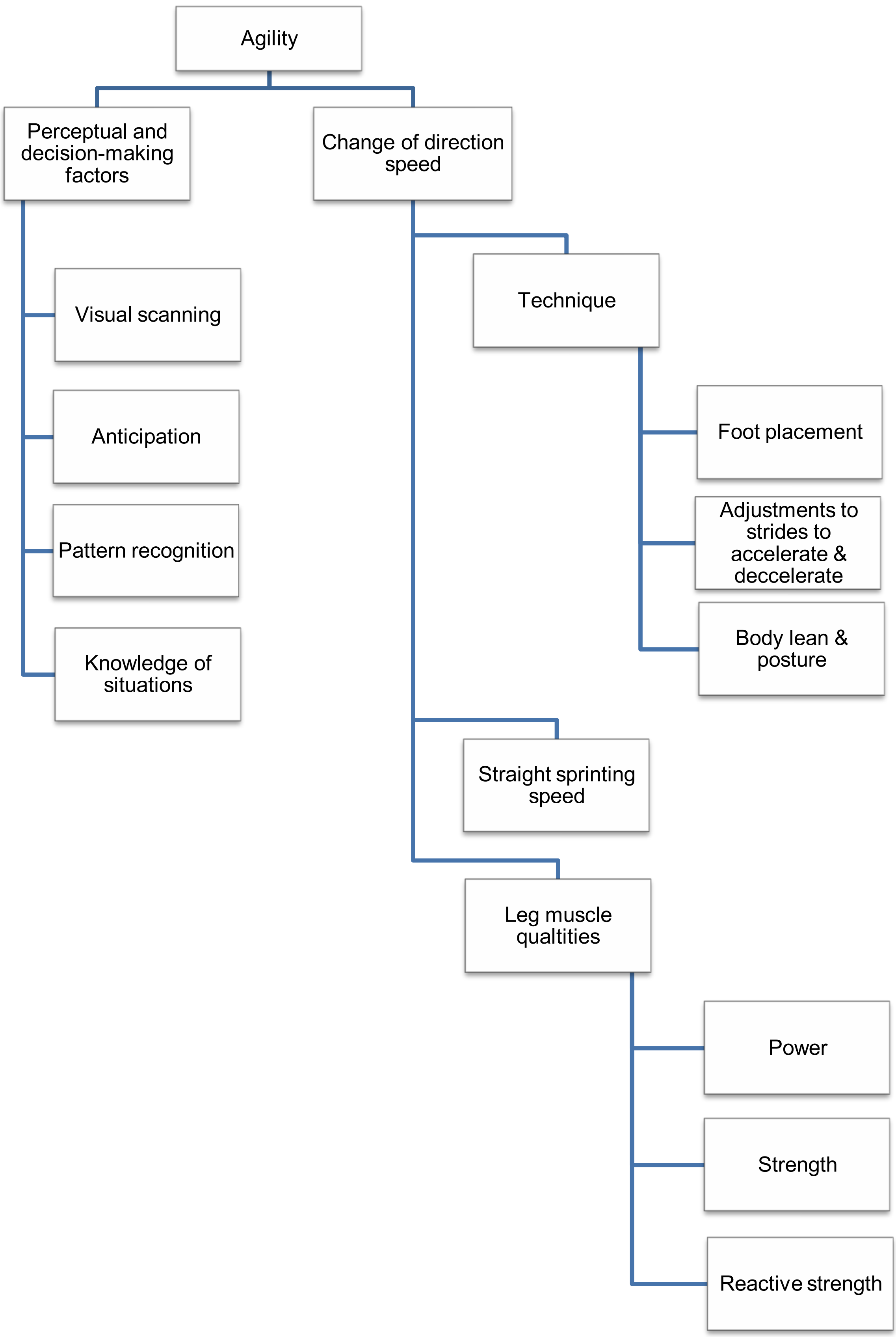

Figure 2.1. Model of components that affects agility performance (Adapted from Young *et al*., 2002).

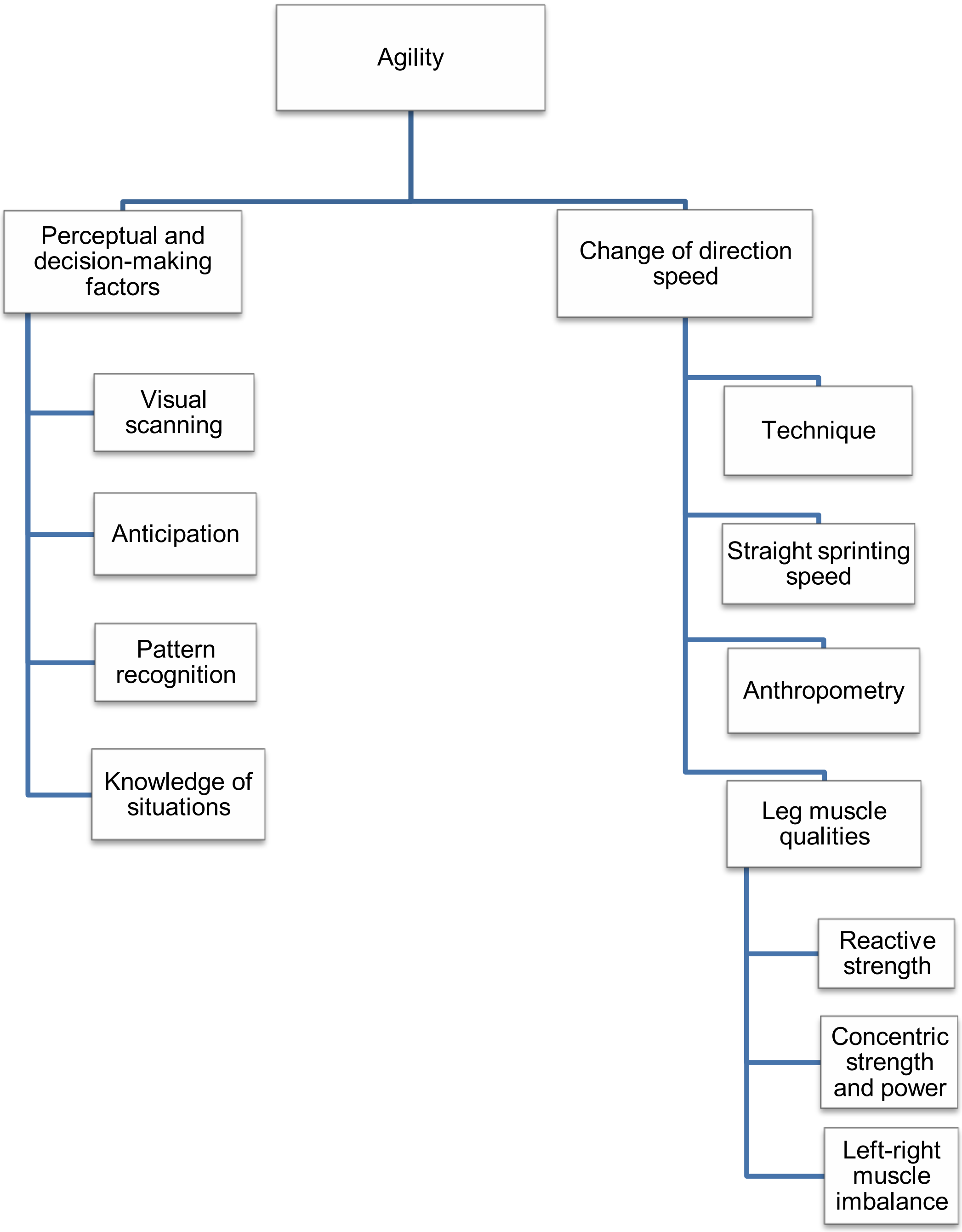

Figure 2.2. Model of agility performance (Adapted from Sheppard and Young, 2006)

To be able to evade an opponent, sprint and change direction, or to defend an opponent or react to a bouncing ball in rugby union, players need to make use of visual processing and decision-making. Thus, the two critical components that need to be present in agility testing are CODS and perceptual skill as the cognitive aspect. Farrow *et al*. (2005) also stated that the performer's physical capacity, as well as the ability to interpret and react to a stimulus, making at least one change of direction, needs to be evaluated in order to appropriately test agility performance.

1. Change of direction speed (CODS)

Many sports such as soccer, tennis, basketball and rugby union require athletes to recognize various sport situations and react suitably in order to be successful (Holmberg, 2009). The type of response and sporting conditions, however, differ for each sport. Rugby union has a field-based environment in which movement predominantly consists of running. Change of direction occurs to advance beyond the opponent's defense line during attack. Thus rugby union requires the ability to manipulate velocity in multiple directions and the execution of side-stepping manoeuvres. Side-stepping manoeuvres are mostly described as either side-stepping or crossover-stepping strategies. During side-stepping the movement is initiated by the outside leg, while with crossover stepping the lateral movement is produced by the inside leg.

Technique

Running technique in rugby union differs quite a bit from the running technique of sprinters, with the most obvious difference being the distances covered. The majority of running in rugby union occurs over less than 10 meters and players rarely sprint more than 30 meters (Benton, 2001; Sayers, 1999; Gambetta, 1996). Furthermore, running in rugby union also requires a different type of body lean and posture, different centre of gravity as well as foot placement.

Foot placement refers to the horizontal displacement of the foot relative to the centre of gravity. Generally, a shorter foot displacement distance (± 5cm) is ideal for sprinting due to the reduction in braking forces during foot strike. However, to perform rapid changes of direction a slightly longer foot displacement distance (heels ± 15cm forward) is required to enable the athlete to exert lateral forces against the ground and to increase balance (Sayers, 1999). An excessive foot displacement may result in a decrease in velocity during foot strike, but research have shown that it can be overcome if athletes drive their feet down and backwards during foot strike (Mann *et al*., 1984). On the other hand, for effective agility performance excessively long strides (≥ 20cm) should rather be avoided (Sayers, 1999). Therefore, to avoid excessive foot displacement, stride rate becomes an important factor in agility skill execution. In a multidirectional sport such as rugby union it is recommended that training programmes seek to improve stride rate in order to improve agility performance.

In contrast to the upright stance and high centre of gravity of sprinters, effective agility performance relies on a low centre of gravity (Francis, 1997). When athletes change direction at high speeds, they first have to decelerate and lower their centre of gravity. Athletes also need to maintain their balance while changing direction. Lowering the centre of gravity will assist in maintaining balance (Sayers, 1999). In sports where changes of direction recurs on a frequent basis athletes need to lower their centre of gravity, run with a greater forward lean and shorter stride lengths than track athletes (Peebles, 2009; Sheppard and Young, 2006).

When coaches train agility they should take into account that the movement patterns are not always planned as the athletes have to react to the given situation. The training need for acceleration is therefore greater as athletes have a shorter time to reach maximum speed (Duthie *et al*., 2006). It is also characteristic for athletes to produce a greater forward lean during acceleration.

Straight sprinting speed

As both agility performance and straight sprinting speed are related to the capacity of the performer's anaerobic energy system, it is wrongly assumed by many strength and conditioning coaches that agility and straight sprinting have a strong relationship (O'Conner, 1992; Baley, 1977). Although it is true that the anaerobic capacities utilized during straight sprint speed training often contains similarities to agility performance (Moore and Murphy, 2003), research on the relationship between straight sprinting speed and agility report limited transfer between the two skills (Little and Williams, 2005; Young *et al*., 2001; Young *et al*., 1996; Draper and Lancaster, 1985).

Little and Williams (2005) tested the straight sprint speed and agility performance of professional soccer players. Speed was measured over 20m and agility was measured using a 20m zigzag course containing four 100° changes of direction. A low to moderate, but statistically significant correlation (r = 0.46) between straight sprint speed and agility execution was reported. A similar correlation (r = 0.47) was found by Draper and Lancaster (1985) when they examined the relationship between the Illinois agility test and a 20m straight sprint. These results mean that less than 25% of agility performance can be explained by straight line sprinting. The relationship between straight sprint speed and agility was also investigated by Young *et al*. (1996) using Australian football players. They compared 20m straight sprint, 20m planned sprint with three 90° changes of direction (sprint 90) and 20m planned sprint with three 120° changes of direction (sprint 120). The correlation between the straight sprint and sprint 90 (r = 0.27) and for the straight sprint and sprint 120 (r = 0.19) was poor. A mere 7% common variance between straight sprint and sprint 90 was reported.

Young *et al*. (2001) found that after a six week training programme straight sprint speed did not improve CODS. The already limited transfer from straight speed to CODS, becomes even less with the addition of changes of direction. CODS also produced a non-significant improvement in straight sprinting speed.

The literature consistently reports a weak relationship between straight sprinting and agility performance. Thus, indicating that agility and straight sprinting speed are both unique and specific qualities and that training cause limited transfer between the two.

Leg muscle qualities

Power, strength and reactive strength are three leg muscle qualities that may potentially influence agility performance. Strength refers to the maximal force that can be exerted by a muscle group or groups during a single effort (Hoffman, 2006), while power is the rate at which work is performed and is commonly seen as the combination of muscular strength and speed. Reactive strength is the ability to quickly change from the eccentric to the concentric phase in the stretch shortening cycle (SSC). Some biomechanical studies suggest that muscle strength and power may influence agility performance, because most agility tasks requires a deceleration phase where leg extensor muscles work eccentrically and is immediately followed by a rapid acceleration phase where leg extensor muscles work concentrically (SSC) (Markovic, 2007).

Kovaleski *et al*. (2001) investigated the relationship between isokinetic muscle strength and agility performance (shuttle running) for open and closed kinetic chain movements. The correlation between isokinetic leg press and agility was reported as r = -0.49 and a weak to moderate correlation (r = -0.51) was reported for agility performance and isokinetic knee extension strength at a speed of $60^{o}.s^{-1}$. Negrete and Brophy (2000) conducted a similar study where they correlated various isokinetic strength tests with a complex agility task (diamond run). They reported a moderate, but statistically significant negative correlation (r = 0.60; $p < 0.05$) between single leg isokinetic squat strength and agility performance. But, when normalised to body weight they reported extremely weak correlations between isokinetic leg press (r = -0.11), single leg press (r = -0.12) and leg extension (r = -0.17) with agility performance.

The relationship between dynamic strength and agility performance was investigated by Young *et al*. (1996) in Australian Rules football players. Strength was measured through a countermovement jump loaded with 50% of their body weight. Agility was measured over a 20m distance with three 90^{o} changes of direction. A very low non-significant correlation of r = 0.01 was reported. As a measure of power Young *et al*. (1996) correlated an unloaded countermovement jump with the same agility task and found a weak negative correlation (r = -0.10). Power, however, seemed to be significantly correlated with a straight 20m sprint (r = -0.66).

Hilsendager *et al*. (1969) compared the effects of strength, speed and agility training programmes on the development of agility performance. The agility training group performed superior in the agility test. The speed training group obtained the highest scores in the 10s squat thrust, but the strength training group did not perform better than the agility training group in any of the agility tasks. Both the strength and speed training groups did however outperform the agility training group in the strength and endurance tests. From the results of this study it may be concluded that the best way to develop agility is through agility specific training programmes.

The study of Young *et al*. (2002) investigated if muscle power was related to change of direction speed. Concentric leg extension power was measured performing an isokinetic squat set at a speed of $40^{o}.s^{-1}$. Muscle power was tested bilaterally and unilaterally. Agility performance was measured over an 8m distance with changes of direction at 20^{o}, 40^{o} or 60^{o}. The correlations between bilateral power and agility performance were generally non-significant with the exception of a single 40^{o} change of direction to the right ($r = 0.54$; $p < 0.05$). The positive correlations in this investigation indicated that athletes that were more powerful had slower agility sprint times. Non-significant correlations were found between all the unilateral leg power and agility tests.

Markovic (2007) correlated six strength and power qualities with three different agility tests. Strength and power were responsible for 20% of the variance for the lateral stepping performance, 34% of the variance for the 20-yard shuttle run and explained 24% of the variance of the slalom run performance. Each of the three agility tests had the strongest relationship with the one-leg rising test. One-leg rising is a functional strength test where participants unilaterally exert muscle force in both eccentric and concentric conditions while maintaining balance. This may suggest that the one-leg rising test may be a more specific strength test to predict agility performance, although more research is needed to address this matter.

Young *et al*. (1996 and 2002) used the drop jump (DJ) test to determine reactive strength. Players were required to rebound for maximum height and minimum ground contact time from a drop off a 30cm box. Both studies determined the relationship between reactive strength and agility performance. Young *et al*. (1996) found a weak correlation (r = 0.30) between reactive strength and a 20m sprint with three 90^{o} changes of direction. The bilateral correlations between drop jump and agility performance of a single change of direction to the right was at 60^{o} (r = -0.35), 40^{o} (r = -0.53) and 20^{o} (r = -0.65). They concluded that the smaller the change of direction, the stronger the relationship between drop jump and agility performance (Young *et al*., 2002). When performing a side-step manoeuvre it would be assumed that the “outside leg” would have the biggest influence if muscle power was related to agility performance. It would; therefore be expected that a correlation with right leg muscle power would be stronger than the left leg when turning left, and vice versa. Young *et al*. (2002) did found that the right leg’s reactive strength correlated stronger when turning left (r = 0.46 - 0.71), but this was not true for the left leg when turning right (r = 0.29 - 0.45). The majority of the participants performed better in the change of direction test to the left and eight of the fifteen participants had a reactive strength imbalance where the right leg was 13 - 20% stronger than the left leg. This may suggest that leg power may only significantly influence agility when a muscle imbalance is present.

It can be concluded that muscle strength and power are relatively poor predictors of agility performance. Higher correlations exist between the muscle strength and power, and straight sprinting. It may be speculated that the good relationship between power and straight sprinting does not transfer to power and agility due to the more complex and multidirectional nature of agility.

Anthropometry

Limited research exist of the relationship between anthropometric variables and agility performance. When comparing two athletes with equal body mass one would expect the athlete with the higher percentage body fat to perform worse in the agility test, as a greater percentage lean mass would contribute to the speed requirements of agility performance.

One would also surmise that due to the increased percentage body fat and inertia the athlete would need to produce more force per unit of lean mass to initiate the desired change of direction (Sheppard and Young, 2006).

A few studies have revealed that athletes who perform better in agility tests tend to have a lower percentage body fat (% BF) (Gabbett, 2007; Meir *et al*., 2001; Gabbett, 2002). However, these studies did not draw direct correlations between agility performance and % BF. Webb and Lander (1983) found a weak relationship between % BF and the three-cone drill (r = 0.21). The exact relationship between % BF and agility performance is still unclear.

As mentioned previously, a lower centre of gravity is more beneficial for agility performance. Hence, height, relative limb lengths and the height of the centre of gravity may potentially influence agility performance. In addition, lunges are typically used to change direction in tennis and Cronin *et al*. (2003) found that limb length explains 85% of the variance in lunge performance. However, as far as can be established the relationship between limb length and agility performance have not yet been investigated.

2. Perceptual and decision-making skills

In many team sports agility performance is preceded by a given stimulus. Because players in team sports, such as rugby union, constantly need to react to the changing environment it is highly likely that perceptual and decision-making skills may influence agility performance. Elite athletes develop effective decision-making strategies due to match-play experience, which in turn reduce their reaction time as less information needs to be processed (Abernethy, 1991). According to the models of Young *et al*. (2002) and Sheppard and Young (2006) agility performance will be enhanced if the player has specific knowledge of the given situation, the ability to recognize pattern of play and to pick up advance visual cues.

Abernethy (1991) also stated that success in open skill sport is determined by effective decision-making strategies. This would; therefore also apply to rugby union.

Serpell *et al*. (2011) investigated if the perception and decision-making components of agility are indeed trainable. The participants were part of a rugby league team that participated in the under-20 national competition in Australia. The reactive agility training consisted of two training sessions per week for three weeks. The training sessions required participants to react to ten video clips. The training group significantly improved ($p < 0.05$) their reactive agility time, but not the control group. A significant difference was also seen in the mean perception and response time for the training group and not the control group. However, the post-intervention CODS did not differ significantly in both groups. It can thus be concluded from the study that perceptual and decision-making components can be trained.

Anticipation and decision-making

Young and Willey (2010) evaluated a new reactive agility test which was developed by Sheppard *et al*. (2006) to see how tester time and decision time influence the total time. The test requires the athlete to react to one of four possible scenarios presented by the tester, indicating a movement to the left or the right. Tester time was defined as the first forward movement of the tester from when the body left the beam to the moment when the foot is planted for the final side-step. Decision time is the time from when the tester planted his foot for the side-step to initiate the change of direction, to the time the participant planted his foot to change direction. Total time was measured using timing gates (Speedlight Timing System, Swift Performance Equipment), and the time started as soon as the participant crossed the first light beams and stopped as soon as he crossed the finish gate. Semi-professional Australian Rules football players participated in the testing. During this reactive agility test players had to respond to one of four possible scenarios displayed by the tester, all resulting in a change of direction either to the left or the right. The strongest relationship existed between decision time and the total time (r = 0.77), making decision time most responsible for the variance in the total time. It can be concluded that speed of decision-making is a key factor in reactive agility. Furthermore, the higher-skilled players were able to initiate a response before the tester planted his foot to indicate the change of direction required. This indicates that the higher-skilled players were able to extract the relevant movement cues earlier and that they have superior anticipatory and decision-making skills compared to the lesser-skilled athletes, and this results in faster reactive agility performance (Young and Willey, 2010; Gabbett and Benton, 2009; Sheppard *et al*., 2006).

Farrow *et al*. (2005) developed a reactive agility test for netball players that required players to react to a life-size video footage of a player passing a ball. Three different skill levels were tested, namely highly-skilled, moderately-skilled and lesser-skilled players. Decision-making time was also investigated separately by the use of a Panasonic SVHS video camera (NV-MS5) to determine its contribution to reactive agility performance. Both the highly-skilled and moderately-skilled players were significantly faster in the reactive agility test than the lesser-skilled players (p = 0.01). Decision-making was also significantly faster for the highly-skilled players than the lesser-skilled players (p = 0.01). The highly-skilled players had a negative mean decision-making time (-149 $\pm$ 132ms) indicating their ability to anticipate the intended movement direction and perform the sprint component at a faster speed, while the mean decision-making time (22 $\pm$ 91ms) of the lesser-skilled players, revealed that they waited for all possible information to be presented before changing direction.

Pattern recognition

Williams and Davids (1995) did a study on the declarative knowledge base of soccer experts and looked at the contribution of anticipation, pattern recognition and recall. Participants were highly-skilled and lesser-skilled soccer players and physically disabled soccer spectators. The highly-skilled players proved to have superior anticipatory skills and recall ability. The higher-skilled players were also superior in their ability to recognize structured and unstructured patterns of play, while no differences were evident between the lesser-skilled soccer players and the physically disabled spectators.

Abernethy *et al*. (2005) investigated the transferability of pattern recognition between expert and non-expert players of different ball team sports. The expert players represented Australian National teams in netball, male and female field hockey and basketball. The non-experts were also experienced in their particular sport, but have not reached national level. Participants viewed video footage of international basketball, field hockey and netball matches. The duration of the video clips was 15 to 22 seconds. After viewing the video footage participants were required to recall the position of each defensive and offensive player. Sport-specific experts consistently performed superior than non-experts in their domain. Moderate effect size (ES) differences were reported between expert and non-experts for, netball (ES = 0.42), basketball (ES = 0.46) and field hockey (ES = 0.77). Experts were able to best recall the patterns in their own sports; they did not do as well in the other sports, but were still superior to non-experts. Therefore, some positive transfer may exist.

Visual Scanning

Savelsbergh *et al*. (2002) investigated the visual search strategies and anticipation of expert soccer goalkeepers compared to novices. The expert players played semi-professional soccer in the Netherlands. Players were presented with video footage of penalty kicks and had to respond accordingly by moving a joystick. The experts were not significantly better in the percentage penalties stopped ($p = 0.06$), but their percentage accuracy in predicting the height ($p < 0.05$) and direction ($p < 0.05$) of the penalty kick was significantly better than the novices. Experts also made fewer corrective adjustments with the joystick. An eye-movement registration system was also used to examine visual behavior. It was found that expert goalkeepers made fewer fixations (2.9 ± 0.4 vs. 4.0 ± 0.5; $p < 0.01$) of much longer durations

(585ms ± 108 vs. 430ms ± 75.9; $p < 0.01$). The expert goalkeepers fixated mostly on the head of the player, the kicking leg as well as the non-kicking leg and ball areas, while the non-experts spend more time fixating on the trunk, arms and hips.

Savelsbergh *et al*. (2005) repeated the above study, but this time investigated differences in visual search behavior of successful and unsuccessful expert goalkeepers. The successful goalkeepers' prediction accuracy for height ($p < 0.01$) and direction ($p < 0.01$) of the penalty kick were significantly better, they waited longer before initiating their response ($p < 0.05$), and they had a longer fixation duration on the non-kicking leg ($p < 0.05$) than the unsuccessful goalkeepers.

Vaeyens *et al*. (2007) analyzed the visual search behavior of successful and less successful skilled youth soccer players using video-based simulations of offensive patterns. The simulations varied from 2 vs. 1 (two attackers and one defender), 3 vs. 1, 3 vs. 2, 4 vs. 3 and 5 vs. 3 conditions. Vaeyens *et al*. (2007) found that the successful soccer players had more fixations of shorter durations and that they made more fixations for all the viewing conditions ($p < 0.001$) compared to the less successful players. Significant differences also existed between the 2 vs. 1 and 3 vs. 1 conditions and the 3 vs. 2, 4 vs. 3 and 5 vs. 3 conditions. In the 2 vs. 1 and 3 vs. 1 conditions the successful players had a fewer number of fixations of longer mean durations. For the other conditions duration time was shorter with a higher number of fixations. The duration time was also significantly longer for the 2 vs. 1 and 3 vs. 1 conditions compared to the 3 vs. 2, 4 vs. 3 and 5 vs. 3 conditions. The successful players fixated most of their time on the players with the ball, even up to 80% of the time in the 2 vs.1 and 3 vs. 1 conditions. Vaeyens *et al*. (2007) found that there is a clear difference in the visual search behavior of higher-skilled and lesser-skilled players. Visual search strategies of the higher-skilled players are more goal-oriented, which facilitated superior decision making and RA.

Abernethy and Zawi (2007) conducted three studies on the perceptual information that expert badminton players use to anticipate stroke direction. Throughout all the experiments the experts significantly outperformed the non-experts in predicting stroke direction. The study found that experts were able to accurately predict stroke direction from the isolated kinematic motion of the racquet ($p < 0.01$) and the lower body ($p < 0.05$), but not for the arm of the upper body. Non-experts were unable to pick up information in isolation, however, their prediction accuracy increased when the segments were linked. The improvement in the non-experts was not only because of more visible points, but due to more vision on specific points such as the lower body. This study indicates that experts pick up advanced visual cues from specific points and are able to do so much earlier than non-experts.

It seems to be consistent in the literature that the ability to respond quicker in reactive agility tests can be recognized as improvements in perceptual skills and it is more than likely that improved ability to pick up advanced kinematic cues contribute to improved reactive agility performance (Abernethy and Zawaki, 2007; Farrow and Abernethy, 2002; Abernethy *et al*., 1999).

D. DYNAMIC STABILITY

Lemmink *et al*. (2004) suggested that agility performance in field hockey players can be defined as the ability to rapidly change direction while maintaining balance and without a reduction in speed. Static balance is when maintaining a fixed base of support, while dynamic balance refers to maintaining stability while executing movements with a changing base of support (Bloomfield *et al*., 2007). The central nervous system regulates the maintenance of balance by afferent visual and tactile impulses combined with proprioceptive and vestibular feedback (Baley, 1977). Dynamic stability plays an important part in executing open skills such as agility in dynamic type sports. For example in rugby union, players need to be able to change direction rapidly without losing balance or speed and do so while holding a rugby ball or passing to an opponent. In soccer players need to maintain dynamic stability while dribbling and kicking the soccer ball. Therefore, dynamic stability can be maintained by adapting the technique (i.e. running with ball in hand) depending on the nature of sport.

Wheeler (2009) constructed a new model of agility performance taking in consideration the dynamic stability of agility as well as the need to study agility in a sport-specific context (*Figure 2.3*). The cognitive and physiological components that determine agility performance do not influence agility as entities on their own. The physiological capacities combine with the technical aspects and are determined by decision-making. Therefore a dynamic stability exists within agility (Lemmink *et al*., 2004). The successful use of agility manoeuvres during competition relies on perceptual factors such as reaction time, visual processing and anticipation, to make the best decision on when to perform agility manoeuvres and in which direction and at what moment in time.

In the study of Bencke *et al*. (2000) dynamic balance training resulted in improved agility performance in experienced handball players. The programme focused on multi-directional dynamic balance stability and included exercises such as single legged side jumps, single leg squats and agility dot-drills. During the side-stepping agility manoeuvre the dynamic stability group had shorter stance times during the propulsive phase of the initial direction change. Bencke *et al*. (2000) proposed that the dynamic stability training led to improved neuromuscular coordination and rate of force development through the propulsive phase.

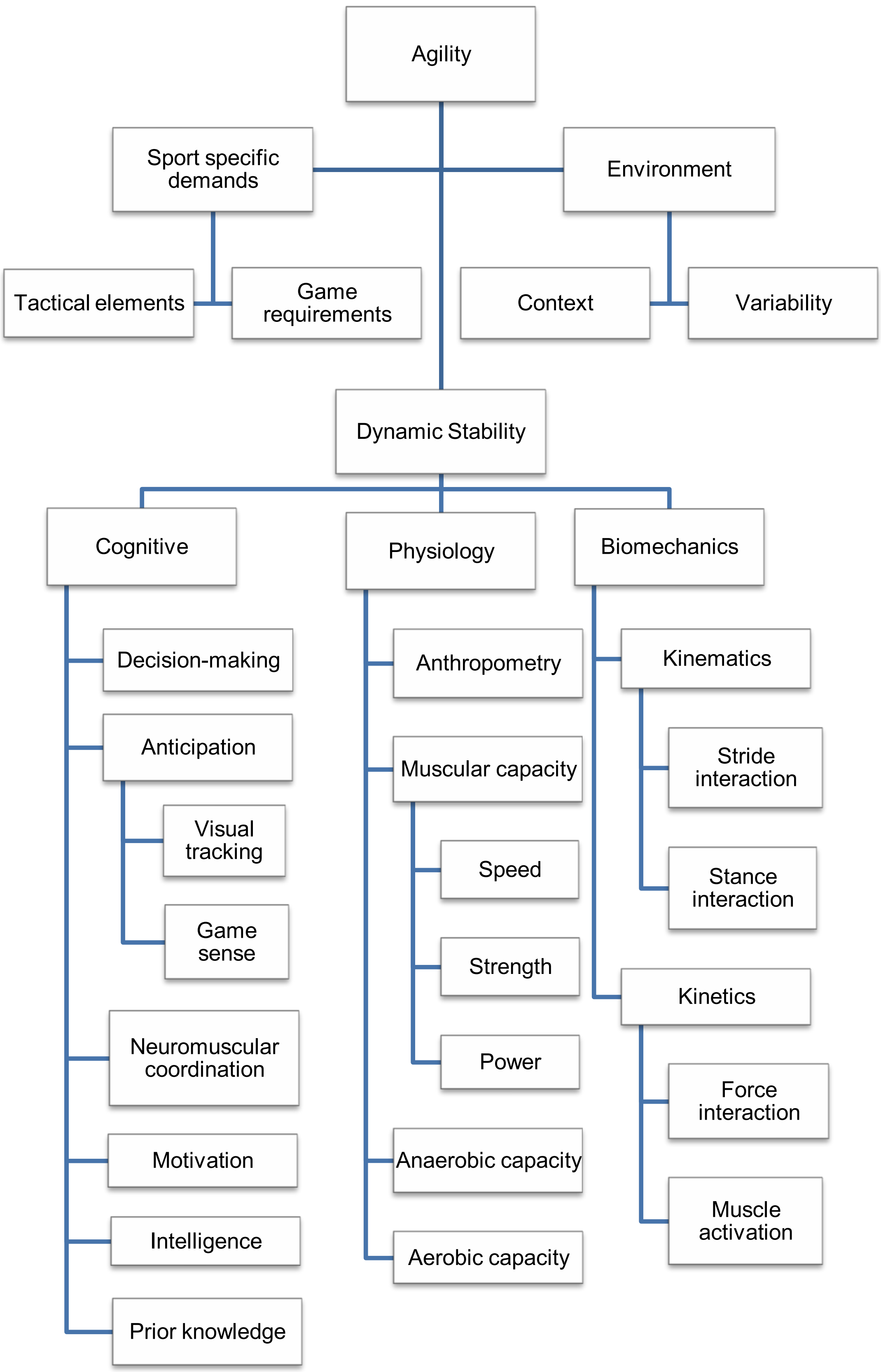

Figure 2.3. New agility performance model by Wheeler (2009) with the emphasis on dynamic stability in a sport-specific environment.

The model of Wheeler (2009) also included sport-specific demands as a component that influences agility performance. The type of movement patterns differ considerably within sports and the type of agility manoeuvres are dependent on the environment. Rugby union is for instance a running-based motion, whereas water polo agility manoeuvres are to be performed in a swimming-based motion. In field hockey players need to be able to run and change direction while dribbling the ball.

Lemmink *et al*. (2004) tested field hockey players to determine the reliability of a sport-specific agility test namely, a sport-specific shuttle sprint and dribble test (ShuttleSDT) and a sport-specific slalom sprint and dribble test (SlalomSDT). The correlation between sprint time and dribble time were low for both tests (ShuttleSDT, r = 0.31 and SlalomSDT, r = 0.24) and statistically significantly different, indicating changes in physical abilities being used and measured. The ShuttleSDT test would also give a better indication of the abilities of defenders and midfielders, while the SlalomSDT closer relates to forwards. The study shows that agility performance is altered when combined with dribbling and that field hockey players should find a dynamic stability between performing agility manoeuvres and dribbling at the same time. The study also indicates the importance of sport-specific testing to get a true reflection of player's performance abilities.

Young *et al*. (1996) included sport-specific factors into their agility testing for Australian Rules football players. Agility performance was tested over a 20m sprint with three 90^0 changes while carrying a ball and performing two bounces (Sprint 90 bounce) or without the ball (Sprint 90). Times increased by 4 - 5% from Sprint 90 to Sprint 90 bouncing. A moderate relationship existed between Sprint 90 bounce and Sprint 90 (r = 0.64). Although bouncing the ball did not largely affect the running speed, it seems to have altered the nature of the skill, as less than 50% of performance in the Sprint 90 bounce was associated with the Sprint 90. Players that performed best in the Sprint 90 did not necessarily perform the best in the

Sprint 90 bounce. It was; therefore suggested that for Australian Rules football agility drills should be performed while carrying a ball.

For effective agility performance in rugby union players to occur, there needs to be an avoidance of being tackled. This is also why, unlike track athletes, it is better for rugby union players to perform change of direction manoeuvres with a slightly slouched upper body and forward lean as to not expose themselves (Sayers, 1999). To maintain dynamic balance rugby union players will also benefit from a lower centre of gravity during agility skill execution (Sayers, 1999). RA performance is influenced by CODS as well as perceptual factors; therefore players need to develop both of these factors together (Wheeler, 2009). It is also important to train RA in a sport-specific context, as the skill may be altered by the sport and its specific environment (Young *et al*., 1996). When training closely resembles the sport it may decrease the information processing time that may lead to quicker responses and the athlete will be able to recognize patterns and advanced visual cues that may result in more accurate responses (Williams and Davids, 1995; Abernethy, 1991).

E. REACTIVE AGILITY AND SKILL LEVEL

Researchers has shown that reactive agility can be used to differentiate between higher-skilled and lesser-skilled players (Young and Wiley, 2010; Gabbett and Benton, 2009; Sheppard *et al*., 2006; Farrow *et al*., 2005). For example, Sheppard *et al*. (2006) found that there was a difference in the reactive agility times of higher and lesser skilled Australian football players (1.55 $\pm$ 0.07s vs. 1.64 $\pm$ 0.08s), while no differences were observed for the 10m straight sprint and CODS times. Higher-skilled athletes even showed faster times in the reactive agility test (1.55 $\pm$ 0.07s) compared to the planned agility test (1.64 $\pm$ 0.09s). They concluded that the difference was due to cognitive abilities (Sheppard *et al*., 2006), i.e. the ability of highly skilled players to interpret and appropriately respond to sport-specific situations. Gabbett and Benton (2009) used the same testing protocol as Sheppard *et al*.

(2006) and found that higher-skilled rugby league players had faster decision and movement times while staying accurate in their responses than lesser-skilled players.

Gabbet *et al*. (2008b) also tested first and second grade rugby league players using the three-cone drill (also known as L-run), 505 agility and modified 505 agility tests as well as a reactive agility test (test developed by Sheppard *et al*., 2006). The CODS test included in the study all represent movement patterns found in rugby league match-play, but it failed to discriminate between higher and lesser skilled players. On the other hand, the higher-skilled players had faster movement and decision-making times in the reactive agility test compared to the lesser-skilled players. In other research rugby union players not only executed the change of direction earlier, but also displayed faster lateral movement speed (Wheeler and Sayers, 2010). Sport-specific video-based reactive agility tests have been developed for soccer and netball players. Both tests found that higher-skilled players initiated movement faster and displayed a higher accuracy in decision-making (Farrow *et al*., 2005; Helsen and Pauwels, 1988).

Meir *et al*. (2001) and Gabbet (2007) tested elite rugby league players' agility using the three-cone drill test and 505-agility test and both found no significant differences between playing positions. This aspect, however, warrants further investigation.

Farrow *et al*. (2005) tested agility and decision-making of netball players by having them react to match-play situations displayed on a life size screen. Higher-skilled athletes had faster agility and decision-making times compared to the lesser-skilled athletes. Negative decision-making times (-0.15 $\pm$ 0.13s) were obtained by the higher-skilled players indicating that they were able to anticipate and predict the correct movement skill required. The planned sprint times and shuffle time (movement time from start gate till one meter forward movement after the completion of side-stepping manoeuvre) had little influence on the between-group differences found during the reactive agility test. The difference between planned and reactive agility is that although planned agility tests may simulate movements required within the sport it lacks the ability to discriminate between higher and lesser skilled players (Gabbett *et al*., 2008c). Planned agility may; therefore not be a true indication of skill level for rugby union where most of the agility performances are in reaction to an opponent.

Helsen and Pauwels, (1988) found that elite soccer players were significantly faster in their initiation time during a response then intermediate soccer players ($p < 0.01$). The players were required to react to match-play situations presented to them through video-footage. The elite soccer players also had significantly better response accuracy then the intermediate players ($p < 0.01$).

Since RA involves both perceptual and decision-making components it means that RA is unique and different from CODS. These components allow RA to discriminate between higher-skilled and lesser-skilled athletes; something that CODS is unable to do on its own. The higher-skilled athletes possess superior perceptual and decision-making skills, have faster RA times and produce more accurate responses than their lesser-skilled counterparts. This once again indicates the importance to train perceptual and decision-making skills, specifically in a sport-specific context as it would lead to success in match-play situations.

F. RESPONSE TIME

During rugby union players constantly have to react in response to an opponent, a teammate or the movement of the ball. The total response time to the specific stimulus can be broken down into reaction time and movement time (Vickers, 2007). Response time is the elapsed time between the retrieval of a sensory stimulus and the response that follows (Spierer *et al*., 2010). Movement time starts when the player plants his foot to initiate the change of direction, while reaction time, also known as total motor time, is the delay between the presentation of an external stimulus and the onset of joint movement. Reaction time is further divided into pre-motor time (PMT) and motor time and is measured using electromyography (EMG). Motor time is the electromechanical delay during which the muscles start to contract. PMT represents the elapsed time between the onset of the stimulus and the onset of myoelectric activity, i.e. the time needed for neural processing and conduction of the impulse from the motor cortex to the related muscles. PMT can be subdivided into visuo-motor related time (VMRT) and motor evoked potentials (MEP latency). VMRT is the time from visual stimulation until the impulse reach the primary motor cortex through the visual cortex, and MEP latency is the time of the impulse from the primary motor cortex (M1) to the muscle. VMRT that reflects the time of visuo-motor integration and control in the posterior parietal cortex can be determined by subtracting MEP latency from PMT (Iacoboni, 2006).

Yotani *et al*. (2011) showed that reaction time can improve by training the central nervous system. Fourteen male college athletes participated in a single training session per week for an eight week period. The athletes had to perform a simple reaction time task while seated in a comfortable chair with a headrest. A visual stimulus was presented to the athletes by a light-emitting diode (LED), placed 1m in front of the athlete at eye level. The athletes were instructed to contract their masseter muscle every time the LED lit up. The LED lit up ten times with a 2 to 6s interval between the presentation of the visual stimulus. PMT and transcranial magnetic stimulation (TMS) over M1 was recorded after each response training session. This short-term response training programme delivered significantly shortened PMT and VMRT with no change in MEP latency, indicating the trainability of VMRT (Yotani *et al*., 2011).

G. PERCEPTUAL SKILLS IN REACTIVE AGILITY

It is clear from the literature that decision making strategies alter agility skill performance and that a moderate correlation exists between planned and reactive agility. Examples of the latter include results for rugby league, r = 0.40 - 0.58 (Gabbett *et al*., 2008c) and netball, r = 0.70 (Farrow *et al*., 2005). It can therefore be concluded that decision making strategies are also a key component of agility manoeuvres in an open skilled sport such as rugby union (Sheppard *et al*., 2006).

Rugby union is a fast-moving ball game where the conditions are constantly changing. It's fundamental for success to penetrate the defense line and advance beyond the advantage line. Agility performance in rugby union is greatly assisted by superior perceptual skills such as pattern recognition, anticipation and decision-making. A higher-skilled player would be able to select the best course of action during competition, rapidly react to changes in the playing environment and will be able to read the game and respond effectively (Meir, 2005). Higher and lesser skilled athletes are not differentiated by basic visual function (i.e. accommodation, acuity, color vision, depth perception, dominance, fixation, peripheral vision, speed of recognition, tracking and vergence), but rather how they interpret and use the visual information to construct their actions (Abernethy and Wood, 2001). Vickers (2007) found that there is a good relationship between gaze control and attention. The athletes' visual abilities may provide the ceiling to performance but does not seem to be related to skill level (Williams, 2002). It is wrongly assumed that the improvement of basic visual functions is directly related to superior sport performance. Helsen and Pauwels (1993) found no difference in the basic visual functions of different skill groups in soccer players. Ward *et al*. (2000) found no differences between the basic visual function of elite and sub-elite football players aged 8 to 18 years. Furthermore, after a four week generalized training programme to improve basic visual function, Wood and Abernethy (1997) did not find any improvement in visual or motor performance in students with competitive experience in racquet sports.

Abernethy and Wood (2001) found similar results where the generalized training programme did not improve basic visual function or motor performance. The differences between higher and lesser skilled athletes are perceptually related and their ability to utilize sport-specific information (Abernathy and Wood, 2001).

Wheeler and Sayers (2010) found that the speed of agility performance in rugby union players during reactive conditions is affected by the ability to anticipate the required running line. The players with the higher anticipation ability initiated side-stepping earlier and had a greater lateral movement speed to the intended direction. This is consistent with the findings of Farrow *et al.* (2005) who also found that higher-skilled athletes initiate change of direction earlier, while the lesser-skilled athletes waited till the end of the presentation of the decision-making stimulus before reacting. The study of Wheeler and Sayers (2010) thus highlighted the importance of anticipation abilities in agility skill execution in rugby union.

Anticipated and unanticipated agility manoeuvres were compared by Besier *et al*. (2001). During anticipated cutting tasks the players knew the required movement patterns and were able to make the proper postural adjustments during the initial COD, but were unable to do so during unanticipated agility tasks. Improved pattern recognition and anticipation may; therefore enable the appropriate foot placement and muscle activation for effective agility skill execution. Besier *et al*. (2001) identified the importance of including reactive components in agility training. The reactive conditions improved the athletes' ability to make proper anticipated postural adjustments such as needed in open skilled sport (i.e. rugby union). Sport-specific reactive conditions would provide an even greater improvement in anticipation and enhanced decision-making that will lead to accurate agility skill execution (Vickers *et al*., 1999).

Visual search strategies with advanced cue recognition should be included in rugby union training to further improve decision-making, while the training methods to improve anticipation and decision-making would have the best transfer to match-play when done in a sport-specific manner (Shim *et al*., 2005; Williams *et al*., 2003).

H. SUMMARY

Agility performance is influenced by many different factors, of which perceptual and decision-making factors are two of the key components. Rugby union is an open skilled sport as the playing environment to which the players have to react is constantly changing. Therefore anticipation and decision-making skills play an important role in the successful execution of agility performance in rugby union. Reactive agility has the ability to differentiate between higher and lesser skilled athletes. Higher-skilled players have the ability to combine the perceptual and decision-making skills with the physiological and technical factors to deliver superior agility performance. It is possible to train and improve reaction time as well as visual search strategies. Sport-specific perceptual training will deliver the most improvement and transfer to competition, and should be included in rugby union training.

CHAPTER THREE

AGILITY TRAINING

A. INTRODUCTION

A number of different training methods exist to improve agility, which may in part be explained by the variety of definitions and vast number of factors that impacts the agility performance of individuals. Therefore it is fair to conclude that agility conditioning is a complex process. To stay ahead in the game coaches need to adapt their coaching methods regularly. Some of these methods have a more physiological approach while others focus more on the perceptual side of agility. Successful performance in team sport requires the athlete to possess perceptual skills as well as the ability to accurately and effectively perform the sport-specific movement patterns (Savelsbergh *et al*., 2005) Therefore, it is not uncommon to see combinations of these coaching methods.

B. PHYSIOLOGICAL TRAINING METHODS

1. Straight sprinting

Agility performance does include a straight sprinting component; therefore speed training is often included into agility training to improve the agility movement time. Young *et al*. (2001) conducted a study to determine if straight sprint training transfers to agility performance. Their participants (male university students) were randomly divided into a straight sprint training group ($n = 11$), an agility training group ($n = 9$) and a control group ($n = 7$). The two experimental groups followed training programmes for six weeks with two sessions per week, with the only difference that the agility group's training included changes of direction. All the participants completed seven sprint tests, of which one was a straight sprint and six included change of direction at different angles. Distances for all the sprints were 30 meters. The speed training group only improved in the straight sprint test (2.9%) and the test with two 160^{o} changes in direction (2.3%; $p < 0.05$). The agility group showed improvements in all the change of direction tests (2.1 - 3.7%), but not the straight sprint test ($p < 0.05$). No changes occurred in the control group. The correlation between the straight sprint test and the most complex change of direction test (five directional changes at 100^{o}) was $r = 0.47$, indicating a mere 22% common variance. Therefore, straight sprinting speed and agility are qualities that exist independent of each other and with very limited transfer. Hilsendager *et al*. (1969) also found that when comparing agility performance in male university students following a 6 week speed or agility training programme, that the agility training group was superior in agility performance. This also suggests that agility training should be specific, as straight sprinting and CODS are unique skills that produce little transfer between one another.

2. Backward locomotion

Backward (BW) locomotion has been found to improve balance and coordination, facilitate correct posture during performance, improve cardiovascular fitness levels and facilitate neuromuscular function (Terblanche *et al*., 2005; Bates and McCaw, 1986). Terblanche and Venter (2009) compared the effects of a six week forward (FW) and BW locomotion training programme on the speed and agility of well trained netball players. In the agility 505 test the BW group had a 2.8% greater improvement on the right leg than the FW group and 1.7% greater improvement on the left leg ($p < 0.05$). For the agility T-test the BW group improved by 5% while the FW group improved by 2.6%, and for the ladder test (test for quickness) the BW group showed a 10% improvement which was much greater than the 1.9% improvement for the FW group ($p < 0.05$). The improvements in agility were thus significantly greater for the BW group than the FW group and could be ascribed to a greater neuromuscular challenge provided by BW locomotion. Furthermore, as the netball players learned to perform BW locomotion effectively and at high speeds it may have improved their balance and coordination, that in turn may assist with improved agility performance.

3. Programmed conditioning versus Random conditioning

Young *et al.* (2001) described rugby union as a randomized intermittent dynamic and skilled movement type sport (RIDS). Programmed conditioning (PC) and random conditioning (RC) have both been recognized as credible methods for developing RIDS (Bangsbo, 1994). During PC the coach provides the players with a specific set of drills, including the volume and intensity at which the drills should be performed. Bloomfield *et al*. (2007) added that PC involves closed skills in a controlled environment and requires the coach to be highly knowledgeable of the sport and its requirements. It is also easy to control the players' effort with PC. Polman *et al.* (2004) established that speed, agility, quickness (SAQ) is a validated method for PC. SAQ involves progressive exercises to develop essential abilities used during dynamic sports, so that athletes execute these abilities more skillfully and at greater speeds and with higher precision. Exercises in SAQ conditioning involves ladder drills, hurdle drills, shuffles, bunny hops, sprints, partner drills and reaction ball to improve footwork, acceleration over short distances, changing direction and deceleration. SAQ claims to improve reaction time and enable athletes to effectively move in multiple directions, to stop quickly and change direction with speed. PC is; therefore an effective method to develop agility technique, but does not specifically relate to the match-play situations or involve decision-making situations.

During RC the coach designs a specific conditioning environment during which each player is responsible for his own effort. RC thus involves open skills that simulate match-play, and is; therefore sport-specific; however the coach has little control over the players, which may lead to undertraining in some of the players and overtraining in others.

In the study of Bloomfield *et al*. (2007), participants in the RC group (n = 16) participated in mini soccer games, while the PC group's (n = 14) training consisted of footwork guided by the SAQ method. After a six week intervention both the PC and RC group showed significant improvements in agility ($p < 0.005$), but PC showed a significantly greater improvement in agility than RC ($p < 0.05$). It may be argued that not all the participants in the RC group received sufficient amount of overload, while PC is structured in such a way that minimal amount of overload is received for each session. Another explanation may be that because RC simulate match play it leads to higher aerobic yield which may compromise agility and not enough recovery time to replenish ATP-PC stores. This conclusion is supported by the results of Hoff *et al*. (2002) who showed that players achieve 91.3% of their maximal heart rates during mini soccer games (equal to 84.5% of maximal oxygen uptake), which indicates that the emphasis is on aerobic training. Training done in PC also assisted in improving leg power that could aid the improvement in agility. It was shown that single leg jump performance improved significantly after the intervention and correlated significantly with the agility T-test ($r = -0.788$; $p < 0.01$). The T-test was the only agility measurement; therefore only assessing planned agility and not reactive agility. PC is more effective than RC to rapidly improve CODS. But it is unclear if PC is the best method to train agility skills in a sport-specific manner, as it was not tested during the study. RC did, however, improved CODS significantly, indicating that it has the ability to improve the movement speed involved in agility performance.

4. Plyometric training

It has been shown that plyometric training improves coordination in the neural system and power output of the lower limbs (Häkkinen and Komi, 1986). Athletes commonly use plyometric training to improve explosiveness. Some studies have reported moderate correlations between agility performance and leg muscle power (Negrete and Brophy, 2000; Kovaleski *et al*., 2001; Young *et al*., 1996). Agility requires fast lateral movement and changing direction, and one method to induce the improved lateral movement may be through plyometric training. Besier *et al*. (2001), also recommended the inclusion of plyometric drills when training reactive agility.

Thomas *et al*. (2009) investigated two different plyometric techniques (drop jump, DJ and countermovement jump, CMJ). Youth soccer players participated in a six week training programme either in the DJ group (n = 7) or CMJ group (n = 5). Following the training both groups improved their vertical jump height and agility performance (505-agility) significantly ($p < 0.05$). CMJ and DJ training had meaningful effect sizes for agility (ES = 1.3 and 1.5, respectively). The study found that both plyometric training techniques improved leg muscle power and this was associated with improved agility performance.

Salonikidis and Zafeiridis (2008) compared the effects of a tennis-specific lateral programme (TLD), plyometric programme (PT) and a tennis-specific plyometric programme (CT) on lateral movement in tennis (n = 16 for each group). Before and after a nine-week intervention the participants underwent a series of tests that included a reaction time test, four meter lateral and linear sprints, twelve meter linear sprints with and without turns, reactive ability, power and strength. Reaction time was determined by the use of a load cell (AMD Co.Ltd., LC 4204 – K600, 1-D, Saitawa, Japan). Participants were required to perform a single side-step manoeuvre as quickly as possible on the load cell in reaction to a visual stimulus. Reaction time was recorded as the time from the presentation of the visual stimulus to the activation of the load cell. The reactivity coefficient (RCT) was determined by the following equation: RCT = drop jump height (cm) / contact time (s). Participants performed three side-stepping trials to the left and three to the right to determine their “slow” side. The training programmes focused only on developing the contralateral leg of the “slow” side, as previous research showed vigorous push-off from the contralateral leg produces the fast lateral movement (Young *et al*., 2002; Chow *et al*., 1999).

Reaction time significantly improved in PT and CT (27 - 29%; $p < 0.001$), and all the groups significantly improved their times for the four meter lateral and linear sprints in their trained legs, but not their untrained legs. The TLD and CT groups also showed improvements in the twelve meter linear sprints, but once again only in the trained legs. All three the training programmes improved reactive ability and power in the trained leg ($p < 0.05$), but only PC and CT improved these qualities in the untrained leg ($p < 0.05$). No strength changes were observed. The training programmes which included plyometric training were superior in improving reaction time (PT: 162ms ± 32; CT: 158ms ± 36; TLD: 196ms ± 23) and reaction ability (PT: 67.8cm/s ± 29.7; CT: 63.3cm/s ± 25.3; TLD: 54.3cm/s ± 12.3) when compared to the TLD programme ($p < 0.05$). In the twelve meter sprints both TLD and CT improved, but CT had a greater improvement. This may be explained by greater power for the first push-off step through plyometric training, with further gains from the specificity of the task and velocity from the TLD programme.

The greater improvements in reactive ability and power in the trained legs of the PT and CT groups compared to the TLD group may possibly be due to superior improvements in explosiveness and rate of force production. The reactive ability and power measured by a drop jump highly correlated with each other ($r = -0.78$). This was also found by Young *et al*. (2002) in a group of men consisting of soccer, Australian football, basketball and tennis players ($r = -0.61$), however, Cronin and Hansen (2005) found a non-significant correlation between reactivity coefficient and 5 m and 10 m sprint performance of rugby league players ($r = -0.35$ to -0.38; $p < 0.05$). Thus, the improvements after the plyometric training are most likely the result of improved neuromuscular adaptations that include improved proprioception. Barnes *et al*. (2007) found moderate to good correlations between agility performance and CMJ ($r = -0.58$; $p < 0.01$) and DJ ($r = -0.32$) in female volleyball players. Swanik *et al*. (2003) reported that a six week plyometric training programme resulted in significantly improved performances in proprioception tasks that involved active reproduction and passive positioning.

From these studies it is noticeable that both CMJ and DJ are both effective plyometric training methods that will result in improved neuromuscular function. Plyometric training improved leg muscle power that provides a more powerful push-off when changing direction. Not only does plyometric training improve CODS, but it also seems to have a positive influence on reactive ability. The best results in agility performance is seen when plyometric training were combined with sport-specific training.

C. PERCEPTUAL TRAINING

1. Proprioceptive training

It is proposed that one of the reasons why BW locomotion improves agility performance may be due to improved balance and posture (van Deursen, 1998; Threlkeld *et al*. 1989). Thus, if improved balance has a positive effect on agility performance, proprioceptive training may lead to the same results. The purpose of proprioceptive training is to advance neuromuscular function to produce stability and balance during static and dynamic activities, providing the body with a kinesthetic sense of all the body parts in relation to each other and to space (Laskowski *et al*., 1997). Proprioceptive training should result in better body awareness, better posture and improved balance and coordination. Improved proprioception may also enhance neural activation and the actual excitation of the motor-neural system, especially the stretch-shortening cycle (Komi, 1984). Gruber and Gollhofer (2004) also found that 8 sessions of proprioceptive training over a four week period that included exercises on wobble boards, two-dimensional free moving boards, spinning tops and soft mats, increased the rate of force development without affecting the maximum strength. With the use of EMG an enhanced neural drive was detected during the onset of force development (0 - 30ms and 0 - 50ms). Therefore, it may be assumed that proprioceptive training may be beneficial for explosive exercise performance.

Given the potential benefits of proprioceptive training, Šalaj *et al*. (2007) investigated the effect of proprioceptive training on agility and jump performance (n = 75). The experimental group (n = 37) followed a ten week training programme with three sessions per week. Training was done on three different types of balancing boards and progression involved double leg to single leg, open to closed eyes, jumping on and off the balancing boards, hopping on the boards and adding disturbances and manipulate the athletes by applying strength exercises while balancing on the boards. Agility performance, that mostly consisted of forward running, did show improvements ($p < 0.05$), indicating that proprioceptive training may contribute to increased acceleration after the change of direction. However, the side-step agility performance did not improve significantly ($p > 0.05$). The proprioceptive training significantly improved ($p < 0.05$) leg muscle power (single leg and double leg Vertical Jump), while the positive improvement in forward running and acceleration was probably assisted by the strengthening of the ankle joint with plantar and dorsal flexion. However, the proprioceptive training programme did not include movements in the medial and lateral directions, and no increases in strength for eversion and inversion ankle movements occurred. This may explain why no changes were found in the side-step test. In conclusion, this study found that explosive speed abilities and acceleration can be improved through proprioceptive training, but that specific exercises must be included to activate the adductor and abductor muscles of the foot and ankle in order to improve lateral movements such as side-stepping. Proprioceptive training improved leg muscular power, improving the explosiveness of the athlete, increased neural activation as well as improve balance, which is important when changing direction and maintaining the low centre of gravity. When proprioceptive training includes drills to strengthen adductor and abductor muscles it would be able to produce improvements in agility performance.

D. IMPLICIT TRAINING

1. Implicit vs. explicit learning

The idea behind perceptual training is that the player should be able to progressively pick-up relevant perceptual information earlier and then perform the adequate movement required. A vital question, however, is whether players should be told what specific information to look out for (explicit learning), or whether they should learn to retrieve information without formal verbal instruction (implicit learning) (Maxwell *et al*., 2000). Implicit knowledge is usually automated and players are unable to verbalize it (Masters, 1992).

Evidence exists that implicit learning is indeed possible and suggestions are that stimulus information is even retained for longer when learning happens implicitly compared to explicitly (Liao and Masters, 2000; Magill, 1998; Masters, 1992). Explicit learning, on the other hand, provides the athlete with a larger pool of knowledge. When athletes consciously use this knowledge to control a movement that usually occurs automatically, they tend to deliver poorer performances and when under pressure it may lead to choking (Leith, 1988). Through implicit learning individuals are less conscious of their knowledge, they spend less time thinking about the execution of a skill during stressful situations and there is less breakdown of the skill. Learning implicitly allows the player to have an external focus when performing a skill (Poolton and Zachry, 2007). Implicit learning is cognitively efficient as it requires less processing resources and reduces the time to motor response in low and high decision-making situations (Lam *et al*., 2010; Masters *et al*., 2008).

Masters (1992) and Maxwell *et al*. (2000) both investigated this proposition on novice golf putters. Masters (1992) divided the participants into one of five groups namely, implicit learning (IL), explicit learning (EL), implicit learning control (ILC), stressed control (SC) and non-stressed control (N-SC). Participants had four training sessions of a 100 putts. The EL group was provided with specific golf putting instructions in the 5 minutes before each training session started. The IL groups did not receive putting specific instructions and were required to perform a secondary task, while the control group did not receive any instructions or additional tasks to perform. The results of the study showed that even under pressure, performance did not decrease when the skill were acquired through implicit learning, which was not the case for the explicit learning group. It also showed that implicit learning is an effective method to train a new skill. Maxwell *et al*. (2000) only had three groups, IL, EL and ILC. The participants had five training sessions, and as was the case with Masters (1992), only the EL group received golf putting specific instructions and the IL groups were required to perform a secondary task when putting. After the five training sessions participants underwent a 72 hour retention test. Golf putting accuracy in all three training groups dropped, and they did not differ significantly. The authors speculated that the secondary task performed by the IL groups may have been too difficult, as it was rarely performed perfectly, and this could have hindered the learning effect on golf putting. From both these studies it's clear that explicit learning negatively affects performance when under pressure and that learning implicitly is achievable. It's suggested that training should mainly be through implicit learning and aided with explicit strategies, i.e. detecting and correcting errors.

Poulter *et al*. (2005) compared the effect of implicit and explicit learning on anticipation, awareness and visual search behavior in young women. The ability to predict the direction of a penalty kick was examined through the use of video clips, where the video was stopped just one frame before contact with the football was made. This technique is called temporal occlusion, where the amount of visual information is systematically varied and it is used to teach players the link between advanced visual cues and the outcome of the movement/play. Participants had no prior experience in playing soccer or viewing penalty kicks. Participants were either in an explicit training, implicit training, placebo or control group. The test involved twelve kicks performed by three different players. The learning phase was completed in one session and consisted of 96 trials (8 blocks of 12 kicks each). All the participants were informed that they would be viewing penalty kicks from the goalkeeper's perspective and would be required to predict the direction of the penalty kick and then rate the confidence of their choice on a scale from 1 to 10 (1 - not confident at all, 10 - completely confident). The explicit training group received information about advanced visual cues and viewed still images to highlight key regions. Instructions were given immediately before and halfway through the learning trials. Feedback was given after the completion of each trial. Participants in the implicit training group were asked to predict the speed of the ball and then rate the confidence of their decision on a scale of 1 to 10. Feedback was given after each clip by repeating the same clip with flight information and verbal feedback on the mean speed of the kick. The placebo group watched 20 minutes of video-footage from two professional soccer matches during the UEFA Champions League. The video-footage did not contain any penalty kicks. The control group only had to predict the direction of the ball and give their confidence rating.

The explicit and placebo groups significantly improved their horizontal prediction accuracy ($p < 0.01$), but only the implicit group improved their vertical prediction accuracy. The reason for improvement seen in the placebo group is uncertain and may be due to increased levels of motivation. Although the improvements were not significant the implicit learning group was the only group to improve in both horizontal and vertical prediction accuracy. The learning phase may have been too short for the implicit learning group to produce significant improvements in prediction accuracy. It should be remembered that the process of learning is slower when done implicitly compared to explicitly (Gentile, 1998; Berry and Broadbent, 1984). Therefore, more trials during training are suggested for implicit learning. Verbal response may also be a limiting factor for performance in the implicit group, as learning occurs non-intentional without explicit knowledge. Greater improvements may have been seen if the participants were tested in a non-verbal manner. The study also found limitations for implicit learning using point-gaze data and that it may be more likely for implicit processing to happen in the periphery.

Farrow and Abernethy (2002) investigated whether anticipatory skills of tennis players can improve through video-based perceptual training, using implicit learning. Participants (n = 32) were randomly divided into an implicit learning, explicit learning, placebo or control group. The experimental groups followed a four week training programme with three training sessions per week. Each video session comprised 50 clips and lasted approximately 20 minutes. The placebo group watched video footage of elite tennis matches that also lasted 20 minutes per session. The control group received no video training. The explicit learning group watched occluded video-based footage of elite tennis players hitting serves. After each occlusion the participant had to immediately record their prediction of the serve. When they made all their responses, players viewed the unoccluded video footage to assess their predictions. This group was also given instructions on the specific advanced visual cues. They watched instructional video footage that was followed by a verbal discussion and written instructions. Each participant also received a summary sheet on advanced visual cues and was provided with feedback during their training sessions. The implicit learning group watched the same occluded serves as the explicit group, but did not receive any verbal instruction about the specific cues. The implicit group was asked to predict the speed of the serve, and when they watched the unoccluded video the speed of each serve was read out to the participants to measure their accuracy in their predictions. The idea was to get them to closely monitor the serve action to predict the speed without explicit instruction, minimizing the conscious processing of anticipatory information.

The implicit group improved their prediction accuracy with approximately 12% at the occlusion that revealed the throwing action of the racquet head up to the point of contact ($p < 0.05$). This was the point where they had to draw the most information from to predict the serve speed. The participants in the implicit group developed an understanding between the relationship of the racquet head swing and the direction of the ball after contact, resulting in improved anticipatory performance. The explicit group did not significantly improve their prediction accuracy ($p > 0.05$). However, the improvement in prediction accuracy was not sustained 32 days after training stopped in either the implicit or explicit training groups. Therefore, further practice is needed to maintain the improvements over an extended period of time. Athletes also responded more effectively when the response was task-specific compared to a verbal response. The results of the study also show that video-based perceptual training does improve perceptual performance and do have the ability to transfer into real-world competition. Importantly also is that learning without verbal instruction about relevant information is possible. The tennis players learned to pick up the relevant informational cues to help them predict the direction of the serve.

These studies show that learning implicitly is possible and that it is effective in improving perceptual skills. This method can also be used to train new skills. This type of training promotes more accurate movement-based responses and the ability to recognize advanced visual cues. The process of learning implicitly may take longer or need more training trials than explicit learning. Further research is needed, especially on implicit learning in invasion type sports. Learning can happen through implicit learning alone, but can be strengthened by some explicit knowledge. Training implicitly may; therefore be an effective method to develop the perceptual and movement components associated with RA.

2. Skill-based conditioning games

Skill-based conditioning games is a good method to make training more sport-specific, as it simulates movement patterns used during match-play and provides a competitive environment where players perform under pressure and fatigue. This type of conditioning would provide an additional challenge to rugby union players compared to non-skill related conditioning. Gabbett (2003) compared the heart rates and blood lactate levels of rugby league players during competition and skill-based conditioning games and found similar results, namely heart rate (152beats.min^{-1} vs. 155beats.min^{-1}) and blood lactate concentration ($5.2mmol.l^{-1}$ vs. $5.2mmol.l^{-1}$). These results show that the exercise intensities of skill-based conditioning are comparable to competition conditions.

A tactical model ("Teaching Games for Understanding") for developing sport at secondary school level was proposed by Bunker and Thorpe (1982). Unlike the technique model that focuses on developing physical skills, this model also emphasizes the development of cognitive skills. It is known that game performance is influenced by skill level as well as knowledge. The knowledge component includes both declarative and procedural knowledge. Declarative knowledge in sport includes knowledge of the rules and goals of the particular sport, while procedural knowledge would, for instance, include the selection of the appropriate action at the correct time. This model seems to be ideal for developing skills in open skilled sports such as rugby union.

Turner and Martinek (1999) tested the soundness of the "games for understanding" model by comparing it to a technical approach of learning. Grade six and seven boys and girls participated in the study that consisted of fifteen field hockey teaching sessions. Sessions in the technique approach group started with a demonstration of the skill followed by practice drills. The skills taught included dribbling, passing, evading an opponent, receiving, shooting, short and long corners and tackling. The "games for understanding" sessions started with mini-hockey games, i.e. 2 vs. 2, and 3 vs. 1. The games were followed by a questioning session from the teacher about the problems they had and how they can solve it. The mini-games were designed in such a way that tactical problems would emerge and the students learned to select the appropriate responses for the game condition. As soon as the student identified the need for a certain skill, the teacher would intervene and teach the particular skill.

Turner and Martinek (1999) used the Henry-Friedel Field Hockey Test to evaluate basic field hockey skills, while hockey knowledge was tested by a questionnaire that included 15 declarative and 15 procedural items of field hockey. Decision-making and the execution of skills were measured by an observational tool during 5 vs. 5 game play. Three categories of behavior were coded, namely control, decision and execution. Control was defined as the successful stopping of the ball, while execution in shooting, for example, was coded as on or off target. The “games for understanding” group performed significantly better in ball control, decision-making during passing, and passing execution ($p < 0.001$) compared to the technique group. No significant differences existed between the groups for the other decision-making and execution variables, although the “games for understanding” group showed a clear tendency towards better decision-making in dribbling (23% higher) and shooting (15% higher) compared to the technique group. Decision-making during game play (dribbling and shooting execution) was also more effectively developed through the teaching “games for understanding” method, although the improvements were not statistically significantly better than for the technique group. The “games for understanding group” performed significantly better in the declarative and procedural hockey knowledge test than the control group ($p < 0.01$), but only slightly better in the procedural knowledge assessment than the technique group. The results of this study also suggest that the “games for understanding” method may improve skill performance during match-play and can be used from a young age. “Games for understanding” proved to be effective in developing skills, without the specific technical training of the particular skills. This is a positive finding for coaches, because not only did this method improve skill execution it also improved perceptual and decision-making abilities of the athletes; therefore saving time as these skills are developed together in a single session. By playing these mini-games the players learn to pick-up the relevant information from their opponent on which to base the decision of their actions, and combined with the improved skills will lead to successful response execution.

Reilly and White (2004) compared the effects of a six week skill-based games conditioning programme to an aerobic interval training programme on the explosive power, agility, soccer skills, anaerobic and aerobic capacity of professional academy soccer players (n = 18). The skill-based conditioning group played 6 x 4 minutes small-sided games (5 vs. 5), while the aerobic interval group completed 6 x 4 minutes runs at 85 - 90% of maximal heart rate. There were no significant differences in any of the outcome variables between the groups and the authors concluded that small-sided games are a sufficient alternative to maintain fitness during the competition season.

Gabbett (2006) investigated the effects of skilled-based conditioning games (n = 32) and traditional training (n = 37) methods on speed, agility, muscular power and maximal aerobic power of rugby league players. The team performance was also analyzed with regards to their win-loss ratio, points scored, points conceded and points difference in a total of eight matches played. Participants followed a nine week training programme of two sessions a week in either a traditional conditioning or skill-based conditioning games group. The improvements in speed (5.2%) and muscular power (4.7%) of the skill-based conditioning group were significantly better compared to the traditional conditioning group. The specificity of the training and the fact that it closely resembled the movement patterns and physiological demands of the sport may be possible reasons for these results. Agility was assessed using the three-cone drill test; however, no improvements were observed in any of the groups. The skill-based conditioning group did, however show superior attacking ability to the traditional conditioning group. Points scored and points difference was significantly better in the skill-based conditioning group compared to the traditional training group ($p < 0.05$). The agility test used in this study only assessed CODS, without considering the perceptual component of agility. It can be speculated that the larger points difference and the higher percentage points scored by the skilled-based conditioning group during their matches may be a result of improved reactive agility due to improved perceptual and decision-making skills, but this is, however, unclear from the study. Though, skill-based conditioning seems to be an acceptable substitute to traditional conditioning methods for improving CODS.

Gabbett (2008a) compared the effectiveness of skill-based conditioning games to instructional training in elite junior volleyball players (n = 25). Skill-based conditioning consisted of small-sided games where learning occurred through random practice. Every time the player touched the ball, he had to run and touch a certain marker before returning to play. Instructional training focused on developing passing, setting, serving, spiking, blocking technique, as well as accuracy. The skill-based group significantly improved their agility (10.4%), and the improvement was significantly more compared to the instructional training group ($p < 0.05$). The results also showed that skill-based training simulated the physiological demands of junior elite volleyball competition and that it provided a specific training stimulus. Furthermore, skill-based conditioning significantly improved the players' physical capacities, but the instructional training resulted in greater improvements in technical skills. Thus, a combination of these conditioning methods would probably lead to the greatest improvement in physical fitness in volleyball players.

Berry *et al*. (2008) observed that expert decision makers participated more frequently in invasive type sports than non-expert decision makers. They also concluded that skill-based conditioning games may be an alternative method of training perceptual and decision-making skills in team sport athletes. Skill-based conditioning games provide the players with a lot of decision-making opportunities, which would increase the cognitive effort needed to successfully perform the skill. These opportunities seldom, if ever, occur in blocked practice drills.

Research on skill-based conditioning games are limited and mostly measures planned agility as opposed to RA. From the available literature it seems that skill-based conditioning games are an effective method in training physical skills and do deliver comparable results to traditional training methods. The skill-based conditioning games also allow learning of skills in a sport-specific context, so the athletes learn how to perform the skills as they would during match-play. It has been shown that skill-based conditioning games will improve CODS and; therefore the movement time associated with RA as well. However, its greatest asset is that it involves higher cognitive effort and in some studies resulted in significant improvements in skill execution and decision-making ability when compared to traditional methods (Gabbett *et al*., 2009; Farrow *et al*., 2008; Turner and Martinek, 1999). Sport-specific mini-games provides a learning ground for advanced visual cues and anticipation, that may all contribute to improved RA. This is also a sufficient method to maintain speed and agility throughout the competition season.

3. Decision training

It is often reported in the literature that elite performers in team sports possess superior perceptual and decision-making skills compared to non-elite or novice performers (Gabbett and Benton, 2009; Sheppard *et al*., 2006; Abernethy *et al*., 2005; Savelsbergh *et al*., 2002). Since both are factors that impact agility, it can be assumed that the improvement in decision-making skills will have a subsequent improvement in agility performance. However, a clear cut method to develop perceptual and decision-making skills have yet to be identified. Elite team sports athletes regard competition to be the most helpful activity to improve their match-play perceptual and decision-making skills (Baker *et al*., 2003). Interestingly, the transfer of perceptual and decision-making skills between sports are also possible, especially if the sport requires the same type of perceptual and decision-making skills (Berry *et al*., 2008). For example, Australian football expert decision makers seem to benefit more from invasion activities in other sports even when the participation of the activity is just for fun and not part of structured conditioning (Berry *et al*., 2008).

Gabbett *et al*. (2008b) speculated that improved decision-making ability will reduce the physiological requirements needed for sport-specific game-based activities. They assessed the decision-making skills of elite women soccer players (the Australian national champions) using sport-specific video footage of international women's soccer matches. Participants had ten pattern recognition and ten pattern prediction trials, and each clip lasted approximately ten seconds. The physiological assessments consisted of speed, repeated sprint ability and maximal aerobic endurance. A coding system was also used to assess on-field decision-making during a small-sided training game, where an appropriate decision was coded as 1 and an inappropriate decision as 0. Participants were either in a video-based perceptual training group (n = 8) or a control group (n = 8). Twelve training sessions were conducted over four weeks and lasted 15 minutes in duration.

After the four weeks of training neither the video-based perceptual training group nor the control group significantly improved their speed, repeated sprint ability or maximal aerobic endurance ($p > 0.05$). However, the video-based perceptual training group performed superior in their decision-making accuracy during the video-based test ($p < 0.05$) and made fewer recall errors ($p = 0.06$). The on-field decision-making assessment showed that video-based perceptual training significantly improved decision-making during passing, dribbling and shooting. It was concluded that decision-making and pattern recognition and prediction ability can be improved by video-based perceptual training and this improvement transferred to better on-field decision-making although it did not decrease the physiological demand of game-based activities.

Rugby union is a complex, dynamic system, where players never know with 100% certainty what their opponents' next move will be. Successful players need to be able to adapt to this dynamic changing environment. Passos *et al*. (2008) proposed that training drills should include a lot of variety and simulate match-play conditions in order to improve decision-making in these uncertain game situations. Training decision-making should also be unique to the specific sport. Araújo *et al*. (2006) suggested that in dynamic environments, the most relevant information for decision-making and the subsequent action are those emerging during performer-environment interactions and not the previously obtained knowledge from past experiences. Athletes are unable to completely plan in advance the specific actions they would execute, as the environmental, performer and task constraints will differ from previous encounters. Training drills should thus focus on developing the perceptual-action coupling and closely resemble the competitive environment.

According to Newell's constraints model, players' decision-making and action will be influenced by the individual's own characteristics such as psychological state, the specific task at hand and the characteristics of the environment (Davids *et al*., 2008; Newell, 1986). Environmental constraints, for example, include weather conditions, the referee, the surface of the field and spectators. The tasks should; therefore seek a balance between stability and variability (e.g. level of fatigue, task goals, wet ball, time to the end of the match).

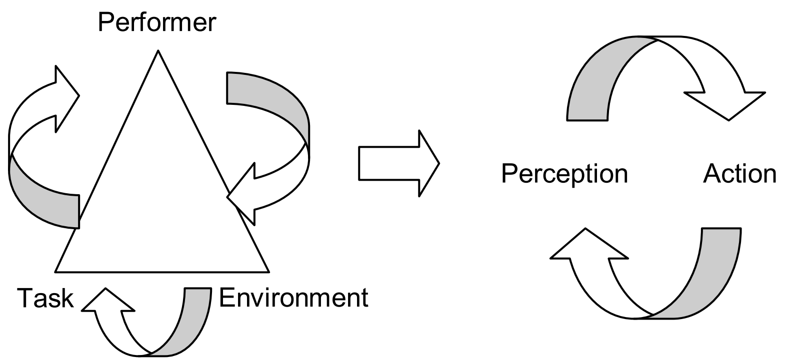

Figure 3.1. A constraints-led perspective.

The constraints-led approach in motor learning emphasizes the interaction of individual, task and environmental constraints (Newell, 1986) (*Figure 3.1*). According to this model, training decision-making can be broken down into four stages, namely first identifying the problem, then working out a strategy to solve the problem (chose the constraints to manipulate), next creating an action model (stability) and lastly creating an exercise (Davids *et al*., 2008). To identify the problem each player is analyzed on the timing and execution of their actions, as well as how they use the space available to them. After the problem is identified, action possibilities should be investigated, for example, through the use of video analysis. These possibilities are then converted to an action model that provides stability to the team as it defines all the possible actions that can be performed by each playing position. The training drills should then be designed in such a way that players can experience the variability in the performance context so that they can improve their decision-making skills. Individual constraints can be manipulated on-field (e.g. motivation, instructional feedback), or off-field (watching DVDs, using imagery), while task constraints can be manipulated by changing the rules, field dimensions, player starting-position or the number of players involved. The stability of the tasks will provide the players with structure and the variability will help them learn to cope with the uncertainty involved in a sport like rugby union.

The ability to recognize pattern may also be a key factor in expert decision-makers. It has been shown that pattern recognition abilities can discriminate between elite and non-elite athletes in invasion type sports (Abernethy *et al*., 2002; Williams, 1993). Berry *et al*. (2004) found expert decision-makers in Australian football also have superior pattern recognition abilities when compared to non-expert decision makers. Players viewed 19 video clips, and after occlusion, were asked to recall the position of the offensive and defensive players. The same clips were then viewed again, but this time the players were asked to predict the next pattern of play. The experts were significantly better in recalling the offensive and defensive players combined ($p < 0.05$) and the defensive players separately ($p < 0.05$). There was also a tendency towards better recall of offensive players ($p = 0.08$). Experts were also significantly better at predicting the outcome of play ($p < 0.05$). When training decision-making it would; therefore be beneficial to include drills or activities that would promote the development of pattern recognition, as it seems that improved pattern recognition abilities will subsequently improve decision-making skills.

Decision-making ability does indeed play an important role in RA, and could be the discriminating factor between experts and non-experts in RA performance. A variety of methods exists to improve decision-making. Game-based conditioning has been shown to be an effective method in improving decision-making ability (Gabbett, 2009; Turner and Martinek, 1999). Decision-making along with agility can be developed using this method. Decision-making skills can also be developed using implicit type learning (Farrow and Abernethy, 2002), while video-based training is another training method that could be used to train perceptual and physiological components of RA at the same time.

4. Video-based training

Expert players have the ability to evaluate situations more completely and also to do it more rapidly than novices (Wiley and Young 2010; Vaeyens *et al*., 2007; Farrow *et al*., 2005). In activities that include decision-making, experts tend to rely more on anticipatory cues than novices (Abernethy and Zawi, 2007; Savelsbergh *et al*., 2005; Abernethy *et al*., 1999; Abernethy, 1991). A number of studies have been done on the use of perceptual video-based training (Jackson *et* al., 2006; Farrow and Abernethy, 2002; Farrow *et al*., 1998; Starkes and Lindley, 1994). The simulations attempted to develop an understanding of advanced cues available in the sport to improve the player's anticipation. The video clips are usually from the player's perspective and the player has to predict the final outcome. It has already been suggested that video-based testing can be used to discriminate between higher and lesser skilled youth soccer players (see chapter two, p. 23) (Vaeyens *et al*., 2007).

A method to evaluate and train accurate decision-making in soccer was created by Helsen and Pauwels (1988) using film simulated tasks where players re-enacted game situations. The film task was projected life-size on a white screen, nine meters in front of the participants. Participants had to respond to 30 game situations with 10 seconds between each clip. Each situation was divided into two phases namely, a preparation phase and a response phase. During the preparation phase, which lasted about 10 to 12 seconds, players on the screen developed a typical attacking pattern, during which sufficient cues were provided for the participant to anticipate the response phase. In the response phase the ball was played in the direction of the participant who then had to react, by either shooting for goal, dribble around the goalkeeper or an opponent, or pass to an open team mate. The response phase was triggered by an auditory signal on the film, indicating that the player now needed to make a decision and respond as quickly and accurately as possible. The initiation time, movement time and total response time were recorded for each participant. The participants were either semi-professional soccer players or college students. The semi-professional players had a significantly faster initiation time ($p < 0.05$) and total response time ($p < 0.001$), but there were no significant differences in the movement time of the groups ($p > 0.05$). Since the higher-skilled players had faster and more accurate response times, it can be concluded that information processing time decrease with an increase in experience. The ability of the higher-skill player to anticipate the opponents' next move was still evident when the predictions occur based on video clips. The higher-skilled players were able to extract relevant informational cues even before the response signal, something that the lesser-skilled players were unable to do. The fixation locations differ between the higher and lesser-skilled players, confirming the higher-skilled players' ability to extract relevant informational cues. This study; therefore showed that sport-specific decision-making in a laboratory based environment can improve anticipatory skills. This study also illustrates that it is possible to recognize advanced visual cues from two dimensional video footage as opposed to real life match-play situations. The closer the simulations resemble the sport-specific movements the better the transfer will be to real life tasks. Video-based training thus allows for the development of perceptual skills in a sport-specific context and can be used as an alternative or add-on to field based sport-specific training.

Abernethy *et al*. (1999) investigated whether or not perceptual skills of elite athletes, such as pattern recognition and anticipation, can be learned by novices involved in racquet sports such as squash, badminton and tennis. Basic visual function, as well as sport-specific anticipatory skill using a video occlusion task was measured. Participants were presented with short video clips from the perspective of a defensive squash player, while showing the opposing player performing a certain stroke. Each clip was occluded at five different time periods (t1 = 160 ms prior to striking the ball; t2 = 80ms prior racquet-ball contact; t3 = at racquet-ball contact; t4 = 80ms after ball strike; t5 = after stroke completion). Participants were then required to predict the direction of the shot (across or down-the-wall) and the depth of the shot (short or long). The decision had to be made within five seconds by pressing a certain key on a computer keyboard. The study had three different groups namely, perceptual training group, placebo group and control group. The perceptual training group watched video footage of the different racquet sports and made anticipatory predictions on the depth and direction of the ball. They also received formal instruction on the biomechanics of the different types of strokes and advanced cues, as well as a 20 minute motor task session per week for four weeks. Both the control and placebo groups also completed the 20 minute motor task session, but the placebo group additionally watched tennis matches and read books on coaching in racquet sports during a 20 minute session. Anticipatory performance significantly improved in the perceptual skills group ($p < 0.01$), but not in the placebo or control group. The results thus show that sport-specific perceptual training does improve perceptual skills and that it is not merely a placebo effect. Furthermore, it confirms the trainability of perceptual skills by novices and that video-based training is effective in doing so. Not only are perceptual skills trainable, but significant improvements can be seen after only four weeks using explicit training methods.

Christina *et al*. (1990) developed a video-based training programme to train the accuracy of football linebackers' responses. The players watched match-play video-footage from a player's perspective and had to quickly and accurately respond to the appropriate cues by using a joystick attached to the video player. After completing a four week training programme consisting of sixteen sessions the players' response accuracy improved significantly. The study was, however, unable to determine if this improvement transferred to match play.

The study conducted by Starkes and Lindley (1994) suggests that video-based perceptual training may be most useful at intermediate level, where players have enough background and information needed to make decisions faster. This study investigated video-based decision training in intermediate women basketball players. Participants had to watch short video-footage of a basketball player and then verbally make their decision on what the optimal offensive move would be. Decision accuracy and voice reaction time (using a highly sensitive microphone) were measured. Participants also had to complete an on-court test. Participants watched play from the stands and again had to make a decision on offensive play. Players performed a certain pattern of play and then froze when the desired play was created. Only decision accuracy was measured during the on-court test. The study had a video training group and a control group. The video training group completed six training sessions (16 to 20 video clips in 15 minutes) over thirteen days. The training was similar to the video test, but after each trial the outcome of the play on the video was shown. A significant main effect was found for decision-making accuracy during the video test ($p < 0.05$); however, the on-court assessment did not result in any significant improvements. This may be due to a small group size, the low number of post-test trials or the difference that existed between the groups during pretesting. The video training group also improved their decision-making time during training significantly by about 540ms ($p < 0.05$). The authors found that video-based training is an effective perceptual training method to add to on-court training in basketball, which also improves decision-making accuracy and decision-making time. These improvements may result in overall faster responses from the players as they would be able to make proper movement adjustments in time.

In a number of video-based perceptual training programmes players had to indicate their responses by pressing a computer key (Singer *et al*., 1996; Singer *et al*., 1994; Burroughs, 1984). The problem with these types of studies is that they do not involve any physical performance and lack perception-action coupling. It is important for an athlete to learn the timing of his response and the correct execution. Due to this Farrow *et al*. (1998) developed a perceptual training programme where the players had to physically react instead of pushing a designated computer key. Players that participated in the study were all beginner tennis players who followed a four week training programme with two sessions per week. In each session players viewed a life size video image of an intermediate tennis player serving the ball. They watched twenty serves per session. The placebo group watched video-footage of professional soccer matches for 15 minutes. To ensure they were paying attention they were frequently asked questions during the session. The control group only participated in the pre- and post-testing. The players in the perceptual training group significantly improved their decision-making and anticipation speed compared to the control and placebo groups. However, their prediction accuracy did not differ from these groups. These results differ from other similar studies that found significant increases in decision-making speed and accuracy (Singer *et al*., 1996; Helsen and Pauwels, 1993; Starkes and Lindley, 1994). The lack of improvement in accuracy may be that beginner players already know what advance cues to focus on, but still finds it difficult to detect them. Another reason may be that during training the perceptual group viewed tennis serves from players of the Victorian Institute of Sport (VIS), but the testing footage included players of the Australian Institute of Sport (AIS). Players at AIS play at a higher level, hit the ball harder and are more capable of disguising their serves than the VIS players. Therefore, the testing conditions were more difficult than the training conditions and could potentially explain the participants' lack of accuracy. Video-based training can be used to improve anticipation in novices, but should be additional and not the only training method.

Jackson *et al*. (2006) investigated the prediction accuracy of skilled and novice rugby union players during one-on-one tackle situations under normal and deceptive conditions (n = 14 per group). Normal conditions are described as situations where no attempt is made to deceive the tackler (participant) and during deception conditions the attacker would attempt side-stepping manoeuvres to evade the participant. The temporal occlusion method was used to test prediction accuracy. Two national level and two club level rugby union players were used to create the testing video clips. Clips contained changing of direction to the left and the right, by either running at a 45^0 angle or performing a side-step. Five different occlusion conditions were presented: t1 (360ms before COD), t2 (240ms before COD), t3 (120ms before COD), t4 (at COD), t5 (120ms after COD). During testing participants were presented with 160 trials in four blocks of 40. Each block contained either the expert or intermediate players, but not both. Participants were asked to defend and physically react to the player on the screen. Video clips were viewed on a 44cm flat screen monitor from approximately 1.5m. After each trial they had to write down their decision and rate the confidence of their decision on a scale of 1 to 10 (1 - not confident at all, 10 - extremely confident). The results showed that skilled participants were less susceptible to deceptive conditions than the novice group. Performances of the skilled group were unchanged for the normal and deception trials, but the novice group performed significantly worse ($p < 0.05$) in the deception trials compared to the normal trials. No significant differences existed between the groups for the normal trials. Performances increased significantly from t1 to t2 to t3 ($p < 0.001$) and these changes were greater in the skilled group. Skilled participants also reported higher confidence ratings during the deception trials compared to the normal trials and confidence increased across occlusion conditions. From this study it is clear that skilled performers are able to pick up advanced visual cues from deceptive movement patterns, that they show superior anticipation ability during deception conditions compared to novices and that they have the ability to discriminate between genuine and deceptive visual information. Skilled athletes thus have the ability to spot agility manoeuvres and produce appropriate responses.

Serpell *et al*. (2011) used semi-professional rugby league players (n = 15) to investigate the trainability of the perceptual and decision-making factors of agility performance. Players were either in a control group or a RA training group who completed two training sessions per week for three weeks. Reactive agility and CODS speed were measured. Reactive agility was tested with a rugby league-specific reactive agility test (RAT). As soon as the players ran through the starting gate a video clip (1 of 8 video clips) of an attacking player were projected on a 2 x 2m screen and the player had to react to the video. The RAT was filmed by a Sony HDV Handycam digital video camera for further investigation in perception and response time. For the CODS test players had to change direction 5 meters from the start line, and had trials to the left and the right. Four players from a national rugby league team were used to create the testing videos, which included scenarios which involved normal and deceptive conditions. Forty of the 48 video clips were selected as the training videos, while the remaining eight were used for RAT. The reactive agility training followed a discovery guided method and was done as a warm-up session before their first training session of the day and included 10 video clips that lasted about 15 minutes. Drills were divided into two parts: firstly the players were presented with the occluded video clips. They had to start running forward as soon as the clip started playing and then react as they would during match play. Players received explicit knowledge on the areas to fixate on (shoulders, trunk, hip) for most relevant visual information. In the second part they viewed the same clip but this time unoccluded. The control group continued with their normal warm-up sessions.

CODS did not improve significantly in any of the groups. The reactive agility training group significantly improved their RAT time and performed significantly better than the control group ($p < 0.05$). The reactive agility training group also had significantly faster ($p < 0.05$) perception and response times after the training. From the results it is reasonable to assume that the improvements were due to increased perceptual skills and that it may be related to an improved ability to identify advanced visual cues. The perceptual and decision making components of agility can indeed be trained. The study also showed that this type of improvements is possible through video-based training. Video-based training does not have to be long to deliver improvements and can be used as part of the warm-up. Furthermore fifteen minutes of video-based training delivered significant improvements in RA performance.

Reactive agility in rugby union is an open motor skill that needs be trained in such a manner. It is important to develop the perceptual and decision-making components that accompany RA performance. Improved anticipation, and the ability to recognize advanced visual cues and pattern of play, may all lead to improved RA performance (Young and Wiley, 2010; Gabbett and Benton, 2009; Abernethy *et al*., 2005). It is suggested that RA will, be optimally developed and have the best transfer when done in a sport-specific manner (Wheeler, 2009). Video-based training seems to be an effective method in training the perceptual and decision-making skills involved in RA. Having the simulations resemble match-play as closely as possible, players would be able to learn pattern recognition and they would be able to pick-up how a player moves when performing a certain agility manoeuvre. When they are able to anticipate the player's movement, they would be able to make a decision on their actions earlier, as well as possibly more accurate decisions. It is, however, not always practical to utilize video-based training. In that case skill-based conditioning games have also been shown an effective sport-specific method in developing RA performance (Gabbett, 2006). Game-based training can also provide the athletes with the same type of physiological demands that competition provides (Gabbett, 2003).

D. SUMMARY

A variety of training methods exists to improve agility performance. Straight sprint speed training is a method that seems less successful as little transfer exists between straight speed and change of direction. This implies that specificity is needed during agility training. Programmed conditioning results in greater improvement in agility compared to random conditioning. One of the drawbacks of random conditioning is that it is very difficult to get all players motivated to the same level of effort. Training methods, such as BW locomotion and plyometrics place greater strain on the neuromuscular system and have been shown to improve agility performance. However, these training methods have high physiological demands. Lately, more research is being done on the perceptual factors that influence agility. These perceptual factors are not only trainable, but video-based training proved to be an effective method in doing so. Skill-based conditioning games have also been shown to be an effective alternative method to traditional conditioning. To get the most out of decision-making training the activities should closely resemble scenarios that would occur during competition.

CHAPTER FOUR

PROBLEM STATEMENT

A. SUMMARY OF THE LITERATURE

Two key components are determining factors in RA performance, namely CODS and perceptual and decision-making factors (Young *et al*., 2002). CODS takes into consideration the player's physical ability to make a COD, whereas the perceptual skill looks at the player's ability to interpret and react to a stimulus. Most studies on reactive agility and its perceptual aspects found that this performance characteristics distinguishes between higher and lesser skilled players (Young and Wiley, 2010; Gabbett *et al*., 2008; Farrow *et al*., 2005). Higher-skilled players have the ability to anticipate and predict their opponents' moves and have faster and more accurate responses than their lesser-skilled counterparts (Abernethy and Zawi, 2007; Sheppard *et al*., 2006; Berry *et al*., 2004; Williams and Davids, 1995).

Yotani *et al*. (2011) showed that it is possible to improve response time. It has also been demonstrated that perceptual and decision-making skills are trainable (Serpell *et al*., 2011; Abernethy *et al*., 1999). One of the methods that have been shown to be successful in improving perceptual and decision-making skills is video-based training (Farrow and Abernethy, 2002; Farrow *et al*., 1998; Christina *et al*., 1990; Helsen and Pauwels, 1988). In particular, Serpell *et al*. (2011) and Jackson *et al*. (2006) showed video-based training may be an effective method to improve RA and its perceptual and decision-making components in rugby league and rugby union players. Video footage are used in a variety of ways, including research on the visual search behaviour of elite athletes, the use of video footage as a sport-specific test, to determine decision-making time and prediction accuracy, as well as a method to train perceptual and decision-making skills (Vaeyens *et al*., 2007; Farrow *et al*., 2005; Abernethy, 1991).

It has been proposed that the best way to develop RA and its perceptual and decision-making skills are through a sport-specific manner (Wheeler, 2009). With sport-specific training the athletes will gain an appropriate knowledge base on the constant changing environment presented to them through an open skilled sport such as rugby union. Thus, sport-specific training will enable athletes to produce more effective responses, that may transfer to match-play (Berry *et al*., 2008; Salonikidis and Zafeiridis 2008; Baker *et al.,* 2003).

Rugby union is an open skilled sport in which the players constantly need to react to their teammates, opponents and the movement of the rugby ball. Players need to deliver quick and correct responses to be successful in match-play. Superior perceptual and decision-making skills and evasive side-stepping manoeuvres seem to lead to the most success in tackle breaks in traveling beyond the advantage line (Wheeler *et al*., 2010; Jackson *et al*., 2006; Sayers and Washington-King, 2005).

B. LIMITATIONS IN THE LITERATURE

Most of the research focuses on the testing of RA, and its ability to discriminate between higher-skilled and lesser-skilled athletes. Research also looked at the links between speed, CODS and RA. Very few studies investigated methods to develop RA, or else they only consider the development of planned agility.

A lot of variety exists in the literature on the response method used during video-based training. These responses included voice responses, pressing a computer key and physical responses. It is unclear which method delivers the best motor learning effect and the best transfer to real life match-play. Research on developing RA in rugby union players, and especially through the use of video-based training is also limited.

C. OBJECTIVES OF THE CURRENT STUDY

The primary aim of the study was to compare a video-based training programme and a field-based training programme to improve the reactive agility in rugby union players.

Specific aims

To determine:

1. If a sport-specific video-based training programme at low to moderate intensity would improve reactive agility in rugby union players.
2. If a video-based training programme is an effective alternative method to a field-based training programme to improve reactive agility.
3. If the changes in reactive agility are sustained six weeks after the training.

CHAPTER FIVE

METHODOLOGY

A. STUDY DESIGN

The study followed an experimental design comparing two reactive agility training programmes. There were three groups involved in the study; a control group (C) and two experimental groups namely, the video training group (VT) and the field training group (FT). The two experimental groups followed a six week intervention programme with two reactive agility sessions per week in addition to their general training. Various performance tests were conducted before and after the intervention, as well as a retention test six weeks after the completion of the intervention.

B. PLAYERS

Forty-two male rugby union players aged 18 to 24 years, volunteered to participate in the study. Of these, 27 players completed the entire study. Ten players dropped out due to illness or injury and a further five players did not complete the minimum number of required training sessions. The players were either members of the Maties Rugby Club or Simonsberg Mens Residence first team and were a sample of convenience. Players were first divided into forwards and backs and then randomly divided into one of the three training groups:

1. VT (n = 10): individual sessions where the player watched video clips with rugby union attacking scenarios and responded physically to each.
2. FT (n = 9): sessions in which players performed training sessions (focusing on RA) on the rugby field.
3. C (n = 7): players followed their team training programme and did not receive any additional reactive agility training sessions.

1. Inclusion and exclusion criteria

Players were included if they were between the ages of 18 and 24 and were an active member of a team that was competing at a similar level at university. Players were excluded from the study if they sustained serious injuries that prevented any further participation in the team, if their adherence to the intervention programme or club training programme was less than 80%, or if they did not obtain at least 60% in the multistage shuttle run and repeated sprint tests as calculated from the norms used by Western Province Rugby (personal communication with M. Hillhouse, sport scientist and biokinetist for Maties Rugby Club) (*Table 5.1*).

Table 5.2. Multistage shuttle run and repeated sprint scores to be obtained for inclusion in the study.

Multistage Shuttle Run		**Repeated Sprint**	
Backline	9.4	Backline	480 - 490
Scrumhalf	9.4	Scrumhalf	490 - 500
Loose Forward	9.1	Loose Forward	460 - 470
Locks and Hookers	8.7	Locks and Hookers	440 - 450
Props	7.8	Props	420 - 430

2. Ethical aspects

The study protocol was approved by the Ethics Committee of Research Subcommittee A at Stellenbosch University (Reference number 376/2010). During the players' first contact session with the researcher, the study protocol and informed consent form were verbally explained to all the players and opportunity for questions were provided. The players then signed the consent forms. The study did not involve any invasive procedures or serious risks.

Players were informed that participation was voluntary and they could withdraw from the study at any time, and without any penalty.

C. EXPERIMENTAL DESIGN

The study was part of the pre-season conditioning programme. The Simonsberg group had their first game four weeks into the study intervention and the group from the Maties rugby club all started playing matches two weeks after the completion of the post testing. The study had two experimental groups, while the third group served as a control group. Reactive agility training was done twice a week over a six week period. One of the experimental groups did their training indoors, while the other group trained on the rugby field. Each player in the VT group scheduled his own training time with the researcher. These sessions were primarily in the mornings, with only two players completing their sessions in the afternoons. For both experimental groups, there was at least 48 hours between the reactive agility training sessions. All the sessions for the FT group were scheduled at 6:30 in the morning. All the players, including the C group, attended 4 rugby practice sessions per week.

1. Contact sessions

Contact 1

During the initial visit the study protocol and objectives were explained to all the volunteers. They were asked to sign a consent form after which various anthropometrical and performance tests were conducted to obtain baseline data. The tests and measurements included stature, body mass, percentage body fat, percentage fat free mass, 10m speed, agility and reactive agility and repeated sprint performance. During this visit the players also completed a training history questionnaire to determine past levels of participation (*Table 5.2*). Points were assigned to the highest level played in each year. Points allocated for each level are presented in *Table 5.3*.

Table 5.2. Rugby union playing experience questionnaire.

Rugby experience: level participated

Age	**School**	**"Koshuis"**	**Club**	**Provincial**	**National**
17					
18					
19					
20					
21					
22					
23					
24					

Table 5.3. Points allocation for level of experience.

	School	"Koshuis"	Club	Provincial	National
1st team	3	2	3	4	5
2nd team	2	1			
3rd team	1				

Contact 2

To ensure an all-out effort; the multistage shuttle run to assess aerobic capacity, was completed on a separate day. The second contact session was scheduled within two days of the first contact session.

Contact 3-14

The following twelve contact sessions were spread over six weeks with each player in the experimental group completing two sessions per week. The VT session lasted 10 minutes each and was completed individually by each player. The sessions for the FT group lasted 20 to 30 minutes and were completed by the group as a whole. Additionally, all players attended four rugby practices per week which lasted 90 to 120 minutes. All sessions were conducted by the researcher.

Contact 15 and 16

Only the study outcome variables (speed, agility and reactive agility) were reassessed during these two sessions. Contact session 15 constituted the post-intervention testing, while session 16 followed six weeks later (retention testing).

2. Place of study

All anthropometrical measurements were done in the Sport Physiology Laboratory at the Department of Sport Science (Stellenbosch University). All performance testing were conducted in an indoor sport hall. The training sessions for the VT group were held indoors, while the training sessions for the FT were on a rugby field.

3. Training procedures

Video training (VT) group

Video clips of various rugby attacking scenarios were recorded using experienced rugby union players from the Stellenbosch Rugby Academy. The ideas for the video sessions was obtained from watching video footage of international rugby matches filmed from an elevated view behind the rugby posts so that running lines can clearly be identified, as well as a rugby coaching manual (Groenewald *et al*., 2001). The clips varied from a single player and up to six players per clip. The moves performed in the clips included the side-step, cross-over step, dummy pass, scissor movements, goose step, double dodge, run around and straight running. All the clips allowed the player to react to either the left side, the right side or straight forward. The video training sessions were developed by the researcher.

Each player completed the video training sessions indoors and on his own to ensure that his reaction was purely based on what was happening on the video clip and not due to the reaction of the players or environmental factors. The video clips were projected on a white screen (2.0m x 1.5m) and players were positioned 8m in front of the screen on a marked line. They had to watch the video clip and react according to the movement of the player(s) on the screen. Players were instructed to start moving forward as soon as the clip started and to defend the last player with the ball. There was an eight second gap between each clip, and after each clip they had to move back to the starting line. Eight cones were placed on the floor to indicate the possible direction of their response (*figure 5.2)*. Each video training session comprised of 50 video clips per session and lasted approximately 10 minutes. All the video sessions contained clips with a single player up to six players appearing in random order. Some clips were repeated over sessions and in some sessions the same clip would occur twice. (Appendix D, DVD of all the training sessions included)

Figure 5.1. Players participating in the video training sessions (Photographs by L. Engelbrecht).

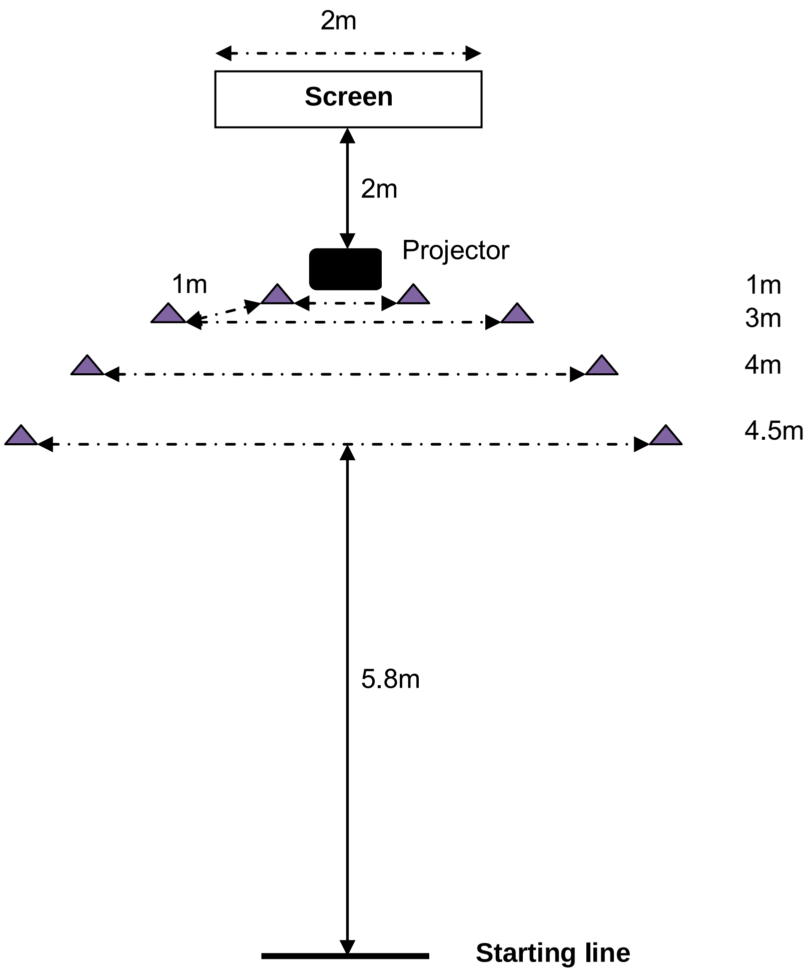

Figure 5.2. Schematic illustration of the layout for the video training sessions.

Field training (FT) group

Training for the field group took place outside on a rugby field. Players participated as a group in these sessions and were instructed to wear their rugby boots during training. These training sessions involved reactive agility drills that encouraged decision-making and pattern recognition. Drills varied from coach command drills, pairs working together, mirror drills and mini-games. These sessions encouraged players to learn to react to auditory cues (the sound of the whistle, the bounce of the ball, sound of a teammate running around a player or coming up to a player's side), as well as visual cues (flight of the ball, opponent running towards a player). See appendix C for more detailed descriptions of the drills.

D. MEASUREMENTS AND TESTS

Anthropometrical assessments were done to obtain the descriptive characteristics of the study sample. The repeated sprint and multistage shuttle run test were done to determine if players were suitable for inclusion into the study, and were only performed at baseline. The dependent (outcome) variables of the study included speed, reactive agility and agility.

1. Anthropometrical measurements

Anthropometrical measurements included stature, body mass and bio-electrical impedance analysis (BIA) to assess percentage body fat and percentage lean body mass.

Stature

Stature was measured with a SECA stadiometer (model 220, Hamburg, Germany). Players were barefoot and their heads positioned in the Frankfurt plane when measurements were taken to the nearest 0.1 centimeter (cm).

Body mass

Body mass was determined using a calibrated electronic scale (UWE BW – 150 freeweight, 1997 model, Brisbane, Australia) and recorded to the nearest 0.1 kilogram (kg). Players were instructed to stand barefoot in the centre of the scale, distributing weight evenly on both legs and looking straight ahead.

Bio-electrical Impedance Analysis (BIA)

The fat and lean mass of the players were measured with a portable body composition monitor (Bodystat Quadscan 4000, Isle of Man, United Kingdom, 2007). Fat mass consists only of adipose tissue, while lean mass comprises the bony skeleton, muscle mass, innards and entire water content of the body. During the BIA procedure a small electrical current (800µA at 50kHz) is sent through the body and an estimate of the resistance of the tissue is obtained. It is assumed that lean tissue provides less resistance than adipose tissue.

Players laid in the supine position, with legs spread apart and limbs not touching the centre of the body, or each other. The right hand and foot were cleaned with alcohol swabs before placing the electrodes on the standard anatomical sites. One electrode was placed on the dorsal side of the hand, one centimeter proximal to the knuckle of the middle finger, while the second electrode was placed on the wrist between the head of the ulna and radius. The third electrode was placed on the dorsal surface of the foot, between the hallux and the third phalange and the fourth electrode was placed between the lateral and medial malleoli. Players were asked to empty their bladders prior to the measurement and refrain from drinking alcohol and caffeine 24 hours before testing.

2. Speed, agility and reactive agility

Oliver and Meyers Test

The Oliver and Meyers (2009) test battery includes three tests, namely a 10m linear sprint, a 10m planned change of direction agility sprint, with a single change of direction to the left and right and lastly a 10m reactive agility sprint also to the left and right. Photoelectric timing gates (Smartspeed, Fushion Sport, Brisbane, Australia) were used to record sprint times. Three timing gates were placed in a straight line at 0m, 5m and 10m for the linear sprint test. The fourth and fifth timing gates were placed to the left and the right of the course in a Y-formation; these were used for the agility and reactive agility sprint test (*Figure 5.3*).

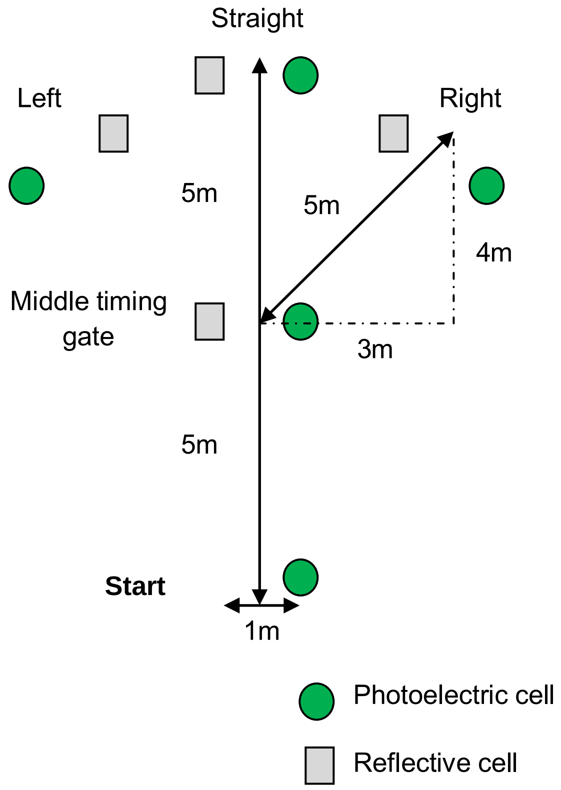

Figure 5.3. Schematic illustration of the Oliver and Meyers (2009) speed, agility and reactive agility test.

Figure 5.4. The 10m speed, agility and reactive agility test of Oliver and Meyers (2009) (Photographs by L. Grobler).

Players started with their leading foot 0.3m behind the first timing gate for all the sprints. The players first completed two trials of the linear sprint, after which they performed a planned change of direction agility sprint always to the left (L) first and then to the right (R), and then they performed the reactive agility test. When the players crossed the middle timing gates during the reactive agility test, coloured lights (red, green, blue) were activated either on the left or right timing gates which indicated the direction in which the player had to sprint (F*igure 5.4)*. The Smartspeed system controls the reactive element during the 1-1-2 formation, allowing objective evaluation of reactive agility. A 40 to 45 millisecond lag time exists between breaking the middle timing gates and the activation of the lights. Players performed repeated trials of the reactive agility test until they completed two sprints to either side or a total of eight trials, whichever came first. A rest period was incorporated by not letting a player complete all his trials at once, but rather allowing players to go one after the other. The test was conducted indoors.

The coefficient of variance (95% confidence interval) for the straight speed, planned agility and reactive agility was 2.5% (2.1 - 3.1), 3.3% (2.7 - 4.1) and 3.0% (2.5 – 3.7) respectively (Oliver and Meyers, 2009). The best effort was given as the time (s) in the linear sprint. The values for the planned and reactive sprints were analyzed separately (L and R), as well as together as a combined agility sprint time, provided that they do not differ by more than 10%. The best effort was used for the planned agility and the means of all the trials was used for the reactive agility.

Three-cone drill test

The three-cone drill test was another planned agility test. This test was chosen due to its popularity in rugby league and football as it resembles the type of change of direction that may occur in rugby union (Gabbett *et* al., 2008; Gabbett, 2006; Webb and Lander, 1983). During a pilot study on seven participants the test-retest reliability was determined as r = 0.92.

Three cones were placed five meters apart in an inverted "L" configuration. Players were instructed to start at cone A, run to cone B turn around and run back to A. As soon as they arrived at cone A they had to change direction again and sprint as fast as possible the "L" configuration, from A to B to C and the same way back (*Figure 5.5)*.

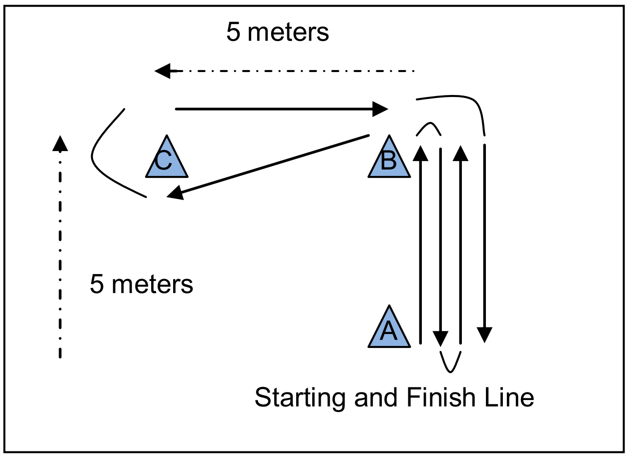

Figure 5.5. Schematic illustration of the three-cone drill test. (Adapted from Webb and Lander, 1983).

Each participant completed three trials with 10 seconds rest between each trial. Times were recorded to the nearest 0.01s using a stopwatch. The fastest time was used as the final score.

3. Anaerobic capacity and aerobic endurance

Repeated sprint

A 35m distance was marked with cones in five meter intervals. Players lined up at the starting line and on the “Go” command ran towards the first line of cones five meters away, touched the ground with their fingers and returned to the starting line, touched the ground and then ran to the second line of cones. They had to repeat this pattern of running for 30s, after which they had a 35s rest interval before starting again. Players had to complete six of these 30s runs.

The distance for each 30s trial was recorded and added together to obtain the total distance covered in the six trials. This was only performed once and the players performed the test in groups of eight.

Multistage shuttle run

A distance of 20m was marked with cones. Players lined up on one end and were instructed to listen to a recording which instructed them throughout the test. Players had to run between the lines and be on the 20m marked line when the recording made a bleep sound. When players failed to reach the line in time for a second time they were eliminated from the test. The level and stage that each player achieved were recorded and was later converted to a maximal cardiovascular capacity estimate (VO_2max) (Léger and Lambert, 1982).

E. STATISTICAL ANALYSIS

Statistical analysis was performed using Microsoft Office Excel (Windows Vista 2007). Data in tables and figures are reported as mean $\pm$ standard deviation (SD). The relationships between various anthropometric and performance outcome variables were determined with Pearson correlation coefficients. The strength of the correlations were determined according to the following criteria, $r = 0$: no correlation, $r = \pm 1$: perfect correlation, $0.75 \leq r \leq 1$: strong correlation, $0.50 \leq r \leq 0.74$: moderate to good correlation, $0.25 \leq r \leq 0.49$: moderate correlation, $0.00 \leq r \leq 0.24$: weak correlation. A single factor ANOVA was used to analyze the descriptive data. The level of significance for all analyses was set at $p \leq 0.05$.

Relative changes (%) in performance between groups are expressed with 90% confidence limits. The effect sizes of the data were determined using a method based on the magnitude of changes. The smallest worthwhile change, SWC (smallest practically important effect) was calculated (0.2 x between-participant SD, based on Cohen's effect size principle) for between-group comparisons to determine if the training programmes were beneficial, unclear or had no practical significant effect on performance. Chances of beneficial / trivial / no practical significant effect were qualitatively assigned as follows: < 1%, almost certainly not; < 7% probably not; < 25% possibly not; < 50 <, trivial / unclear; < 75% possibly; < 93% probably; < 99% almost certainly.

Figure 5.6 illustrates the analysis for the between group comparisons, i.e. to determine if one intervention resulted in more practically meaningful changes than the other. For example, to determine if FT had a greater effect on RA compared to VT, the smallest worthwhile change was calculated (in this case 1.2%), meaning that for an intervention to be practically meaningful, it had to result in a change in the outcome variable that is greater than the SWC. The change in RA after the FT intervention was then compared to the change in RA after the VT intervention (ΔFT - ΔVT). If a positive difference was observed, it means that FT resulted in a greater change in RA than VT. If a negative difference was observed, it means that VT resulted in a greater change in RA than FT. This relative change between interventions was described in qualitative terms, for instance one programme was *possibly more beneficial* to improve RA than the other.

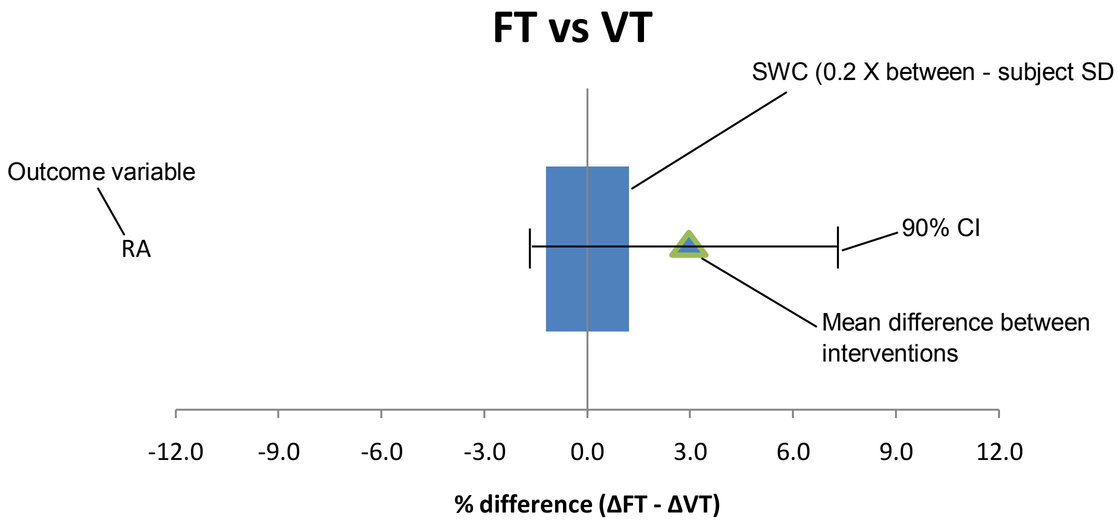

Figure 5.6. Example of a graph for between-group comparisons

CHAPTER SIX

RESULTS

A. DESCRIPTIVE CHARACTERISTICS

The physical and physiological characteristics of the participants are summarized in *Table 6.1*. The 26 players that participated in the study were healthy male rugby union players between the ages of 19 and 23 years of age. Players had a minimum of 10 years of rugby playing experience, represented their schools' first team and at the time of the study were playing at club level (Maties Rugby Club) or university residence first team (Simonsberg). In addition to the intervention programme, the players participated in their regular rugby training four times a week and each session lasted approximately 90 minutes. There were no statistically significant differences in any of the descriptive characteristics among the three groups ($p > 0.05$).

Table 6.1. Physical and physiological characteristics of the players.

Characteristics	**C (n = 7)**		**VT (n = 10)**		**FT (n = 9)**	
	Mean ± SD	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**
Age (years)	22 ± 1	20 -23	21 ± 1	19 - 23	20 ± 1	19 - 22
Height (cm)	184 ± 6.4	174 - 191	184 ± 10.2	171 - 206	185 ± 6.9	178 - 199
Body mass (kg)	88.8 ± 10.7	74.2 - 103.3	92.0 ± 11.6	77.4 - 108.8	94.0 ± 11.9	72.0 - 114.4
% BF	16 ± 3.8	12.0 - 23.6	15 ± 3.9	8.7 - 20.5	15 ± 4.5	8.5 - 24
% LBM	84 ± 3.8	76.4 - 88	85 ± 3.9	79.5 – 91.3	85 ± 4.5	76 - 91.5
RS (m)	700 ± 37	645 - 755	727 ± 15	715 - 760	694 ± 47	610 - 770
Estimated VO_{2max} ($ml.min^{-1}.kg^{-1}$)	52.2 ± 3.3	47.4 - 57.4	52.5 ± 3.6	46.8 - 58.5	52.5 ± 7.5	40.5 - 67.5
Experience (rating)	11 ± 4	7 - 18	13 ± 3	9 - 17	11 ± 3	8 - 16

% BF, percentage body fat; % LBM, percentage lean body mass; RS, repeated sprint; VO_{2max}, maximum aerobic capacity

B. OUTCOME VARIABLES

1. Speed, agility and reactive agility

a. Absolute changes

A comparison between the three groups for the results on the 10m speed, planned change of direction speed and reactive agility are presented in *Table 6.2*. No statistically significant differences existed between the groups for these performance parameters during pretesting ($p > 0.05$). After the intervention and retention period no statistically significant differences existed in speed performance between the three groups ($p > 0.25$) and the experimental groups did not differ significantly from the C group in their CODS performance. VT performed significantly better than FT in CODS after the intervention period ($p = 0.028$), however, this difference in performance disappeared at the retention test. The RA performances for both experimental groups were significantly better than the C group after the intervention ($p = 0.0013$; $p = 0.0003$), but there were no statistically significant differences in RA between VT and FT at any time point.

Table 6.2. Ten meter sprint times for straight sprint speed, planned change of direction speed and reactive agility.

Time (s)		C Mean ± SD	VT Mean ± SD	FT Mean ± SD
Speed		1.91 ± 0.09	1.86 ± 0.08	1.89 ± 0.07
CODS	Pre	2.04 ±0.14	1.97 ± 0.08	2.02 ± 0.14
Reactive Agility		2.75 ± 0.16	2.79 ± 0.18	2.88 ± 0.13
Speed		1.96 ± 0.10	1.85 ± 0.12	1.93 ± 0.10
CODS	Post	2.05 ± 0.12	1.88 ± 0.09	2.03 ± 0.14#
Reactive Agility		3.00 ± 0.12	2.69 ± 0.15*	2.70 ± 0.15*
Speed		1.89 ± 0.15	1.85 ± 0.08	1.87 ± 0.05
CODS	Retention	1.99 ± 0.16	1.94 ± 0.12	1.96 ± 0.06
Reactive Agility		2.69 ± 0.10‡	2.70 ± 0.19	2.71 ± 0.13

CODS, Change of direction speed; * $p < 0.01$ from C; # $p < 0.05$ from VT; ‡ Significant difference post-retention ($p < 0.01$).

b. Within-group changes

The within-group relative changes from baseline of the three groups are presented in *Figure 6.1 - 6.3*. Changes in speed performance following the intervention and retention periods were similar in FT and C with a mean percentage difference at post testing of only 0.7 ± 3.4%. The VT group had the fastest average speed times, but these were not statistically significantly faster compared to the other groups at any time point. Speed practically stayed the same in the VT group with a 0.9 ± 7.9% difference pre to post, and 0.7 ± 5.1% difference post to retention.

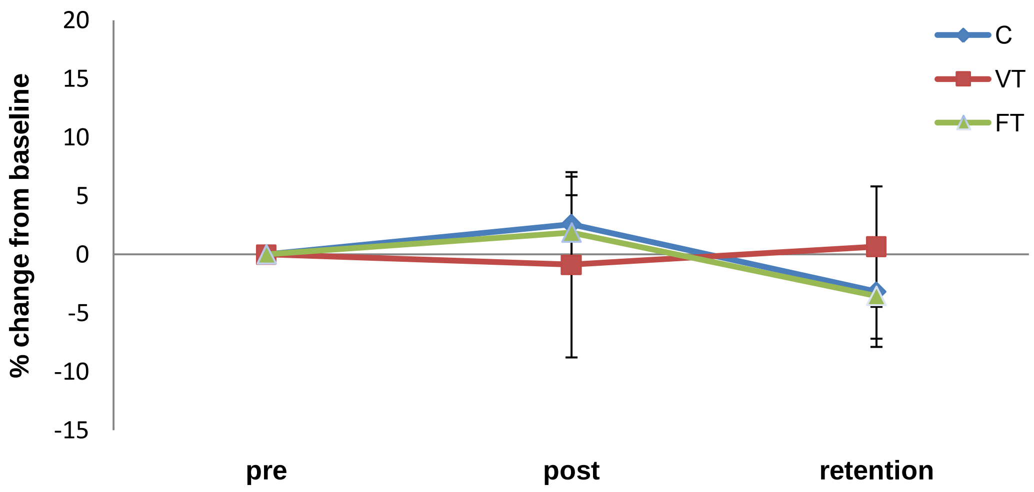

Figure 6.1. Within-group changes from baseline in 10m speed performance.

Changes in CODS performance following the intervention were once again similar in FT and C, with a negligible small mean difference (0.3 ± 4.5%). Following the retention period FT had a greater improvement in CODS than C, with a relative mean difference of 1.8 ± 4.6%, however, this difference was not statistically significant. VT was significantly faster than FT after the intervention, but also significantly slower than FT and C following the retention period ($p < 0.05$).

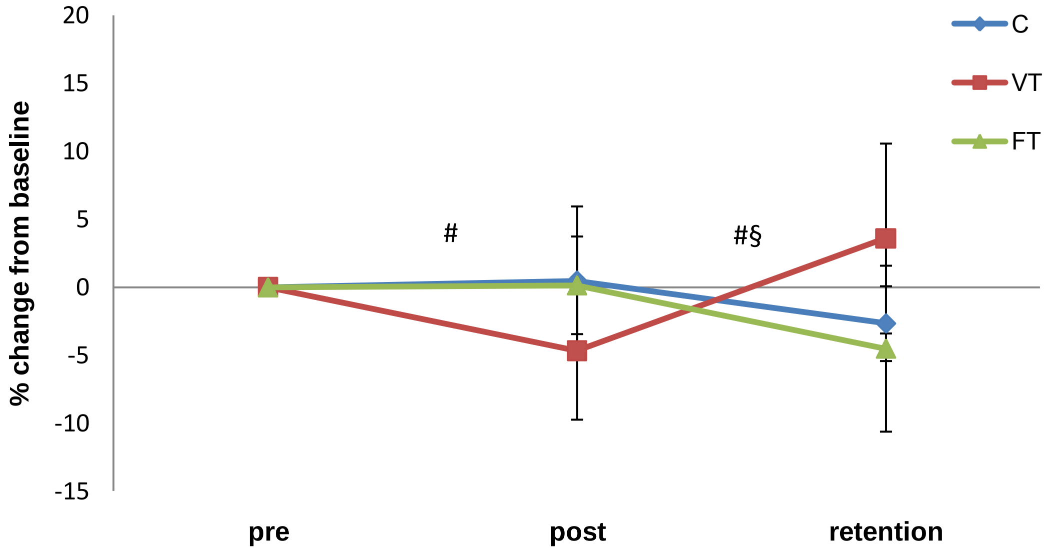

Figure 6.2. Within-group changes from baseline in CODS performance. # p < 0.05 between VT and FT. § p < 0.05 between VT and C.

The C group had a significant decrease in RA performance after the intervention period, but improved their RA performance significantly after the retention period ($p < 0.05$). In contrast, VT and FT significantly improved their RA performance after training ($p < 0.05$), but showed slight decrements in performance following the retention period (VT: 0.8 $\pm$ 7.7% decrease; FT: 1.2 $\pm$ 4.6% decrease ($p > 0.05$).

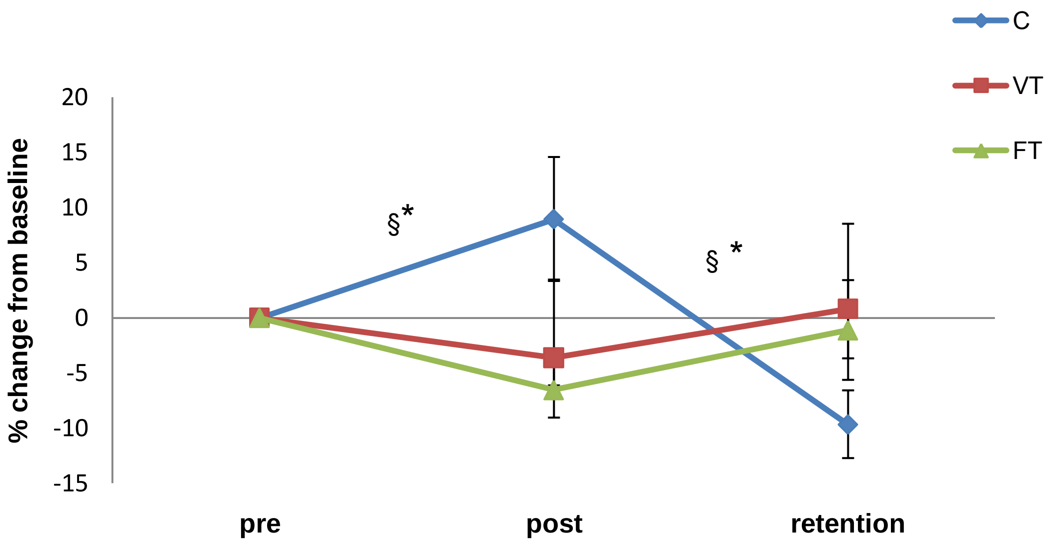

Figure 6.3. Within-group changes from baseline in RA performance. § p < 0.01 between VT and C; * p < 0.01 between FT and C.

c. Between-group comparisons for the training period

The relative changes (mean difference ± 90% confidence limits) and qualitative outcomes for the between-group analysis in speed, CODS and RA from pre to post testing are reported in *Figure 6.4* (a-c). VT was possibly more beneficial to improve 10m sprint time than FT (2.7 ± 5.0% faster) and C (3.6 ± 5.3% faster). VT was also probably more beneficial to improve CODS than FT (4.7 ± 3.6% faster), as well as C (5.3 ± 4.8% faster). FT provided no clear benefit compared to rugby training alone (C) to improve speed and CODS. Both VT and FT are almost certainly more beneficial to improve RA compared to rugby training alone (C), with differences in the training effect of 13.4% (± 5.6) and 16.7% (± 4.4), respectively. Furthermore, FT is possibly more beneficial than VT to improve RA (3.0 ± 4.4%).

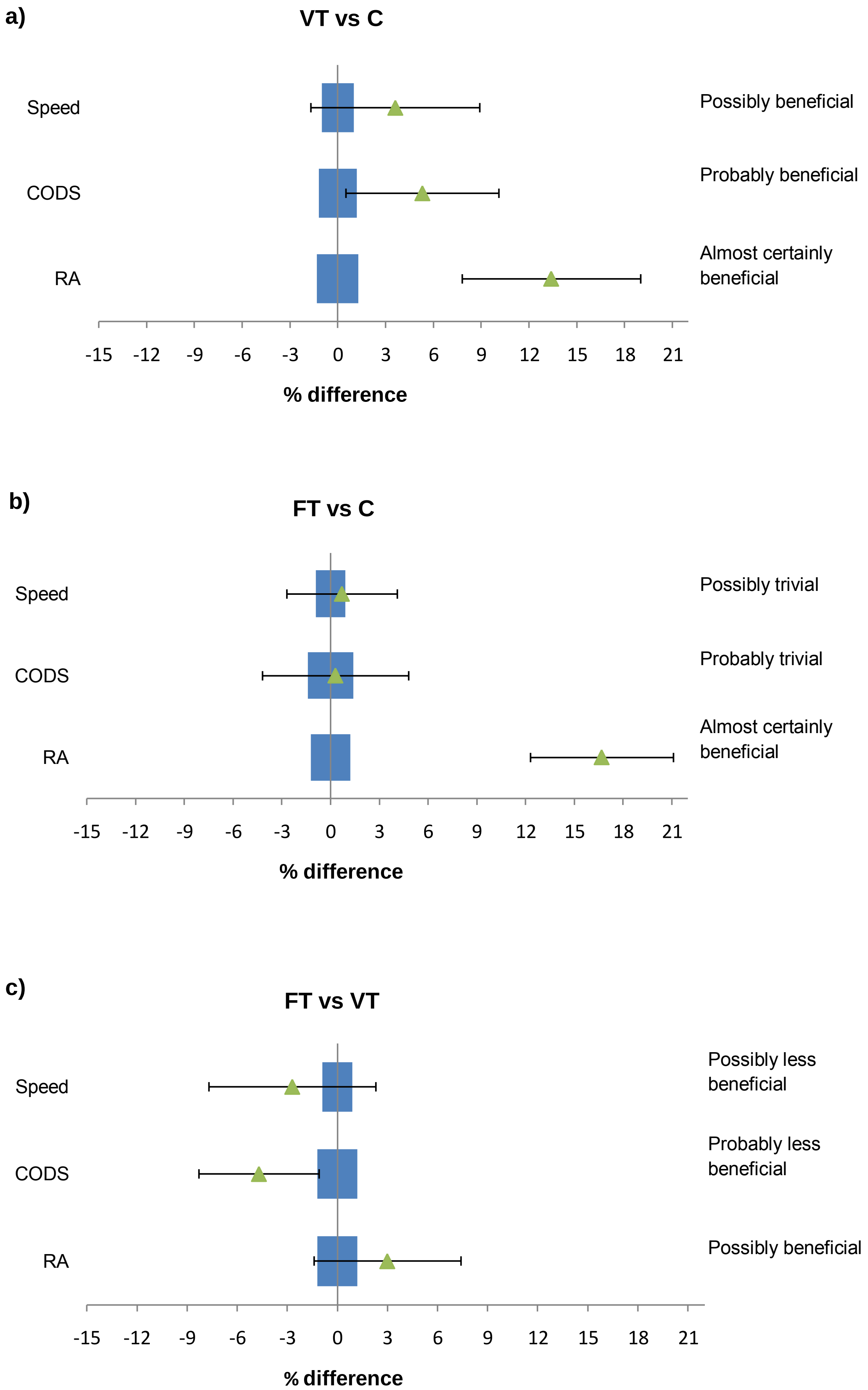

Figure 6.4. Relative changes and qualitative outcomes for the training effect in speed, change of direction speed and reactive agility in **a)** VT versus C **b)** FT versus C and **c)** FT versus VT.

d. Between-group comparisons for the retention period

Figure 6.5 (a-c) illustrates the relative changes (mean difference ± 90% confidence limits) and qualitative outcomes between the groups for the retention period. Albeit not a statistically significant change, both FT and C improved their speed performance after the retention period, but FT did not facilitate greater improvements in speed than C. The VT group showed no significant change in speed after the retention period (0.66 ± 5.14%), but the average time was still faster than FT and C after the retention period.

VT was probably less beneficial than both FT and C to maintain CODS after the retention period, with FT resulting in an 8.4% (± 6) and C in a 6.1% (± 5.2) greater improvement in CODS compared to VT. Both FT and C improved their CODS times after the retention period, however, FT was not more successful in improving CODS compared to C (only an 1.8 ± 4.6% greater improvement in FT).

The magnitude of change in RA following the retention period was similar for VT (0.8 ± 7.7%) and FT (1.2 ± 4.6%), while C improved significantly (9.7 ± 3.1%) after the retention period. This improvement in RA was almost certainly more than the changes seen in VT (10.0 ± 5.7% more) and FT (8.2 ± 3.9% more), with no differences between FT and VT.

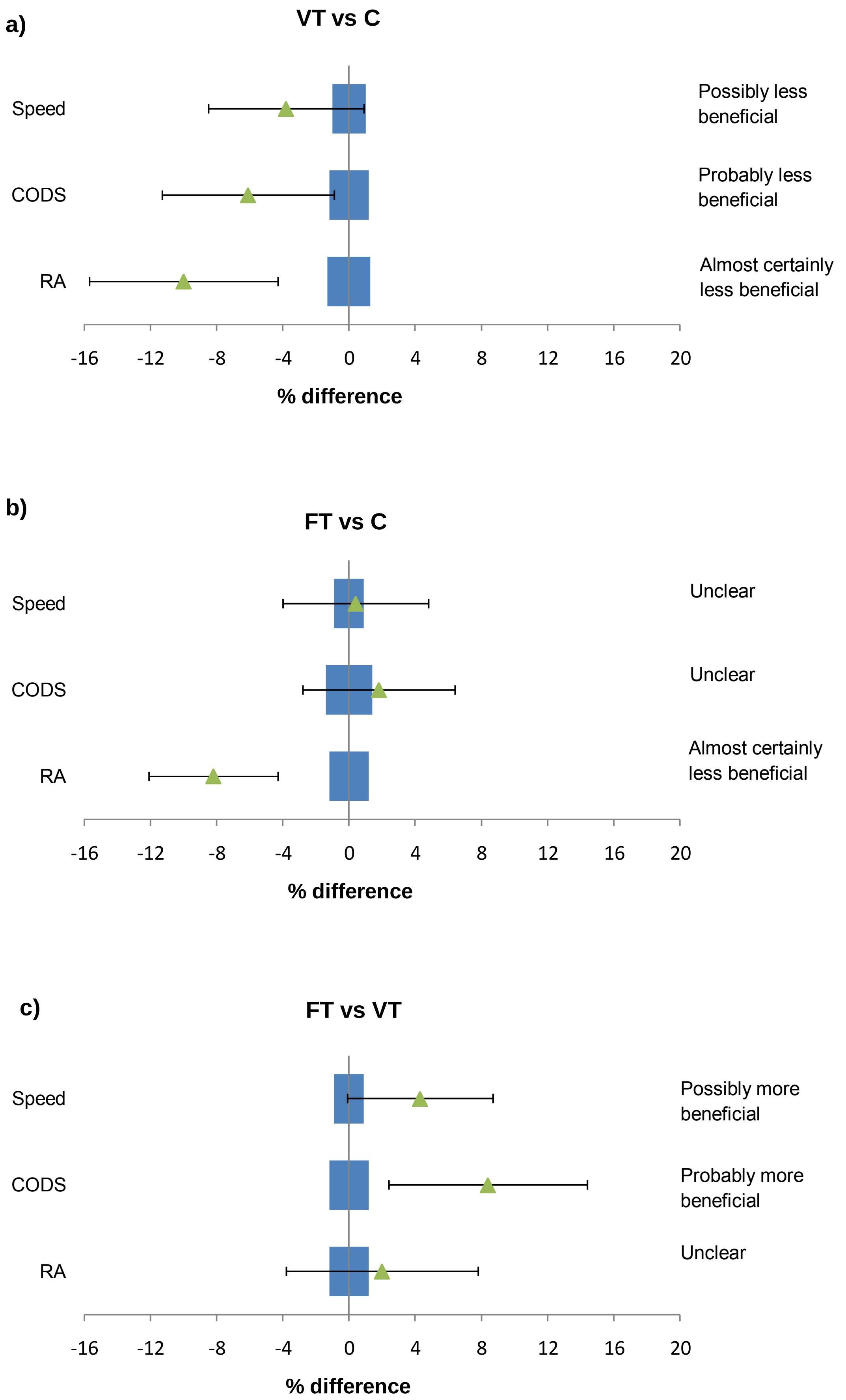

Figure 6.5. Relative changes and qualitative outcomes for the retention effect in speed, change of direction speed and reactive agility **a)** VT versus C **b)** FT versus C and **c)** FT versus VT.

2. Agility – three-cone drill

a. *Absolute changes*

The absolute values (mean ± SD) for planned agility performance in the three-cone drill test are presented in *Table 6.3*. No statistically significant differences existed between any of the groups at any of the time points ($p > 0.07$).

Table 6.3. Agility sprint times

Time (s)		C Mean ± SD	VT Mean ± SD	FT Mean ± SD
	Pre	8.85 ± 0.54	8.60 ± 0.49	8.85 ± 0.56
Three-cone agility	Post	8.25 ± 0.56	8.32 ± 0.23	8.88 ± 0.56
	Retention	8.47 ± 0.66	8.38 ± 0.39	8.70 ± 0.27

b. *Within-group changes*

The relative percentage changes over time for each group are represented in *Figure 6.6*. Although no statistically significant differences existed between the groups, C improved significantly after the intervention period ($p < 0.05$), but also lost all of these gains after the retention period. Performances after the intervention period were significantly different between VT and FT, and FT and C ($p < 0.05$), however, there were no differences in performance after the retention period.

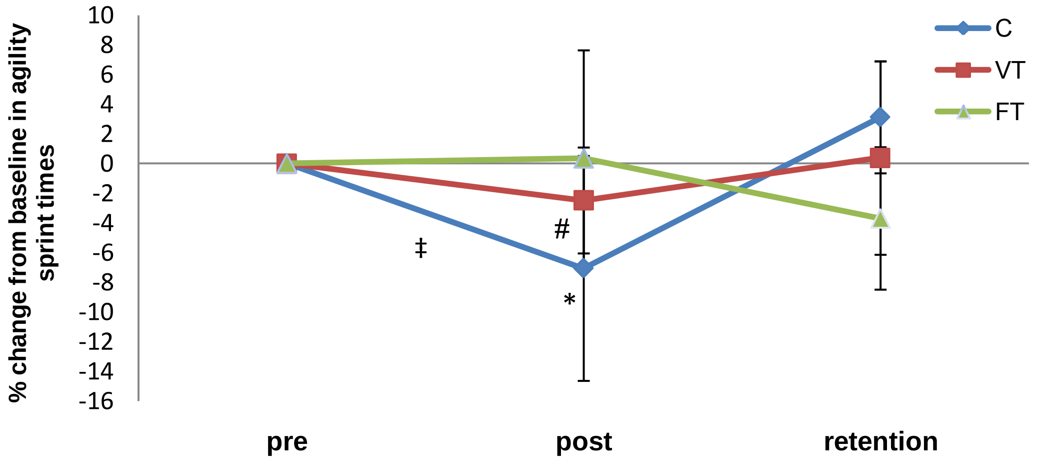

Figure 6.6. Within group relative changes from baseline in agility sprint performance. ‡ Significant difference ($p < 0.01$) pre - post intervention in C; # $p < 0.05$ between VT and FT; * Significant difference ($p < 0.05$) between FT and C.

c. Between-group comparisons for the training period

The relative changes (mean difference ± 90% confidence limits) between the three groups are presented in *Figure 6.7.* Both VT and FT failed to facilitate greater improvements in agility sprint performance than rugby training alone (C). FT was the only group who performed worse after the intervention period and this programme was also possibly less beneficial than VT to cause changes in agility sprint performance. VT resulted in 2.8% (±5.0) faster times than FT after the training period, although this change is only possibly more beneficial than FT.

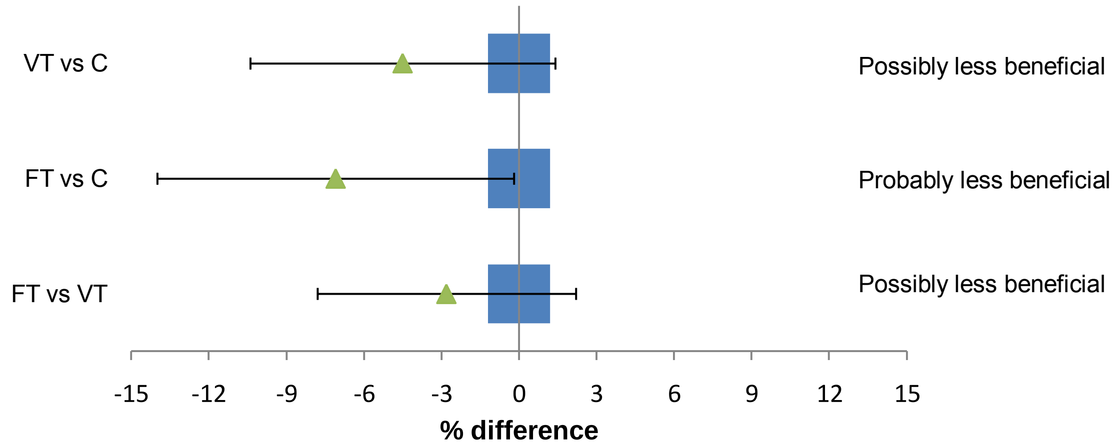

Figure 6.7 Relative changes and qualitative outcomes pre to post intervention in agility sprint performance.

d. Between-group comparisons for the retention period

The relative changes (mean difference ± 90% confidence limits) between the three groups after the retention period are presented in *Figure 6.8.* FT was the only group to improve their agility sprint performance after the retention period (3.7 ± 4.8%). The smallest change after the retention period occurred in the VT group with only a 0.4 ± 6.5% difference in the average times. VT was possibly better than C (2.8 ± 6.8%) and FT was probably better than C (7.0 ± 6.8%) in retaining agility times after six weeks.

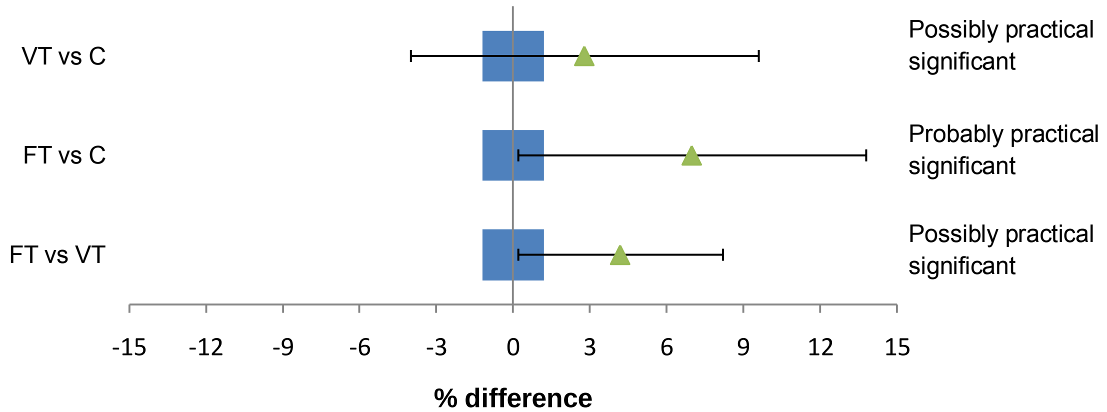

Figure 6.8. Relative changes and qualitative outcomes in agility sprint performance after the retention period.

3. Further analysis of CODS and RA performance

a. Absolute changes

Both CODS and RA was measured to the left and to the right. *Table 6.4* summarizes the absolute values (mean ± SD) of CODS to the left and right. Overall, VT performed significantly better than C ($p < 0.01$) and FT ($p < 0.05$) in both directions. In the FT group there was a significant difference between CODS to the left and right after the intervention ($p = 0.04$).

Table 6.4. Change of direction speed to the left and the right.

Time (s)		C Mean ± SD	VT Mean ± SD	FT Mean ± SD
CODS Left	Pre	2.04 ± 0.14	1.97 ± 0.08	2.06 ± 0.17
CODS Right		2.04 ± 0.15	1.95 ± 0.09	1.99 ± 0.14
CODS Left	Post	2.03 ± 0.14	1.86 ± 0.09	2.01 ± 0.15
CODS Right		2.06 ± 0.11	1.92 ± 0.12	2.05 ± 0.13*
CODS Left	Retention	1.94 ± 0.20	1.92 ± 0.11	1.94 ± 0.07
CODS Right		2.03 ± 0.15	1.96 ± 0.13	1.97 ± 0.07

CODS Left, Change of direction speed to the left; CODS Right, Change of direction speed to the right.

* Significantly different ($p < 0.05$) pre - post intervention from left.

The absolute values of RA to the left and right are presented in *Table 6.5*. A significant difference existed between left and right RA from pre to post intervention in C ($p = 0.04$). VT and FT were both significantly better than C for RA to the left and right, post intervention ($p < 0.05$). Both RA to the left and right were improved in C after the retention period, and these changes were significantly better than for VT and FT ($p < 0.01$).

Table 6.5. Reactive agility to the left and the right.

Time (s)		C Mean $\pm$ SD	VT Mean $\pm$ SD	FT Mean $\pm$ SD
RA Left	Pre	2.71 $\pm$ 0.22	2.75 $\pm$ 0.15	2.93 $\pm$ 0.23
RA Right		2.79 $\pm$ 0.18	2.83 $\pm$ 0.26	2.84 $\pm$ 0.15
RA Left	Post	3.13 $\pm$ 0.27	2.71 $\pm$ 0.22§	2.70 $\pm$ 0.24#
RA Right		2.88 $\pm$ 0.18*	2.68 $\pm$ 0.15‡	2.70 $\pm$ 0.15#
RA Left	Retention	2.66 $\pm$ 0.10	2.70 $\pm$ 0.23§	2.75 $\pm$ 0.14#
RA Right		2.73 $\pm$ 0.10	2.78 $\pm$ 0.48	2.65 $\pm$ 0.14

RA Left, Reactive agility to the left; RA Right, Reactive agility to the right

* Significantly different (p < 0.05) pre - post intervention from left; § p < 0.01 between VT and C; and ‡ p < 0.05 between VT and C. # p < 0.01 between FT and C.

b. Within-group changes

The percentage changes over time in CODS is illustrated in *Figure 6.9* (a and b) and RA in *Figure 6.9* (c and d). There were no statistically significant differences in CODS to the left and right in any of the three groups at any time point ($p > 0.05$). In both cases VT performed best after the intervention, however, the differences between the groups were not statistically significant.

C had a significant reduction ($p < 0.01$) in RA performance to the left after the intervention period, but a significant improvement ($p < 0.01$) following the retention period. Both experimental groups were significantly better in RA to the left and right compared to C following the intervention period ($p < 0.01$), however, after the retention period these gains were lost.

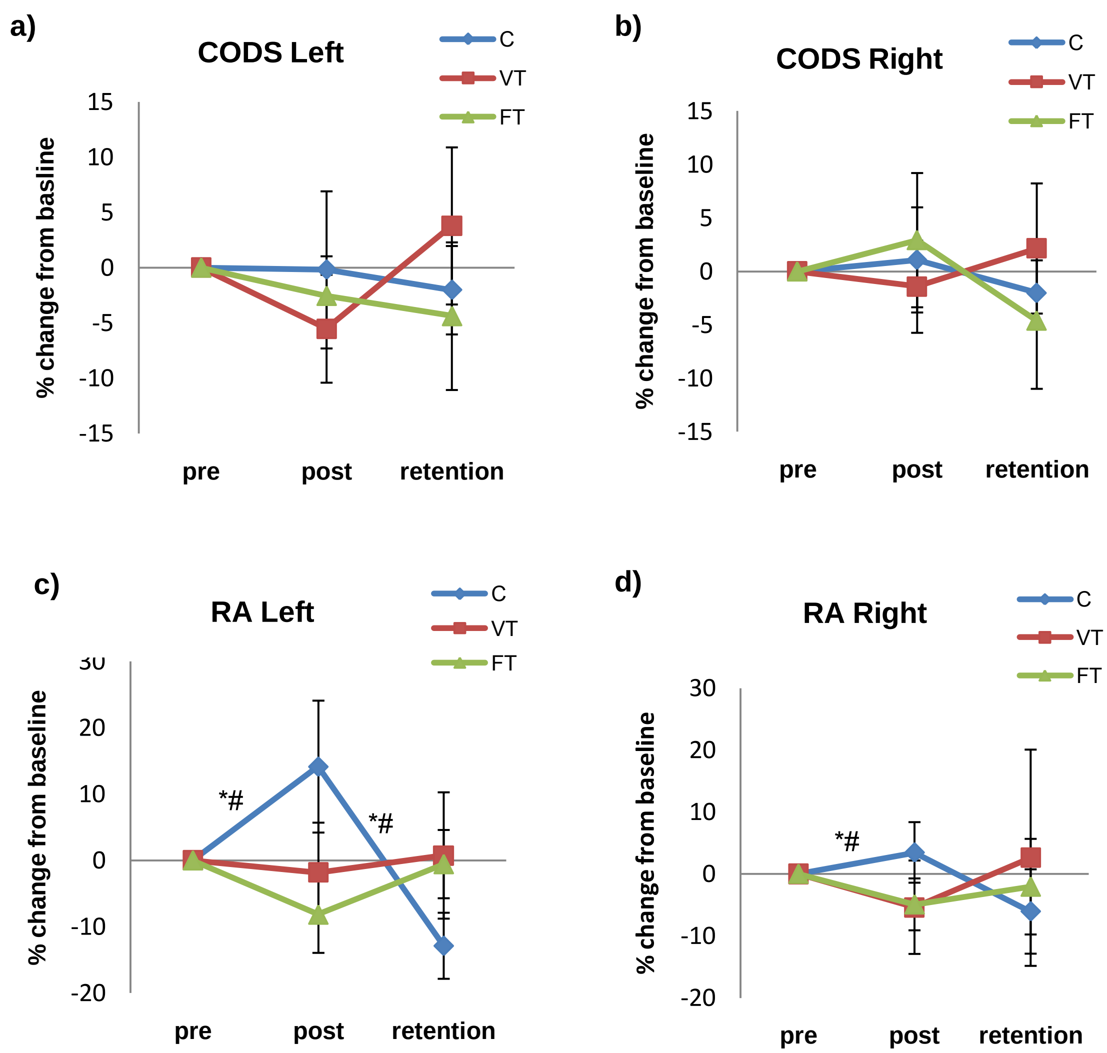

Figure 6.9. Within group relative changes (mean + SD) for **a)** CODS to the left **b)** CODS to the right **c)** RA to the left and **d)** RA to the right. # Significant difference ($p < 0.05$) between C and VT; * Significant difference ($p < 0.01$) between C and FT.

c. Between-group comparisons for the training period

Figure 6.10 (a - c) illustrates the relative changes (mean difference ± 90% confidence limits) and qualitative outcomes after the intervention between the groups for CODS and RA to the left and right. The VT group had a 5.5 ± 4.9% increase in CODS performance to the left, with only a 1.9 ± 7.5% improvement in RA to the left following the intervention period. Almost the exact opposite was seen in their performance to the right with a 1.4 ± 4.3% improved time in CODS and 5.4 ± 7.5% improvement in RA. In both directions, VT was possibly better than FT (L: 2.9 ± 3.5%; R: 4.1 ± 4.6%) and C (L: 5.5 ± 5.8%; R: 2.5 ± 4.2%) to improve CODS. It is unclear if a difference exists between FT and C in the development of CODS to the left and right.

Both VT (17.4 ± 8.4%) and FT (25 ± 8.1%) were almost certainly better than rugby training alone (C) to improve RA to the left, while FT was probably better than VT (6.5 ± 5.5%) to improve RA to the left. VT was probably better than C (9.3 ± 5.5%) to improve RA to the right, while FT was almost certainly better than C (8.7 ± 4.2%) for the same direction. It is unclear whether there is a difference between VT and FT to improve RA to the right (0.5 ± 5.0%).

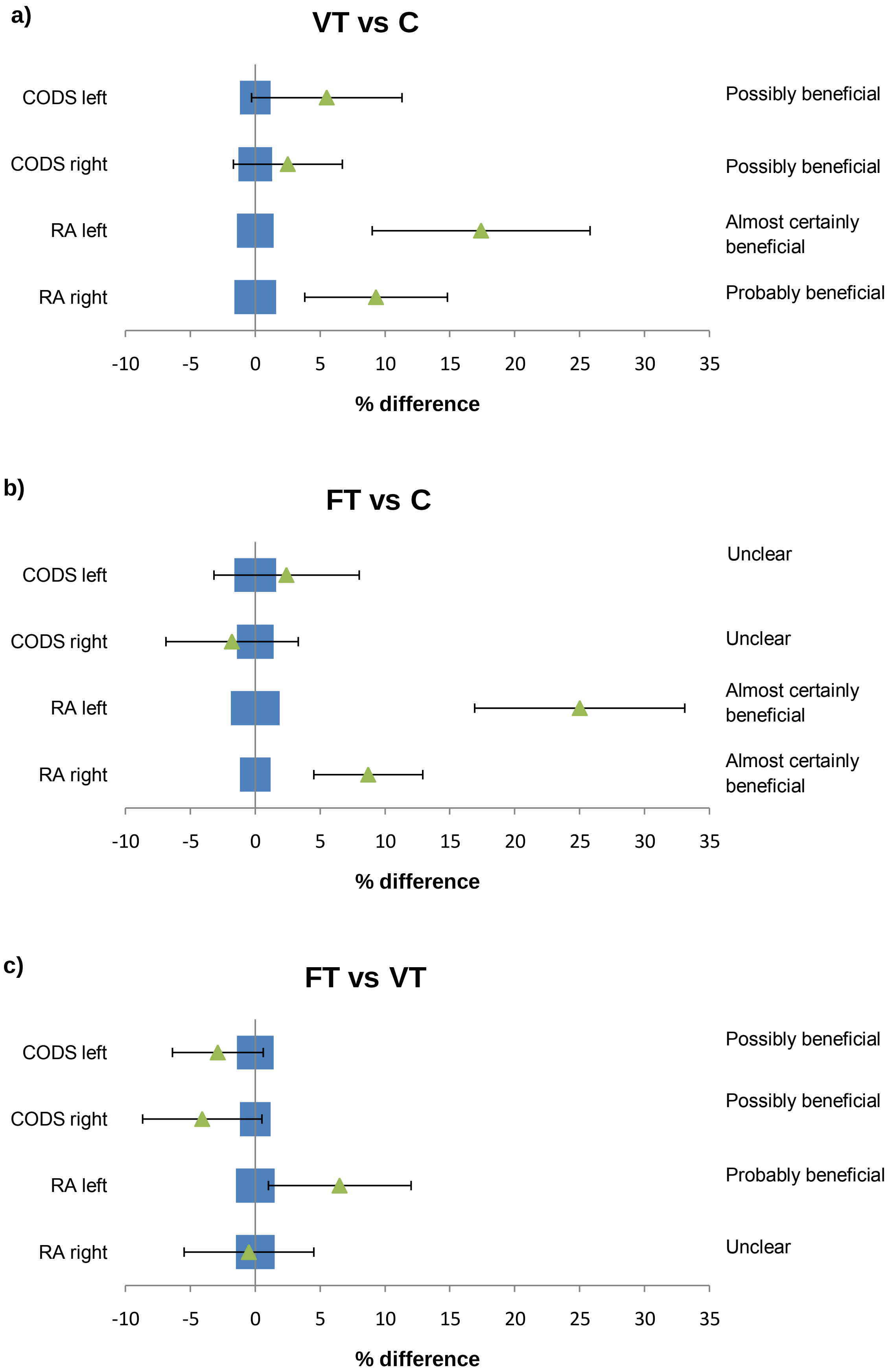

Figure 6.10. Relative changes and qualitative outcomes in CODS and RA to the left and right pre to post intervention in **a)** VT versus C **b)** FT versus C and **c)** FT versus VT.

d. Between-group comparisons for the retention period

The relative changes and qualitative outcomes in CODS and RA to the left and right after the retention period are presented in *Figure 6.11* (a - c). The gains that the VT group made in CODS in both directions were lost after the retention period. CODS left dropped by 3.8 ± 7.1% and CODS to the right dropped by 2.2 ± 6.1%. Thus, VT was not more beneficial than rugby training alone (C) to maintain CODS to the left and right. Similarly, there were no differences in the CODS responses of the FT and C groups after the retention period. Since the VT group performed worse after the retention period, while the FT group improved slightly, the analysis indicate that FT may be more beneficial than VT during the retention period.

There were significant improvements in RA to the left and right after the retention period in C (12.9 ± 4.5% and 6.1 ± 6.8%, respectively) and these changes were more than for VT and FT. Only small changes in RA were observed for the intervention groups in both directions. There was no clear difference in the changes for RA to the left between FT and VT, however, FT showed a greater improvement in RA to the right compared to VT after the retention period.

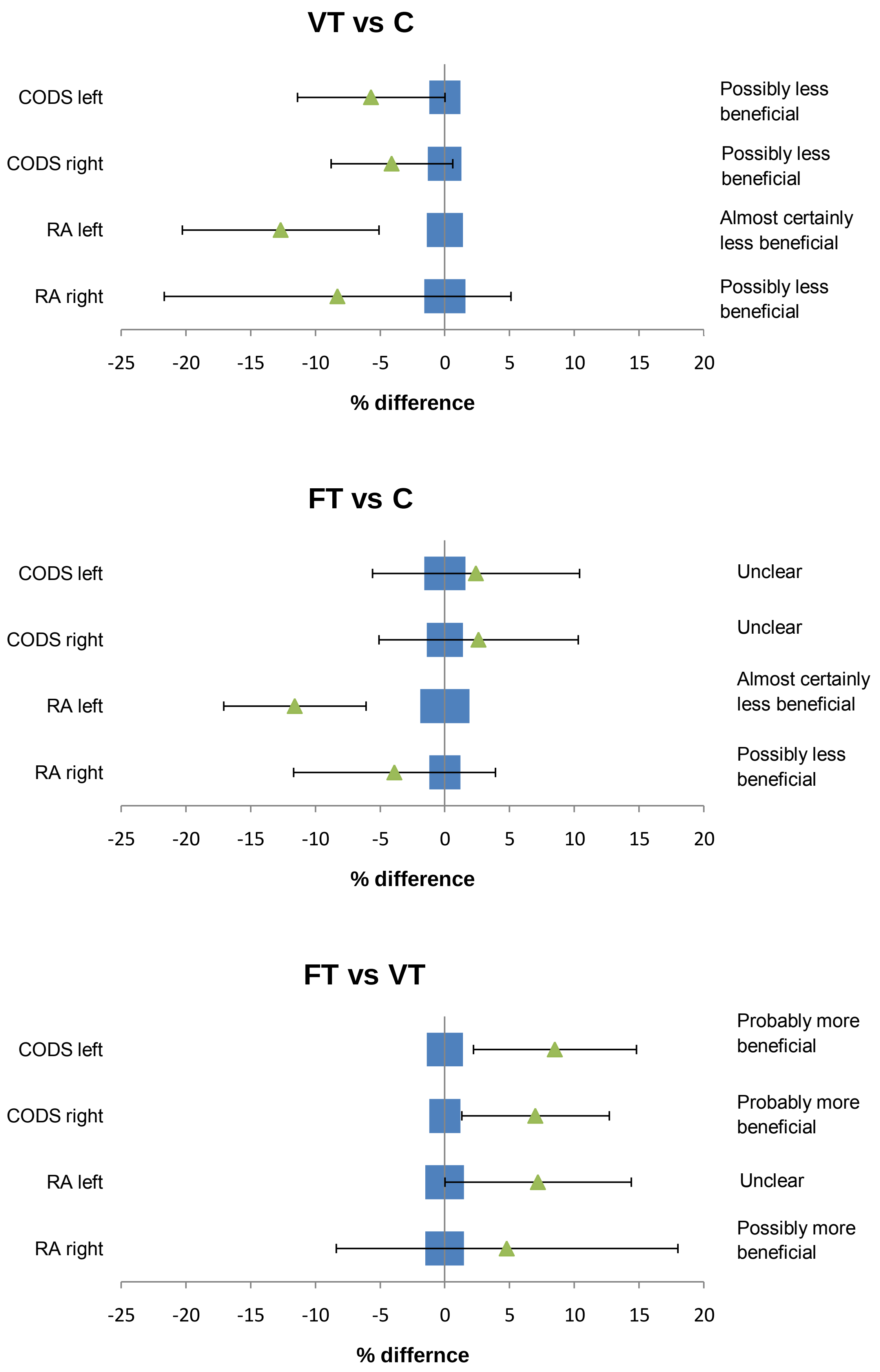

Figure 6.11. Relative changes and qualitative outcomes in CODS and RA to the left and right post to retention testing in **a)** VT versus C **b)** FT versus C and **c)** FT versus VT.

C. CORRELATIONS

The relationships between straight sprint speed over a ten meter distance, CODS and RA were determined with the values obtained during pre testing (*Figure 6.12*). A strong relationship existed between straight speed and CODS (r = 0.78) and a weak correlation between straight speed and RA (r = 0.05). Only a moderate relationship exists between CODS and RA (r = 0.29). *(Table 6.6).*

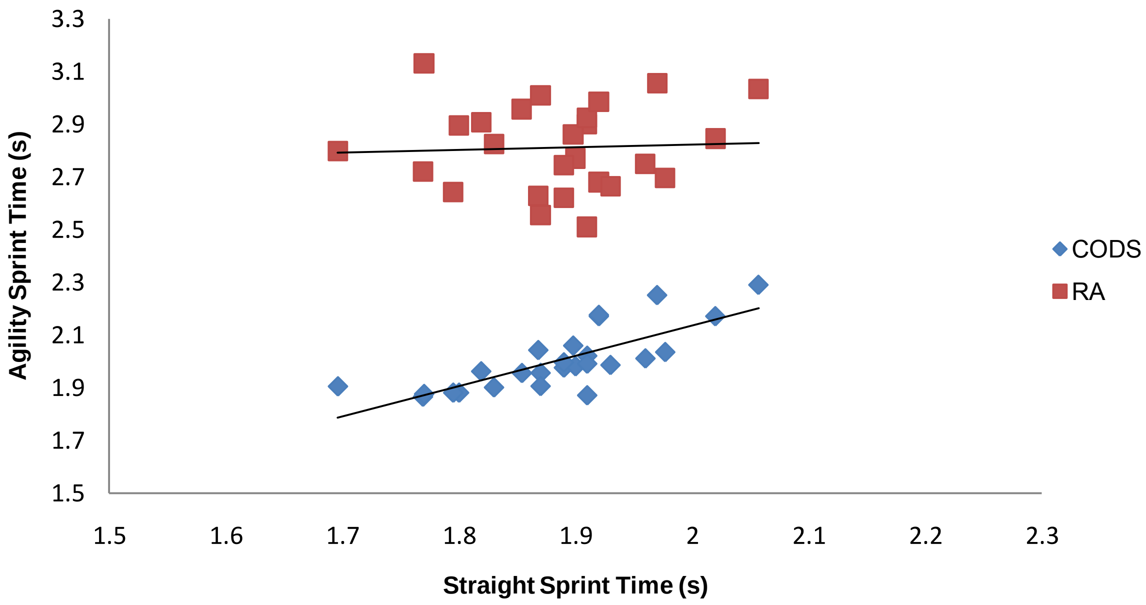

Figure 6.12. The relationship between 10m straight sprint speed and both 10m change of direction speed and 10m reactive agility.

Table 6.6. Correlations between the outcome variables.

Outcome Variable	Speed	CODS	3 - Cone
Speed	1.00		
CODS	0.78	1.00	
3 - Cone	0.45	0.64	1.00
RA	0.05	0.29	0.21

CODS, Change of direction speed; 3 - Cone, three-cone drill test; RA, reactive agility

The correlations between the performance variables and the descriptive characteristics are presented in *Table* 6.7. RA correlated poorly with all the anthropometrical data (r < 0.15), however, body fat percentage correlated moderately with speed and CODS. The relationships between RA and aerobic and anaerobic capacity were also weak (r = 0.13 and 0.05, respectively), while moderate to good negative relationships were observed between anaerobic capacity and speed, CODS and three-cone agility (r > -0.52). There was no relationship between the level of experience of the players in the study and the performance variables.

Table 6.7. Correlations between the outcome variables and the descriptive characteristics.

Characteristics	Speed	CODS	3 - Cone	RA
Age	-0.02	-0.08	-0.19	-0.11
Height	-0.47	-0.11	0.16	0.08
Body mass	0.05	0.30	0.32	0.13
% BF	0.46	0.49	0.28	0.15
% LBM	-0.46	-0.49	-0.28	-0.15
RS	-0.52	-0.64	-0.53	0.05
VO_{2max}	-0.12	-0.25	-0.26	0.13
Experience	-0.03	0.05	0.01	0.01

CODS, Change of direction speed; 3 - Cone, three-cone drill test; RA, reactive agility; % BF, percentage body fat; % LBM, percentage lean body mass; RS, repeated sprint; VO_{2max}, maximum aerobic capacity

CHAPTER SEVEN

DISCUSSION

A. INTRODUCTION

The current study examined the effectiveness of a sport-specific video-based RA programme for rugby union players as a possible alternative method to field-based training. The advantages of a video-based training programme is that it is of low to moderate intensities, short in duration and that it can be used indoors.

The main findings of the current study are that VT and FT do indeed improve RA performance in intermediate rugby union players and that the training effect after 12 sessions is significantly greater than with rugby training alone (C). There was no statistically significant difference in the change in RA between VT and FT and it can thus be concluded that VT is an effective alternative method, or add-on, to traditional training methods to develop RA in rugby union. Furthermore, the study showed that training two days a week for six weeks was adequate to facilitate long term motor learning, as the improvements in RA were maintained after a six week period without receiving the training stimulus.

Rugby union players are constantly exposed to dynamic changing environments, where successful performance relies on the way they react to these situations (Pool, 2006). Sprints that include changes in direction occur frequently in rugby union and evasive manoeuvres seem to be the most effective way to advance beyond the advantage line (Duthie *et al*., 2006; Sayers and Washington-King, 2005). RA performance has the ability to discriminate between highly-skilled and lesser-skilled performance and should; therefore be a key component in the conditioning of rugby union players (Young and Wiley, 2010; Sheppard *et al*., 2006; Helsen and Pauwels, 1993).

B. DESCRIPTIVE CHARACTERISTICS

Although research on the relationship between anthropometric variables and agility performance are limited, it may be assumed that a higher percentage body fat will lead to a decrease in agility performance due to increased fat mass and inertia, and also requiring more force production per unit of lean mass (Sheppard and Young, 2006).

Although correlation statistics were not always reported, some studies concluded that athletes with faster agility times tend to have less body fat (Gabbett, 2007; Gabbet, 2002; Meir *et al*., 2001). This view was not supported by this study as some of the athletes with the lowest % BF had the slowest agility times and vice versa, which was reflected in the low correlation between % BF and RA (r = 0.15). Webb and Lander (1983) also found a low correlation (r = 0.21) between % BF and planned agility (three-cone drill test). Slightly better correlations were found in this study between % BF and 10m CODS and the three-cone drill test (r = 0.49; r = 0.28, respectively), however, from the limited studies available it seems unlikely that % BF is an important determining factor in agility performance.

Similar conclusions can be drawn with regards to the other physical characteristics, namely age, height, body mass and % LBM. Of these, body weight had a moderate relationship with CODS (10m CODS, r = 0.30; 3-Cone, r = 0.32), while height had a moderate negative correlation with speed (r = -0.47). However, all these variables explain less than 20% of the variance in agility performance.

Rugby union involves intermittent low and high intensity activities. High intensity activities typically include sprinting, rucking/mauling, tackling and scrummaging. Forwards spent 12 to 14% and backs 4 to 6% of total time in high intensity activities (Roberts *et al*., 2008; Duthie *et al*., 2005), while the work to rest ratios between high intensity and low intensity activities are

1:1 and 1:1.9 (McLean, 1992). Duthie *et al*. (2006) found that forwards and backs frequently reach 90 - 100% of their maximal sprinting velocity during match-play. Therefore, both aerobic and anaerobic capacity may influence rugby players' performance during high intensity running patterns. The average maximal oxygen uptake relative to body mass of the players in this study (52.4 $\pm$ 5.1ml.min^{-1}.kg^{-1}) was slightly lower than those of elite under 21 players (55.6ml.min^{-1}.kg^{-}1), but still fell within the ranges required for Junior and Senior rugby players (51.6 - 59.3ml.min^{-1}.kg^{-1}) (Norms used by Maties Rugby Club, personal communication with M. Hillhouse).

Contrary to what may be intuitively expected, the aerobic endurance capacity (Multistage shuttle run) of players in this study had a weak correlation with RA (r = 0.13), while the relationship between anaerobic capacity (repeated sprint) and RA (r = 0.05) was even weaker. Webb and Lander (1983) also found a weak negative correlation between aerobic endurance and agility (r = -0.22). It can be concluded that although aerobic and anaerobic capacity in rugby union do not appear to be determining factors of RA performance specifically, one cannot deny the importance of both qualities in high level overall performance.

The relationship between the level of experience of the players and RA was very weak (r = 0.01), however, this could be partially explained by the sample characteristics. South African under 19 schools team was the highest level obtained by two of the players, a further two players represented their respective provinces at age 18, eight players played club level rugby, while the remaining players represented the first team of their residence. Thus, there was very little variation in playing experience and this, together with the small sample size, could explain the lack of relationship.

C. OUTCOME VARIABLES

1. Speed, agility and reactive agility

According to the models of Young *et al*. (2002), Sheppard and Young (2006) and Wheeler (2009), straight sprinting speed, CODS and perceptual skills are all components that influence RA performance. Running in rugby union seldom occurs over more than 10 meters (Benton, 2001; Sayers, 1999; Gambetta, 1996) and for this reason speed and agility are very important attributes. This is particularly true for backline players, as they need to out-manoeuvre and out-run the approaching defenders.

Speed

Some may argue that speed over 10 meters is only an estimate of acceleration and that 30 to 40 meters are required to measure maximal velocity (Duthie *et al*., 2003). However, a 10 meter distance was chosen for this study because the ability to quickly accelerate is seen as a more important requirement of agility performance than maximal velocity and also because rugby union players do not often sprint distances further than 10 meters. Time-motion analysis on Super 12 rugby union matches revealed that the average duration of sprints in forwards are 2.04 $\pm$ 0.72s, with a maximum of less than 5 seconds, while sprints for backs lasted 3 to 6 seconds (Deutsch *et al*., 2007; Duthie *et al*., 2005). Roberts *et al*. (2008) reported even shorter sprint times of 1.2s for forwards and backs in elite English rugby union. The choice of the 10m straight sprint test is thus warranted.

Speed performance was not significantly different between the groups at the start of the intervention, directly after the intervention or six weeks later. Speed in VT stayed constant throughout the training and towards the end of the retention period. VT did not include any speed training, as the focus was on the development of the perceptual aspects of agility. This may explain why no changes were seen in average straight speed sprint times. FT and C initially dropped their performance following the intervention period, but then again improved following the six weeks of retention. One would have suspected the FT group to improve their speed during the intervention period, because the training included running based activities on the field as well as mini-games. This was inconsistent with the findings of Gabbett (2006) who reported that skill-based conditioning games significantly improved 10 meter speed in rugby league players ($p < 0.05$). However, in this study running mostly involved COD and was seldom straight sprinting. Considering that the changes in FT and C were similar (0.4 $\pm$ 4.4%), it is suggested that the changes for both groups are due to regular rugby training and not a result of the training intervention.

Unlike most of the literature a strong relationship was found between 10m straight sprinting speed and 10m CODS that involves a single change of direction at 45^0 ($r = 0.78$). Oliver and Meyers (2009) found an even stronger relationship ($r = 0.93$) using the same test. Sheppard *et al*. (2006) found a similarly high correlation ($r = 0.74$) for speed and CODS over 10m, sharing a common variance of 54%. Young *et al*. (2001) also found a strong relationship ($r = 0.92$) between 30m straight sprinting speed and 30m CODS with only two directional changes at 160^0, however, the relationship became weaker when correlated with CODS that involved five changes in direction at 100^0 angles ($r = 0.47$). This was also the case when 10m speed was correlated with agility sprint performance in the three-cone drill test ($r = 0.45$). Most of the research that correlated speed with CODS found weak to moderate correlations and the more complex the change in direction the weaker the relationship (Little and Williams, 2005, Young *et al*., 1996; Draper and Lancaster, 1985). These results may suggest that 10m straight speed, which more closely resembles acceleration speed, may indeed be a good predictor of CODS that involves minimal directional changes. Yet, when the distance is increased and the number of changes as well as the angle of changes become more severe, straight sprinting and CODS appear to be unique skills with little transfer between each other and needs to be trained specifically and possibly separately.

The relationship between straight speed and RA in this study, on the other hand, was very weak (r = 0.05). This is in contrast to the results of Oliver and Meyers (2009) who found a strong correlation (r = 0.83) between these two attributes in university students participating in various sports. Green *et al.* (2009) also found a good relationship (r = 0.72) between 10m speed and RA using the same test on rugby union players. Gabbett *et al*. (2008c) (rugby league) and Sheppard *et al*. (2006) (Australian football) both reported moderate correlations between 10m speed and RA (r = 0.41; r = 0.33, respectively). The fact that speed had a high correlation with CODS, but not with RA, may suggest that there is something more to RA than just purely running speed. Superior speed performance seems unlikely to transfer to superior RA performance, however, the findings that were reported to date in the literature are inconsistent and thus warrants further investigation.

Change of direction speed (CODS)

CODS was measured using two different tests, namely a 10m sprint with a single 45^0 change of direction and the three-cone drill test.

The VT group was the only group to improve (4.6 $\pm$ 5.1 %) their times in the 10m CODS test, although the change was not statistically significant. There were no significant training effects for the FT and C groups, respectively, and the difference in the training effect between these two groups was trivial. On the other hand, VT resulted in a statistically significant greater training effect than FT (p = 0.028), and a tendency towards a statistically significant improvement compared to C (p = 0.073). Thus, there is a higher probability to improve CODS with VT, than with FT or rugby training alone. The improvement seen in CODS in the VT group is in contrast with the results of Serpell *et al*. (2011) who found a non-significant change in CODS performance following a video-based RA training programme. Serpell *et al*. (2011) studied rugby league players and their intervention only lasted three weeks, compared to the six weeks of this study. Gabbet (2006) also found a non-significant change of only 0.5% improvement in mean CODS in rugby league players following a skill-based conditioning games training programme that lasted nine weeks. Neitzke *et al*. (2010) on the other hand found significant improvements in agility of male adolescents following a six weeks reactive agility drills training programme ($p < 0.01$). This may suggest that at least six weeks of training is necessary to facilitate improvements in CODS.

During the VT training sessions players were only required to react to the player on the screen with a resultant movement either to the right or the left. This is very similar to the movement in the 10m CODS test. The FT group, on the other hand, was exposed to a greater variety of reaction drills and different movement patterns. Thus, the greater improvement in CODS in the VT group may be explained by the specific movement patterns developed during training and how it directly relates to the test.

Results in the three-cone drill test were slightly different. The FT group showed a slight, but non-significant decrease in performance, while both C and VT improved their performance in this test. Surprisingly, C had the greatest improvement in performance but the reason for this finding is unclear. It should be noted that the average agility times of players in this study were much slower than those reported for rugby league club players also tested using the thee-cone drill test (C: 8.25 $\pm$ 0.56; VT: 8.32 $\pm$ 0.23; FT: 8.88 $\pm$ 0.56 versus rugby league: 6.49 $\pm$ 0.40) (Gabbett *et al*., 2008c). Whether these differences were due to differences in the level of the players or whether this is indicative of the ineffectiveness of the interventions to improve CODS, are not apparent.

The retention period led to mixed results. The FT group improved their CODS time in both of the tests, while C improved in the 10m CODS test, but not the three-cone drill test. Although performance times for the VT group deteriorated after the end of the intervention period, it was still faster than the average time before the intervention. The results suggest that the benefits obtained with VT training were not sustained after six weeks without the training stimulus, and therefore a true learning effect did not occur.

The FT training included game-based training and this has been shown to improve CODS (Reilly and White, 2004). However, learning through this type of training takes longer than planned technique practice (Young *et al*., 2001) and thus it is possible that the improved CODS time in FT following the retention period may be a delayed learning effect.

Reactive agility (RA)

According to the literature the perceptual component of agility performance seems to be the differential factor between elite and sub-elite athletes (Young and Wiley, 2010; Gabbett and Benton, 2009; Gabbett *et al*., 2008c; Sheppard *et al*., 2006; Farrow *et al*., 2005).

The relative change in RA performance following the intervention programme was significantly better in VT (13.4 $\pm$ 5.6 %) and FT (16.7 $\pm$ 4.4 %) than C ($p < 0.01$). Therefore, VT and FT are almost certainly more beneficial in improving RA performance than rugby training alone; indicating that even short-term exposure to RA training (12 sessions) may indeed improve RA performance. While both the experimental groups improved their RA to both sides, C did worse following the intervention, especially to the left. This may indicate that the type of rugby training done at their clubs during the intervention period may not have provided the players with any perceptual or decision-making components and that the improvements seen in VT and FT can truly be due to the extra training they received. Importantly for this study is that the video-based training was also effective in improving RA performance. This is in accordance with Serpell *et al*. (2011) who also found an improvement in RA performance in rugby league players when targeting the perceptual and decision-making components through video-based training. These authors were able to link the increase in RA performance with improved perceptual skills, as they specifically tested perceptual and response times which also improved significantly after the intervention.

Similar positive findings were also reported for other sports. Starkes and Lindley (1994) reported that video-based perceptual training is an effective training method that could be added to traditional on-court training for basketball players and that it can be successfully implemented for intermediate level players. Farrow *et al*. (1998) found that video-based training improves response times in beginner tennis players. Although they did not test reactive agility, Abernethy *et al*. (1999) found that perceptual skills can be trained by sport-specific video-based training.

A direct comparison of the two training methods in this study revealed that FT resulted in a slightly greater improvement (3.0 $\pm$ 4.4 %) in RA than VT ($p > 0.05$). Although VT is also sport-specific and the players had to react to the game-like situations, FT allows for more physical involvement and the use of more senses. In VT it was only the player and the video display, whereas in FT players were involved in mini-game situations where they had team mates and opponents to focus on, there were drills that required a reaction to the bounce of the ball, while others included the coach's whistle and movements to certain areas or colours. Thus, FT training may have required more cognitive involvement than VT. Gabbett (2006) also found that skill-based conditioning games significantly improved rugby league players' attacking abilities, which may be due to increased ability to read patterns of play. The latter would thus support the findings in this study.

Turner and Martinek (1999) found that hockey players who developed their skills through the games for understanding approach performed significantly better in decision-making when passing and executing a pass, than players in a technique only group. Decision-making also seem to positively transfer to match-play better with the games-based approach. Game-based training is also associated with higher cognitive effort, which is an important aspect when learning skills (Gabbett *et al*., 2009). Since mini-games were used as part of the training in the FT group, it could be argued that they may have been exposed to more decision-making training than the VT group, which could have contributed to the greater gains in RA in the FT group.

In this study weak to moderate relationships were observed between RA and the CODS tests (r = 0.21 - 0.29). These correlations suggest that CODS have limited transfer to RA performance. Salonikidis and Zafeiridis (2008) found extremely low correlations between the reaction times of tennis players in a single side-step and a 4m side step test and 12m CODS (r = 0.02 and 0.03, respectively), while Sheppard *et al*. (2006) found a moderate relationship between CODS and RA in Australian football players (r = 0.32). Gabbett *et al*. (2008c) found moderate to good relationships (r = 0.40 - 0.58) between RA total movement time (time starts when braking the start beam of the speed cells and stops when moving through the finish gate) in rugby league players and three different CODS tests (505 - agility, modified 505 - agility, three-cone drill test). When they tested the relationship between CODS time and RA decision-making time (i.e. the time from presentation of stimuli to initiation of COD movement), the results were quite different (r = -0.02 - 0.07). Response accuracy during the RA test also had negative and weak correlations with CODS (r = -0.19 - -0.01). Therefore, CODS may influence total movement time of RA, but does not affect the reaction time or the response accuracy. These findings highlight the need to specifically train the perceptual components of RA and emphasizes that the focus cannot be purely on developing CODS.

On the other hand, the findings of Oliver and Meyers (2009) and Farrow *et al*. (2005) are in contrast to the above results. Farrow *et al*. (2005) found a good relationship between CODS and RA in netball players (r = 0.70), while Oliver and Meyers (2009) and Green *et al*. (2009) both reported strong correlations between CODS and RA in university students and rugby union players (r = 0.83 and 0.78, respectively). Oliver and Meyers (2009) and Green *et al*. (2009) used the same tests. In this test CODS and RA involves the same movement pattern, but the difference between the two is that in CODS the player knows beforehand if he needs to go left or right. With the RA test the participant is directed to the left or right once he crosses the 5m timing gate when a light indicates the direction. This could explain the strong correlation between RA and CODS in these two studies, although these results were not replicated in the current study (r = 0.21). The difference in findings between this study and especially the study of Green *et al*. (2009) is unclear, because the study sample was very similar (semi-professional rugby union players with a mean age of 19.5 $\pm$ 1.5 years).

From the above it is clear that inconsistent results are reported in the literature on the relationship between CODS and RA. CODS do, however, seem to play a part in movement time during RA performance. However, CODS and RA as a whole seem to be distinct and different qualities and; therefore require different training strategies. If an athlete has poor CODS the focus of training should be more on developing the physical qualities related to CODS, while poor RA is likely to benefit more from training decision-making ability to improve perceptual skills. The latter conclusion is supported by the findings of Young and Wiley (2010). Young and Wiley (2010) broke down the RA test used by Gabbett *et al.* (2008c) to see how the different components influence the total time (time from moving through the start gate to the finishing gate). They found that decision time correlated highly with total time in RA (r = 0.77), and that decision time accounts for most of the variability in total time. Thus, the speed of decision-making time is vitally important in RA performance - a conclusion that has also been made in earlier studies (Gabbett and Benton, 2009; Farrow *et al*., 2005).

Improvements in RA from the two training programmes (VT and FT) were not completely lost following the six weeks retention period. In fact, only minor changes in RA were observed for both groups (VT: 2.69 $\pm$ 0.15s to 2.70 $\pm$ 0.19s and FT: 2.70 $\pm$ 0.15s to 2.71 $\pm$ 0.13s), and the magnitude of change was the same for the two interventions. The positive retention responses could be related to the specific training programmes, since both resembled implicit discovery learning. Masters (1992) found that when novice golf putters acquired their skills through implicit learning they were better at retaining their skills when placed under pressure situations. Magill and Clark (1998) found that when comparing implicit versus explicit learning strategies, the implicit group were better at retaining the skills learned. However, there are also findings to the contrary. Maxwell *et al*. (2000) that also used novice golf putters found no differences between groups after a 72 hour retention period following implicit and explicit training, although the explicit group performed marginally better. Tennis players were also unable to sustain their improved prediction accuracy of a tennis serve gained from video-based implicit learning following a 32 days retention period (Farrow and Abernethy, 2002). Not a lot of research has been done on the delayed retention ability of implicit motor learning. Implicit learning strategies do, however, seem to help athletes maintain their skill level when under pressure and reduce motor response time (Lam *et al*., 2010; Masters *et al*., 2008; Masters, 1992). Poolton *et al*. (2007) stated that implicit learning reduces thinking time and produce automated responses and allows performance to remain stable over time as well as, when placed under pressure.

A surprising finding was the fact that there was a significant improvement in RA of the C group following the retention period ($p < 0.01$). This group did not receive any additional RA training, or any type of perceptual or decision-making training during the intervention period. However, the retention period coincided with the start of the competition phase for all the players. One may; therefore speculate that the exposure to competition-like decision-making situations and the requirement for RA manoeuvres presented during matches, as well as the accompanied changes in their rugby training programmes, may be the reason for the improvement seen in this group. If this is indeed the case, one can further speculate that the reason why the VT and FT groups did not further increase their RA performance, is because these training programmes are more effective in improving RA than exposure to competition only. The sustainment of improved RA performance in both the training groups indicates that perceptual skills have been learned, and that VT and FT are effective methods of motor learning. The increase in the control group may thus only be a temporary performance improvement.

There were no significant differences in terms of speed and CODS performance between FT and C following the intervention period. However, FT was almost certainly better than C in improving RA, with a 16.7 $\pm$ 4.4 % difference in the training effect. In support of this finding, Gabbett (2006) did not find improvements in CODS in rugby league players following a skilled-games conditioning programme, however, the players did show superior attacking and try scoring abilities compared to the traditional conditioning group following the intervention period. Farrow *et al*. (2005) concluded that CODS is not a true reflection of an athlete's agility performance in open skilled sports and that the inclusion of perceptual components significantly influences agility performance. It may; therefore be assumed that sport-specific RA training programmes may improve the perceptual abilities of rugby union players.

The VT group improved their CODS as well as their RA, however, the improvements for RA was greater than the improvements in CODS and it was maintained after the six weeks retention period. Although it was not specifically tested in this study, it is speculated that the improvements seen in RA may be the result of improved perceptual skills. This conclusion is supported by the following results: a smaller increase in CODS than RA performance in the VT group, the lack of improvement in CODS in FT, and the decrease in RA performance in C.

2. Further analysis of CODS and RA performance

CODS and RA performances were further analysed by discriminating between responses measured to the left and right. CODS performance to the right was significantly faster compared to the left in the FT group after the training period, however, this difference disappeared after the retention period. FT had similar improvements in CODS to the left and right following the retention period (0.2 $\pm$ 5.9% more in CODS right) with little variation between the players (CODS left: 3.8%; CODS right: 3.3%). VT decreased their performance after the retention period and again the biggest change was seen with CODS to the left (1.6 $\pm$ 6.0%) and more variability between the players (CODS left: 5.8%; CODS right: 6.6%). Young *et al*. (2002) suggested that agility performance may be affected by imbalances within leg muscle power. Although leg power was not measured in this study, nine of the ten players in the VT group indicated that their right leg is their dominant leg. If it is assumed that leg dominance may be related to leg power, it could provide an explanation why this group performed better in the CODS to the left. When moving to the left, the “outside leg” that initiates the movement, is the right leg and possibly the stronger leg. This could; therefore explain their faster times to the left. This could also be true for FT as only one of the players in this group has left leg dominance.

VT had greater improvements in RA to the right than the left, but the opposite was true for FT. Surprisingly, after the retention period both VT and FT slightly dropped their performance to the side they showed the most improvement during the intervention (VT: RA right; FT: RA left), while they still improved their RA times to the other side. Collectively the improvements following the intervention seem to be maintained, for at least six weeks.

D. ANALYSIS OF THE INTERVENTION PROGRAMMES

The different phases of training during a season do not always allow for too many high intensity sessions. Training weeks are usually very busy and bad weather can also limit training. For this reason it would be beneficial to have a relatively low impact reactive agility programme that can be conducted indoors. Hence coaches do not have to skip a training session, while players can still improve their reactive agility.

The VT programme was designed in such a way that there is a component of decision-making, although the decisions are limited to reacting to the left or the right. Even though this does not constitute major decisions, they are based on sport-specific actions. In this way the training also aims to improve the players' perceptual ability that should lead to an overall improved reactive agility. VT followed an implicit learning method, as no explicit knowledge was provided to the players, so that learning can occur through discovery. Players were only instructed to defend the last player with the ball. Players also did not receive any external feedback, but could immediately see if they made the right decision, as the outcome was displayed on the video clip. Implicit learning methods were chosen for both groups since elite athletes have stated previously that most of their experience in decision-making is gained in match-play situations (Baker *et al*., 2003). Skills are then learned without specific instructions received before the time and players are usually unable to verbalise how they performed the certain skill; therefore the skill is automated. Berry *et al*. (2008) found that expert decision-makers spend more time participating in invasion type sports than non-experts, where they more than likely improve their decision-making skills in an implicit manner by participating in match-play situations.

It has been shown that video-based training has the ability to improve perceptual and decision-making skills in a variety of sports, i.e. soccer (Helsen and Pauwels, 1988, 1993), racquet sports (Farrow and Abernethy, 2002; Abernethy *et al*., 1999; Farrow *et al*., 1998), football linebackers (Christina *et al*., 1990), basketball (Starkes and Lindley, 1994), rugby league (Serpell, 2011) and rugby union (Jackson *et al*., 2006). Video-based training may lead to faster and more accurate decision-making. These studies, however, involved different training methods, i.e. some required the athletes to respond by pushing a computer key or moving a joystick, while others involved physical reactions. The VT programme in this study included physical responses to incorporate perceptual-action coupling as this may facilitate better learning and transfer to real life match-play (Davids *et al*., 2008; Araújo *et al*., 2006).

The FT programme included drills specifically focused on developing RA and included mini-games. FT was designed in a way that it would closely resemble sport-specific requirements and provide players with decision-making situations. Some of the drills chosen are typically used to develop perceptual skills used in reactive situations (Fagan, 2009; Holmberg, 2009; Dawes, 2008). Mini-games produce the same physiological demands than match-play (Gabbett, 2003). Experts in team sports claim that match-play provides them with the best opportunity to develop their perceptual and decision-making skills (Baker *et al*., 2003). Therefore, mini-games appear to be an effective method to improve these skills and RA as it supplies the players with comparable decision-making situations that they would be presented with during match-play. Thus the FT programme, was a combination of traditional and game-based conditioning which have been shown to improve RA (Gabbett, 2009; Reilly and White, 2004). FT also made use of implicit learning, as players were only provided with knowledge about the specific drill. FT sessions lasted 20 to 30 minutes and could; therefore be effective as a sport-specific warm-up.

VT and FT both seems to be valid methods for the conditioning of RA. Both VT and FT was conducted in a sport-specific manner. VT was specific in the way that players viewed video footage of rugby attacking play. Players in the video clips displayed various agility manoeuvres and movements typically seen in rugby match-play. (side-stepping, crossover stepping, goose step, COD at certain angles, dummy pass). The number of players in each video clip varied from a single player up to six players. Players participating in VT had to physically respond to the video clips, teaching them to connect the correct movement patterns to the correct interpretation of the situation displayed in the video footage. This enables the players to learn how to read a player when performing a certain movement, so that they would be able to pick-up the cues before the time and make faster reactions. FT training is effective, because in each training session the players were challenged with various decision-making situations. The type of drills simulated match-play situations, putting the players under pressure to perform and make the appropriate decisions on how to react to the defensive players and work with his team mates.

E. CONCLUSION

This is one of few studies that investigated the effect of sport-specific video-based training on reactive agility in rugby union players. Most studies on video-based training explored whether this type of training can improve response accuracy and response time. Quite a few of these studies were done on racquet sports, while others used invasion type sports such as soccer, basketball, football and rugby league. It is apparent from the literature that video-based training is an adequate method to develop perceptual skills for the specific sport (Serpell *et al*., 2011; Abernethy *et al*., 1999; Farrow *et al*., 1998; Starkes and Lindley, 1991; Christina *et al*., 1990).

VT training in this study was unique in the sense that the players did not receive any form of verbal feedback and the video clips was not occluded at a certain point that would provide them with advanced visual cues. The players purely had to react on the entire move and was immediately provided with the outcome of which direction the player on the screen moved, so they would immediately know if they made the correct decision or not.

The results of this study showed that video-based training consisting of ten minute sessions twice a week for six weeks cause practically significant improvements in the RA of intermediate rugby union players. Although the improvement for VT was less than those for FT, it was significantly greater compared to pre-season rugby training alone. This study also showed that FT, which included game-based training, significantly improved RA, and that VT caused comparable results. Thus, VT may be an effective method to develop RA and can be used as an add-on or an alternative method of training RA. VT is short in duration and low to moderate in intensity (unlike FT which needs longer and more intense sessions), thus making this type of training ideal to add to busy and/or intense training weeks and have the additional advantage of developing the perceptual aspects of RA. This is also a training method that coaches can use on extremely bad weather days when training is limited to indoors. It is clear from this study that players benefit more from additional RA training that includes perceptual and decision-making components, other than just the training provided during match-play. The important message from this study is that the perceptual component should be present when developing or testing RA and that it is best when done in a sport-specific manner. Finally, it can be concluded that speed and CODS may not be improved by RA training, as limited transfer exists between the skills. Speed and CODS should; therefore rather be developed as separate skills.

What made this study different from those of Serpell *et al.* (2011) and Jackson *et al.* (2006) is that it compared the VT training with FT to investigate if it would deliver similar improvements. It also differs in that the video clips were not occluded at any point. The video clips lasted on average three seconds, displaying the start of the movement, the evasive agility manoeuvre and the direction in which the player in the clip proceeded in. The players were; therefore immediately provided with the outcome and did not receive any form of external feedback, thus making learning discovery based. The training intervention was longer than that of Serpell *et al*. (2011), namely 6 weeks as opposed to 3 weeks. Sessions in the study of Serpell *et al*. (2011) lasted 15 minutes and contained 10 video clips, while sessions in the current study lasted only 10 minutes and the players were presented with 50 video clips. Video clips in Serpell *et al*. (2011) and Jackson *et al*. (2006) contained a single player, while the number of players per clip in the current study varied from one to six players. The players viewed a greater variety of match-play situations in a shorter amount of time and had 8 seconds to recover between each video clip.

F. STUDY LIMITATIONS AND FUTURE RESEARCH

Limitations of this study were that although training was done in a sport-specific manner, the RA test was not sport-specific. It would be preferred that the test also involved rugby union specific stimulus instead of a light stimuli to provide ecological validity. Furthermore, the perceptual and decision-making components that may influence RA performance was not specifically tested; therefore not providing the underlying mechanisms that may explain the improvements in RA seen in both the training groups. A further limitation is that the study did not test if the improved RA transferred into match-play.

One of the practical implications of VT is that players have to participate on their own so that they are not influenced by their teammates. It may; therefore be difficult to find timeslots for each player, because training schedules are usually already busy and may require players to do this type of training in their own time. Because of the low to moderate intensity of this training method it could be used during down weeks when the training loads are lower.

A sport-specific reactive agility programme should ideally improve anticipation and pick-up of advanced visual cues, enhance the ability to read the game and execute pattern recognition and improve overall decision-making and response accuracy, together with CODS. Furthermore, it would be best to simulate the sport or activity as closely as possible. Future studies could investigate methods to develop all these skills so that it would lead to superior RA.

Future research should make use of sport-specific tests and a high speed video camera to assess decision-making time separately, and response accuracy should also be measured. No golden standard exists to measure RA; therefore more research is needed on RA testing, and especially the development of rugby union specific RA tests. Future research could also film players participating in VT, to assess how response accuracy and response time improve throughout the training. More research should be done on the visual search strategies of expert decision makers in rugby union and the development of a rugby union specific RA test, as well as developing decision-making strategies in rugby union players. Studies should look into practical sport-specific ways to train athletes to identify advanced visual cues and improve their RA. Research on video-based training mostly used clips viewed from a defense perspective and studies should investigate a way to develop offensive play via video-based training. Future studies should also investigate how well improvements in perceptual skills and RA gained through video-based training transfer into match-play.

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APPENDIX A

STELLENBOSCH UNIVERSITY
CONSENT TO PARTICIPATE IN RESEARCH

Title of the research project: Sport-specific video-based reactive agility training in rugby union players.

You are asked to participate in a research study conducted by Louise Engelbrecht, BHons Sport Science (High performance sport) from the Department of Sport Science at Stellenbosch University. The results obtained from the research will contribute to a thesis in fulfillment of the requirements for the degree Master in Sport Science. You were selected as a possible participant in this study because you are a male rugby player between the ages of 18 and 25 and part of a structured rugby training programme.

1. PURPOSE OF THE STUDY

The purpose of the study is to develop a video based reactive agility training programme for rugby union players which addresses the change of direction speed and perceptual factors associated with reactive agility. The video based training will be sport-specific by having players physically react to video clips of different rugby attacking scenarios.

The video based training will be compared to field based training to test its effectiveness. If successful it could be used as an alternative method of developing reactive agility.

2. PROCEDURES

If you volunteer to participate in this study, we would ask you to do the following:

2.1 Pre- and post- intervention testing and one retention test

Before the start of the intervention a variety of tests will be performed. The tests include anthropometrical measurements, fitness tests, speed, change of direction speed and reactive agility. All these tests are standard for rugby union players and you may even be familiar with some of it. All tests will be performed at the Sport Science Department, before and after an intervention of six weeks. The retention test will be performed 6 weeks after completion of the intervention.

2.2 Intervention

The intervention programme will consist of two sessions per week for a maximum of 30 minutes each and will last six weeks. You will be required to participate in either a video training group or a field-based reactive agility training. Both interventions will be of low to moderate intensity and will not interfere with your regular rugby training programme.

3. POTENTIAL RISKS AND DISCOMFORTS

All safety measures will be followed to prevent injury and reduce possible risks. The study does not hold any additional risks other than what is usually associated with rugby speed and agility training. You may experience delayed onset of muscle soreness (DOMS) in the beginning of the intervention, but this will only last for a 48-72 hours and clear by itself. Exercise will be stopped as soon as injury occurs.

4. POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

The study may lead to an improvement in your reactive agility, which may lead to overall improvement in rugby playing ability due to faster and more accurate responses to changes in the rugby environment.

5. PAYMENT FOR PARTICIPATION

Participants will not receive any payment for participation in the study. There is no cost associated with participating in the study.

6. CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of numerically coding the data sheets. No names will be included in data analysis. This means that reported results will not include any names.

Recorded data will be securely retained for a period of six years at the Sport Science Department. Only the principle researcher and the project supervisor will be able to access the raw data. Please take note that the overall data may be published in a peer reviewed scientific journal.

7. PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don’t want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so. Your participation will be stopped once you missed more than 80% of the intervention or regular rugby training. It will also be stopped if injury occurs that prevents further participation. Your consent to participate in this research will be indicated by your signing and dating or the consent form. Signing the consent form indicates that you have freely given your consent to participate, and there has been no coercion to participate.

8. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact the principle researcher Louise Engelbrecht (**079 491 9072 or 14579464@sun.ac.za**) or the project supervisor Prof E. Terblanche (**021 808 27 42 or et2@sun.ac.za**) at any time if you feel a topic has not been explained to your complete satisfaction.

9. RIGHTS OF RESEARCH PARTICIPANTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research participant, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

SIGNATURE OF RESEARCH PARTICIPANT OR LEGAL REPRESENTATIVE

The information above was described to ________________________________ by Louise Engelbrecht in English and the participant in command of this language or it was satisfactorily translated to him. I was given the opportunity to ask questions and these questions were answered to my satisfaction.

I hereby consent voluntarily to participate in this study. I have been given a copy of this form.

____

Name of Participant

____ ______________

Signature of Participant **Date**

SIGNATURE OF INVESTIGATOR

I declare that I explained the information given in this document to ______________________. He was encouraged and given ample time to ask me any questions. This conversation was conducted in English.

____ ______________

Signature of Investigator **Date**

APPENDIX B

ETHICAL CLEARANCE

Researcher:	Ms Louise Engelbrecht
Research Project:	Sport-specific video-based reactive agility training in rugby union players
Nature of the Research Project:	M degree, Department of Sport Science, Stellenbosch University
Reference number:	376/2010
Date:	6 August 2010

Ethical clearance for the project, *Sport-specific video-based reactive agility training in rugby union players*, has been obtained from the Ethics Committee on 6 August 2010 on condition that:

1) That the researcher remains within the procedures and protocols indicated in the proposal,
2) The researcher stay within the boundaries of applicable national legislation, institutional guidelines, and applicable standards of scientific rigor that are followed within this field of study,
3) Any substantive changes to the research project should be brought to the attention of the Ethics Committee with a view to obtain ethical clearance for it.

Appendix C

Field Training - SESSION 1

Equipment: whistle; stopwatch; ± 30 cones; 2 rugby balls

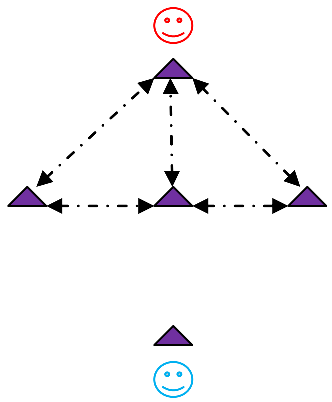
1) Coach command drill

Players spread out on try line facing the coach. Blow the whistle and point up, down, left, right, forward or backward. Players have to respond as follows:

- Up - Jump
- Down - Lie down on the ground
- Left - Shuffle left
- Right - Shuffle right
- Forward - Run backwards
- Backwards - Run forward

Change direction every 1 - 3 seconds for 15 - 20 seconds. W:R - 20:80s x3

2) Triangle-mirror drill

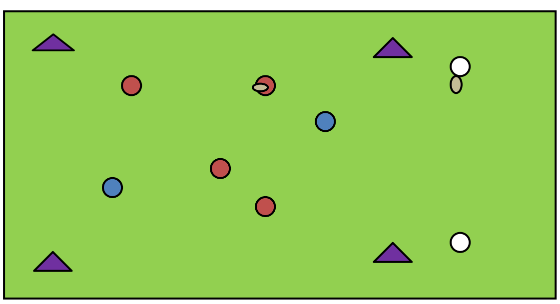



Leader
Follower

Work in pairs of two. The leader may run how however he please (i.e. forwards, backwards, shuffle) in his side of the triangle. Follower must mirror his moves.

15:45s (each player lead 3x)

3) Rugby, Speed pass



8 players per group

6 in playing area; 2 outside

10 x 15m grid

4 vs. 2 situations in playing area.
2 outside pass the ball 25x then, switch with 2 players in playing area.
Continue until every player had a turn to pass outside.

SESSION 2

Equipment: whistle; stopwatch; ± 30 cones; 6 rugby balls

Warm-up: Knee tag game

Work in pairs of two, try to tag partner's knee, will avoiding being tagged.

1) Ball reaction drill

Work in pairs
One player lies flat on the ground, on his stomach facing the playing area.

The partner throws the rugby ball over the player lying down, towards the playing area. As soon as the playing lying down notice the ball he has to jump up and try and catch the ball before the second bounce. 15 throws each

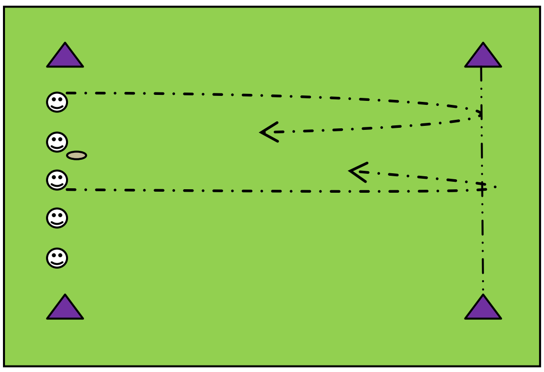
2) Partner lane drills

Two players line-up opposite each other.

one leader one follower, may run any way they please

20:60s (3x each)

3) React to situation 3 vs. 2



5 players pass a ball in a line, when the whistle blows, the 2 players closest to the ball run to the opposite beacons, as soon as they turn the 3 players become attacking players and should try and score at the opposite side.

Play 8 - 10mins

SESSION 3

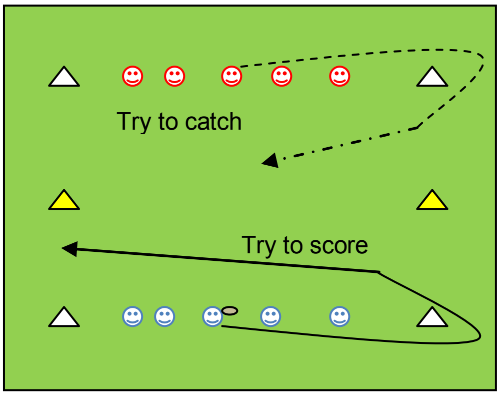
Equipment: whistle; stopwatch; ± 30 cones (2 colours); 4 rugby balls; 12 tags

Warm-up: Tail catch

Each player receives a tag, to wear as a tail, play in a 20 x 20m grid.

Try to catch the other players tails. Play till a winner or 5 minutes

1) Rugby 1 vs. 1 race



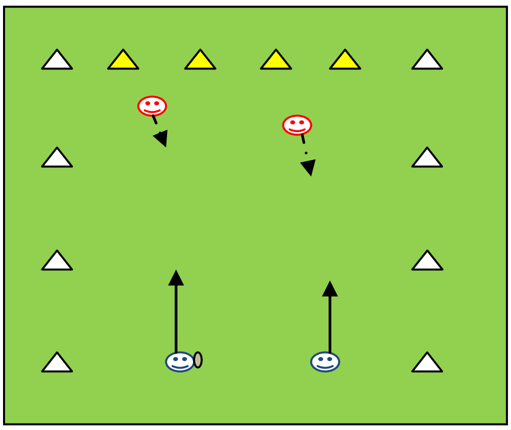
Attacking side pass the ball in the line, on the command go the player with the ball runs as illustrated in the sketch. The opposite player should try and tag the player with the ball before he reaches the line.

Defenders

Attackers

Play 8 - 10mins

2) 2 vs. 2



10 m channel

2 attackers 2 defenders

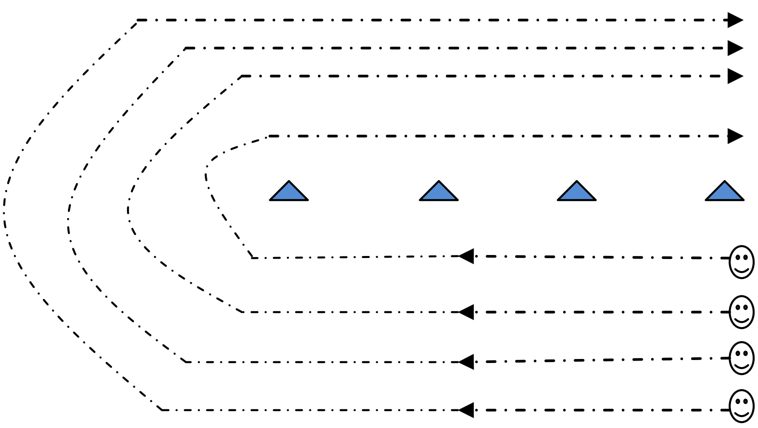
5 attempts to score at the yellow end.

swap after 5; repeat 3x

SESSION 4

Equipment: whistle; stopwatch; ± 20 cones; 2 balls

Warm-up: Running and pass



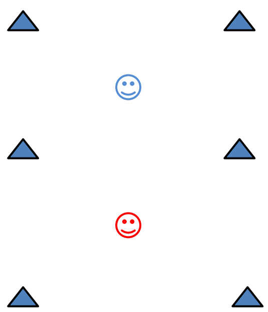
1) 1/2 pace to far cone and back

2) easy out – 3/4 pace back

3) fast – fast

repeat each scenario 2x

1) 6-Cone mirror drill



One leader ☺ and one follower ☺

Start in the centre of the box, the leader can run to any cone and return to the centre, before running to the next cone

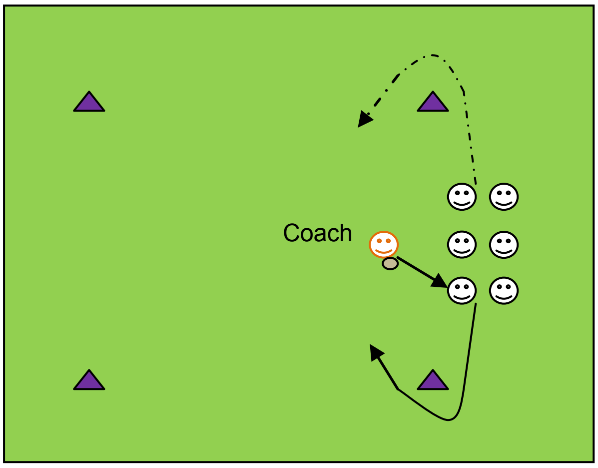
20:60s; lead 4x

2) Line drill with auditory cues

Players change direction on the blow of a whistle

10:30 repeat 5x

3) 2 vs. 1



The coach start with the ball and throw the ball to either one of the outside players.

The player in the middle joins the player that received the ball and becomes the attackers.

The third player becomes the defender creating a 2 vs. 1 situation.

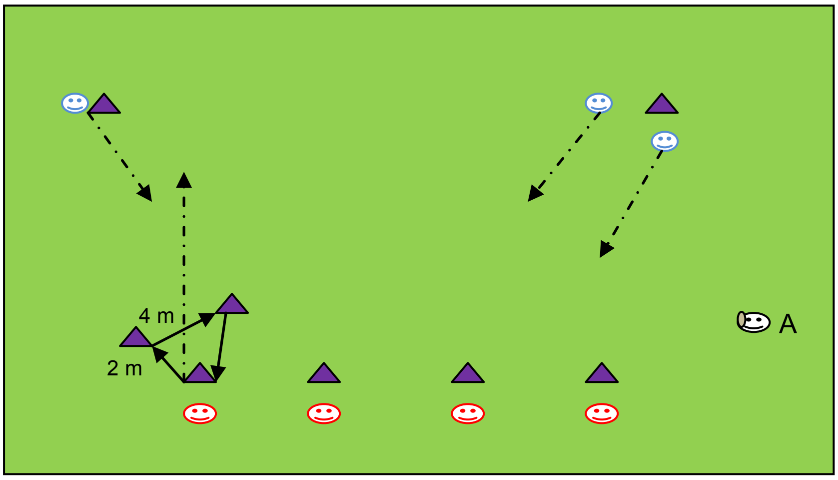
Players have to run around the cones nearest to them before initiating play.

20 x 15m grid, play for 5 - 8 minutes.

SESSION 5

Equipment: whistle; stopwatch; ± 30 cones; 2 balls

Warm-up: Footspeed Attack / Defence



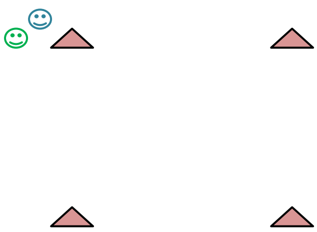
20x25m grid

Attackers

Defenders

Attackers start running the triangle as illustrated on the sketch, at each cone they have to touch the ground. Back at the starting cone, attackers must jump in the air, then player A will pass the ball into play. Once the ball is in play the defenders may start moving and attackers should try and score at the opposite side.

1) 15m box tag



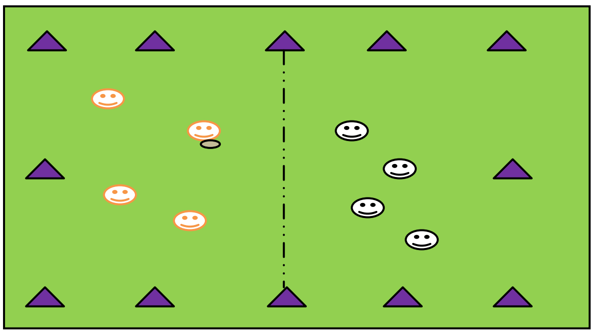
Two players leader and follower

Coach blow whistle twice to give the leader slight head start

Follower should try and catch the leader for 10s, may run as

they please, should just stay in the box (15x15m)   10:50s 6x

2) Kick tennis



The aim of the game is to kick/punt the ball into the oppositions half. If the ball bounces on the ground or is knocked on then you get 1 point. If the ball is caught cleanly then no points are allocated. Ball must stay in the grid.

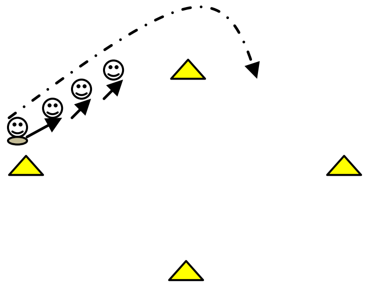
40x20m grid

Play for 10 minutes

SESSION 6

Equipment: whistle; stopwatch; ± 20 cones; 4 balls, tags (2 colours)

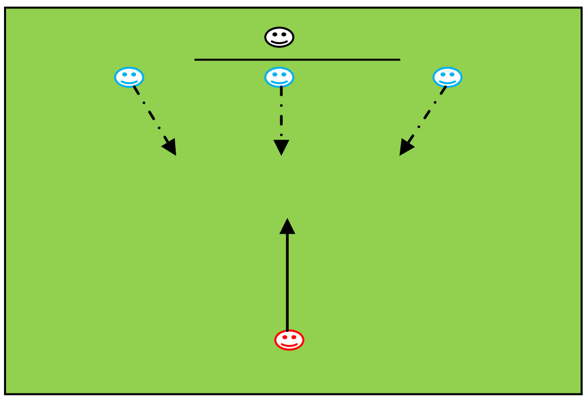
Warm-up: Round and round



Players line up at the cone, as illustrated in the sketch. First player picks the ball up at the cone and pass to the next player, then runs around the back to receive the ball from the last player, how puts the ball down at the cone and picks it up again to start the next round of passing.

Repeat 2x each way around

1) Continues attacking



Coach Attacker

Defenders

4 players, 3 defenders, 1 attacker

Coach calls number of defenders i.e. 1 vs.1; 1 vs. 2 or 1 vs. 3

each player attack 5x

2) 5 vs. 5 touch rugby

After 3 touches change possession

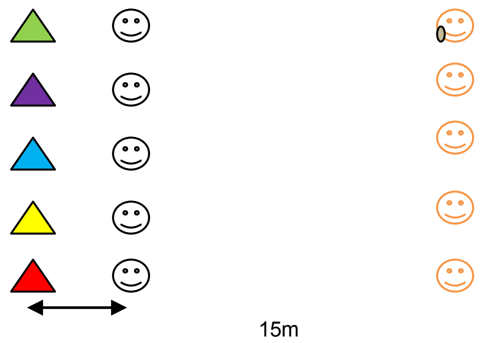
When touched, tackler stays in passive contact, ball carrier slides to ground and present ball, nearest supporting player acts as scrumhalf.

SESSION 7

Equipment: whistle; stopwatch; 5 different coloured cones; 5 balls

Warm-up: Defense cone drop game

Defenders Attackers



Each defender receives a colour, coach calls a colour then that player should back paddle around the cone before joining the defense

Play in total 10 minutes

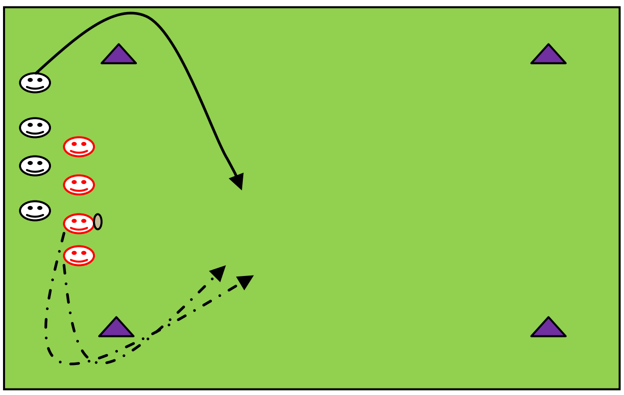
1) Ball over head throw

Work in groups of three, Two players lie on the ground facing the playing area. The third player, throws the ball over the players lying on the ground into the playing area. As soon as the notice the ball, players should jump up and compete for the ball.

Try to catch the ball before the second bounce.

15 throws

2) React, Run and defend



Defenders Attackers

15x20m grid

Coach call the a number of attackers and defenders, any variation i.e. 2 vs. 1

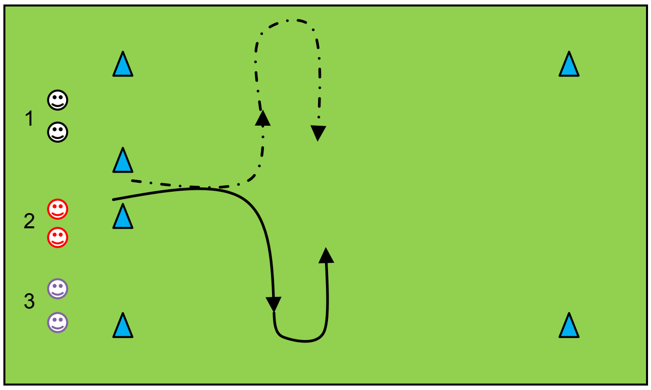
Players run around cones into playing area and attack.

Play for 10 minutes

SESSION 8

Equipment: whistle; stopwatch; ± 30 cones; 6 rugby balls

Warm-up: Rugby 1 vs. 1



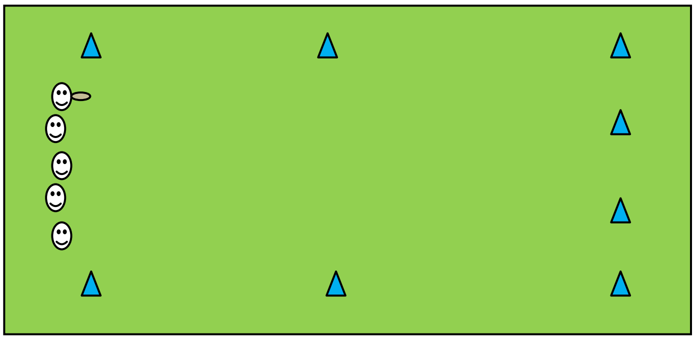
Players work in pairs, each pair receives a number.

Coach calls a number and that pair create a 1 on 1 situation, as illustrated on the sketch.

15x20m grid

play 5 - 8minutes

1) Change reaction – progression



Players pass the ball across the line in a chain moving to the opposite cones. After the first pass, the player that started the chain remains in the middle to become a defender.

5 players

20x10m grid

Play 10mins

2) One on one touch-shadow rugby

Two equal teams

Playing area dependent on size of the teams

Play game of two handed touch rugby.

Each player gets partner in opposite team, only allowed to defend that player.

Play 8 - 10mins

SESSION 9

Equipment: whistle; stopwatch; ± 30 cones; 4 rugby balls; bands (4 colours)

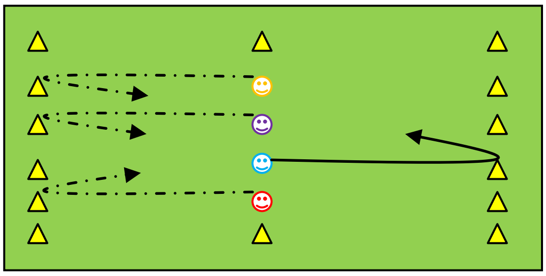
Warm-up: Coach command drill

Players spread out on try line facing the coach. Blow the whistle and point up, down, left, right, forward or backward. Players have to respond as follows:

- Up - Jump
- Down - Lie down on the ground
- Left - Shuffle left
- Right - Shuffle right
- Forward - Run backwards
- Backwards - Run forward

Change direction every 1 - 3 seconds for 15 - 20 seconds. 20:80s x3

1) 3 vs. 1



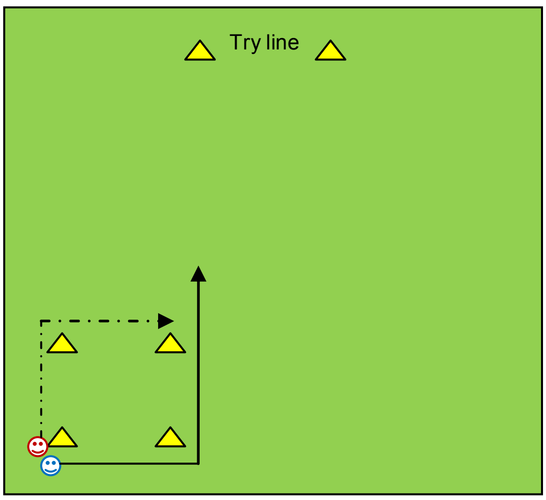
4 players, each a different coloured band

Start in the middle of a 10x20m grid

Coach calls colour i.e. blue, that player, becomes the attacker, the rest defenders

Play 8 -10mins

2) Rugby, defeating the opponent



Player A Player B

Two players, back against each other on the corner of a 15x15m grid.

On the blow of the whistle they head for the opposite corners.

Player A should try and beat the defense, i.e. grubber, chip, dummy.

Each player attack 5x

SESSION 10

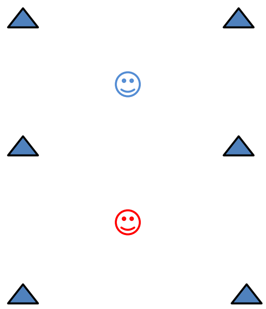
Equipment: whistle; stopwatch; ± 30 cones; 4 rugby balls, tags

Warm-up: Two-tail catch

Each player gets two tails, have to catch both tails before player is out.

Play for 5 minutes or until one player left.

1) 1) 6-Cone mirror drill



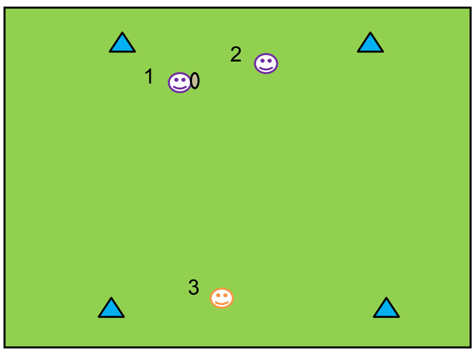
One leader and one follower

Start in the centre of the box, the leader can run to any cone

and return to the centre, before running to the next cone

20:60s; lead 4x

2) 2 on 1 Evasion



Attackers Defender

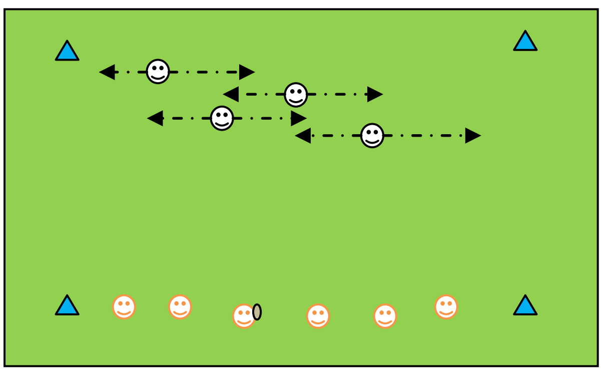
3 players in a 10x10m grid

1 pass to 2 with plenty of room to move and attempts to beat 3 with any agility manoeuvre.

3 starts to move as soon as the ball leaves 1's hand

Each player defends 5x

3) Rugby scattered defense 6 vs. 4



Defenders Attackers

4 defenders, 6 attackers. 15x20m grid

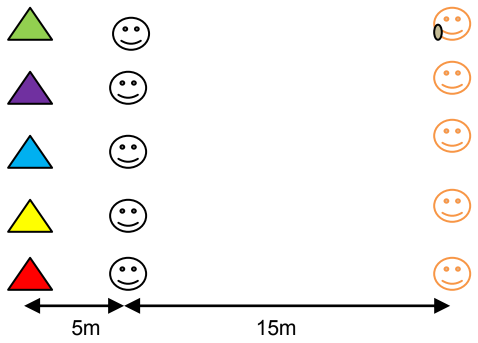
Defenders only aloud to move sideways.

Play for 8mins

SESSION 11

Equipment: whistle; stopwatch; ± 30 cones (5 colours); 4 rugby balls, bands (2 colours)

Warm-up: Defense cone drop game

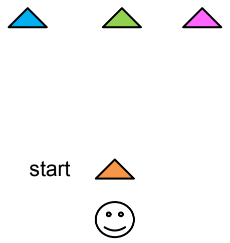


Defenders Attackers

Each defender receives a colour, coach calls a colour then that player should back paddle around the cone before joining the defense

Play in total 5-8 minutes

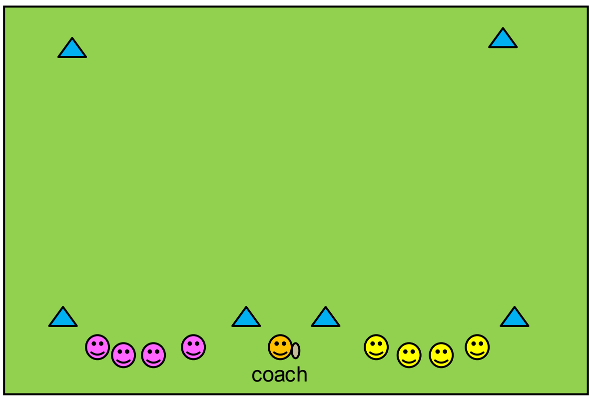
1) Colour T-drill



Coach calls any colour, player runs towards that colour and back paddle till the next colour is called.

10:30 repeat 5x

2) Continues break



30x30m grid

attackers defenders

Two teams of equal number players.

Coach kicks the ball into play and call 2 numbers.

1st number of attackers and 2nd number of defenders, delay the 2nd number.

Play 8-10 minutes

3) Touchies

After 3 touches change possession

When touched, tackler stays in passive contact, ball carrier slides to ground and present ball, nearest supporting player acts as scrumhalf.

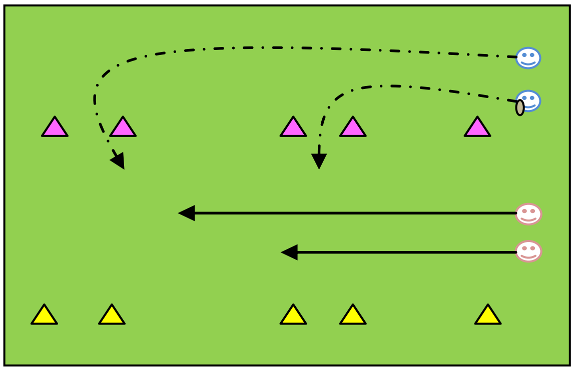
SESSION 12

Equipment: whistle; stopwatch; ± 30 cones (5 colours); 4 rugby balls

Warm-up: Knee tag game

Work in pairs of two, try to tag partner's knee, will avoiding being tagged.

1) Decision making 2 vs. 1



10x30m grid

Attackers Defenders

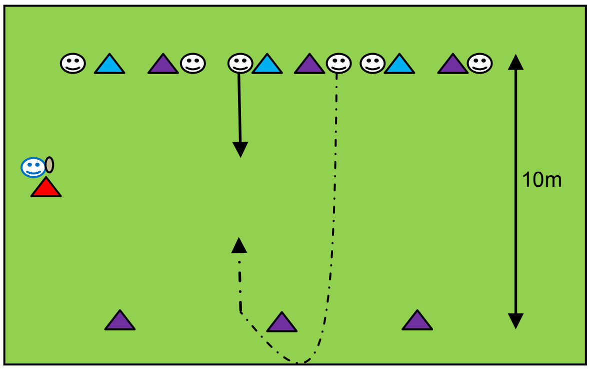
4 players, 2 outside and 2 inside the grid

Outside players pass to inside players, before they run through the pink gates.

Inside players try to score at opposite end

Each pair attack 5x

2) Decision making in attack 3 vs. 2



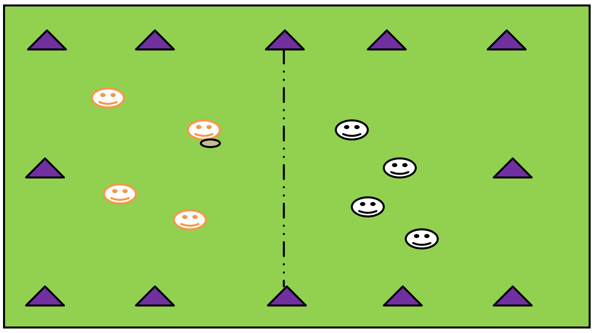
Players line up as illustrated in the sketch

Coach calls a colour i.e. purple, players next to that colour runs around the cone 10m on the opposite side and becomes the defenders. Coach calls one defender out of play

Players next to the blue cones becomes the attackers. Creating a 3 vs. 2 situation

Play 8-10 minutes

3) Kick tennis



The aim of the game is to kick/punt the ball into the oppositions half. If the ball bounces on the ground or is knocked on then you get 1 point. If the ball is caught cleanly then no points are allocated. Ball must stay in the grid.

40x20m grid

Play for 10 minutes

APPENDIX D