A Comparative Study of the Effects of Sprint and Plyometric Training on the Speed, Agility and Power Output in Intermediate Rugby Players

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Fitness

Speed

Agility

Power

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DECLARATION

I declare that the thesis titled "A Comparative Study of the Effects of Sprint and Plyometric Training on the Speed, Agility and Power Output in Intermediate Rugby Players" is my own work, that it has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

Full Name: Wynona Louw November 2019

Signature:

DEDICATION

This thesis is dedicated to my mother Yvonne, who supported me throughout my academic journey and without whom none of this would have been possible.

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ABSTRACT

Rugby games are characterised by intense bursts of speed mainly executed by backline players at either maximum or sub-maximum velocities over distances of up to 70 meters. Other key features of the game include rapid directional changes, displays of power and other dynamic activities such as lifting and jumping in the lineouts, tackling, pushing in scrums and contesting for the ball. These bouts of intense physical activity constitute a major part of the game, which take place over a period of 80 minutes and in some instances even longer. These powerful spells of play are interspersed by brief periods of rest mainly due to stoppages called by the referees when rules are infringed, when the ball is out of play, or when players incur injuries. These breaks can also be due to play being reviewed by match officials.

It is quite evident from the aforementioned that speed, agility and power are essential performance components for any rugby player and, with an increased focus on mobility and speed in the modern game, the importance of these components has increased in significance. Coaches are consequently continuously searching for training and coaching techniques that will maximally develop these qualities to give their teams an advantage over their opponents. Both line sprinting and plyometric training have proven to have beneficial effects on speed and power output. However, there is a dearth of research information on which one of the two approaches is the most beneficial. The purpose of this study, therefore, was to determine which training regime, line sprinting or plyometric training, brings about the biggest improvement in the

speed, lower body power output, agility and speed of intermediate rugby players.

This study employed a quasi-experimental research design, as it did not include a control group. Participants included 22 rugby players participating at club level, aged 18-25 years, with training sessions on at least three days of the week and a league or friendly match once a week. The players were randomly placed in either the line sprinting group or the plyometric training group (11 players per group). Participants were informed of the possible experimental risks of the study. All participants were required to complete a health questionnaire to ensure no chronic illnesses or major signs and symptoms suggestive of coronary artery or pulmonary disease were present in anyone taking part in the study. Participants took part in either sprint or plyometric training twice a day, with at least one day of rest in between training days. Participants were assessed on their speed, speed endurance, agility and power components pre -and post the eight-week intervention period. For the speed tests done before and after the intervention programme, participants performed maximal sprints over 40- and 80-metre distances. For agility, the T-test was used, and for power, the standing long jump. The research received ethics clearance from the University of the Western Cape's Biomedical Research Ethics Committee (Ethics Reference Number: BM17/1/17).

After the eight-week intervention programme, the line sprinting group improved significantly in their performances for three of the four performance measures. The only measure that did not improve significantly was the 80m sprint. The plyometric group on the other hand showed improvements in two categories only - agility and the standing long jump – while no significant improvements were found in any of the sprint distances.

In conclusion, the findings demonstrated that both line sprinting and plyometric training regimes are effective in improving agility and leg power and that line sprinting performed over 10, 20, 40 and 100 metres is an effective training protocol to improve 40m sprint time. Neither the line sprinting nor the plyometric training resulted in significant improvements over the 80-m distance. A comparison of the effect sizes of the two training methods revealed that except for the improvement in agility of the plyometric training group, the speed, power and sprint endurance training benefits of these two training methods do not differ.

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CHAPTER ONE

INTRODUCTION

1.1 Background

Rugby games are characterised by intense bursts of speed mainly executed by backline players at either maximum or sub-maximum velocities over distances of up to 80 meters. Other key features of the game include rapid directional changes, displays of power and other dynamic activities such as lifting and jumping in the lineouts, tackling, pushing in scrums and contesting for the ball (Bompa & Claro, 2009). These bouts of intense physical activity constitute a major part of the game, which takes place over a period of 80 minutes and in some instances even longer. These powerful spells are interspersed by brief periods of rest mainly due to stoppages called by the referees when rules are infringed, when the ball is out of play, or when players incur injuries. These breaks or stoppages in play can also be due to play being reviewed by match officials (Duthie, Pyne & Hooper, 2003).

Set pieces like the scum and lineout are activities that require maximal power output. The shoving action, used in attempts to drive the opposition pack backwards in contest for possession of the ball, is an example of a passage of play where power is required among the forwards, while at the lineout, the lifting of the jumper also requires a burst of power. Tackling and competing for the ball at rucks require continuous bouts of powerful play. Agility is another performance component that features strongly, especially when players need to change direction quickly on attack while carrying the ball, or when they need to change their position or alignment on defence to prevent an opponent from gaining an advantage. This makes speed, agility and power important performance components in rugby, with these components differing in importance among the different playing positions (Duthie, Pyne & Hooper, 2003).

Speed which is defined as the ability to perform a movement or cover a distance within a short period of time (Thomas, French & Hayes, 2010). Speed is especially important for backline players, as these players often have to sprint longer distances (up to the full length of the field) to score tries. However, it is expected of all players to break through tackles, rush onto a defender or the ball or outrun a defender.

Adams, O'Shea and Climstein (1992) defined power as the amount of work that can be performed or produced by a single muscle or by a group of muscles per unit of time. Power is also of great importance for rugby players, as their capacity to produce wide-ranging explosive actions including sprinting, jumping, kicking, tackling and sudden acceleration, are important factors when it comes to achieving success in the sport (Meylan & Malatesta, 2009). As a rugby match is played over 80 minutes, the ability to produce power over a sustained period is just as crucial as the ability to exert maximal power during a single action.

Sudden changes of direction at speed, or agility is also a crucial component for all players, especially backline players. Twist and Benicky (1996) defined agility as the ability to maintain or control your body position while quickly changing direction during a series of movements. During the performance of agility activities, motor programming is reinforced through neural adaptation in muscle spindles, joint proprioceptors and Golgi-tendon organs, while neuromuscular conditioning also takes place (Barnes & Attaway, 1996; Craig, 2004, Potteiger, Lockwood & Haub, 1999). From this, it can be deduced that agility is likely to improve with greater balance and control of body positions during movement.

Coaches are employing various techniques to develop these qualities in rugby players. Plyometric training has been shown to improve the production of muscle force and power, speed and agility (Rimmer & Sleivert, 2002; Thomas, French & Hayes, 2009). It occurs when a muscle stretches quickly (eccentric action), before an immediate shortening (concentric) action of the same muscle and connective tissue. This action is performed by using elastic energy stored during the stretching phase (Thomas et al., 2009). During plyometric, training the fast force production of the trained muscle improves, coupled with smaller increases in maximum isometric force (Thomas et al., 2009).

Line sprinting is an explosive movement which is commonly used in sports training. It involves repetitive full sprints over varying short distances (10m – 100m). Studies have shown that this method of training could lead to improvements in muscle power capabilities and speed, however, no research articles have produced positive results on the effects of line sprinting on agility alone (Mero, Komi & Gregor, 1992; Enoksen, Haugen, Shaher et al., 2011).

1.2 Statement of the Problem

Rugby is a very complex sport in which two teams of 15 players compete in a highly physical contest for possession of the ball in an attempt to create scoring chances. The sport has undergone significant changes since it was introduced over a century ago. Rugby is a game characterised by high bursts of speed either at maximum or sub-maximum velocities, high displays of power, quick changes in direction in addition to activities such as lifting and jumping in the lineouts, tackling, pushing in scrums and wrestling for the ball, either standing (maul) or on the ground (ruck) (Bompa & Claro, 2009). Speed, agility and power are therefore key qualities of rugby players and coaches continuously search for training and coaching techniques that will maximally develop these qualities to give their teams an advantage over their opponents.

Both line speed- and plyometric training have been reported to have beneficial effects on speed and human power output, however, there is a paucity of literature as to which approach is the most beneficial. The purpose of this study is therefore to determine which eight-week training regime, line sprinting or plyometric training, will deliver the most significant improvement in speed, agility and peak power in intermediate rugby players.

1.3 Aims and Objectives

This study aims to test and compare the impact of line sprinting and plyometric training on the speed, power and agility of intermediate rugby players.

The objectives of this study are to:

- To assess the effect of line sprinting on speed
- To assess the effect of line sprinting agility
- To assess the effect of line sprinting on power output, and
- To assess the effect of plyometric training on speed
- To assess the effect of plyometric training on agility
- To assess the effect of plyometric training on peak power output.
- To compare the training effects of the two different training methods on speed, agility and peak power.

1.4 Research Questions

- What are the effects of line sprinting on agility, sprinting speed and power output?
- What are the effects of plyometric training on agility, sprinting speed and power?
- Which training protocol is more effective for improving agility, sprinting speed and power output?

1.5 Research Hypothesis

It was hypothesised that both protocols will produce improvements in speed, agility and power output. It was further hypothesised that sprint training will bring about greater improvements in speed, agility and power compared to plyometric training.

1.6 Significance of the Study

Sport scientists, coaches and sportspersons around the globe are continuously exploring different avenues through which they can enhance and maximize key sport specific performance components. Rugby players also need the most effective and appropriate training stimuli to enhance the key physical attributes of their sport in order to achieve optimal performance results. With competitions and tournaments growing in size and number, athletes, coaches and trainers are under increasing pressure to obtain peak performance results in the least amount of time. This study may help to provide more effective and efficient training approaches for coaches and players looking to improve speed, ability and power output.

1.7 Limitations

- Since sprint testing was conducted in an unprotected environment, atmospheric conditions such as wind could have influenced sprint times.

- The participants' extramural activities were not be monitored; therefore, it was not controlled. This means participants could have engaged in activities that could possibly have influenced the outcome of this study
- Genetic differences cannot be controlled
- The participants' dietary intake were not controlled. Certain participants may consume a diet that better aids protein re-synthesis than other participants, therefore resulting in more efficient muscle recovery and an improved capacity to perform the prescribed exercises

- The study did not include a control group

1.8 Delimitations

- Training intervention programmes will be designed and supervised by the same individual
- The participants used for this study will be club level rugby players.
- Results of this study will only be applicable to such individuals
- Participants will not be blind to the treatment that they receive, however, they will be blind to the theory of each treatment and the expected outcome

1.9 Definition of Terms

Sprint - running at maximal speed, over a short distance (Merriam Webster)

Sprint Training - speed training is the improvement of your speed or explosive bodily potential as used in various fitness disciplines (Merriam Webster)

Plyometric - exercise involving repeated rapid stretching and contracting of muscles (as by jumping and rebounding) to increase muscle power (Merriam Webster)

Plyometric Training – "Jump" training which incorporates powerful movements performed quickly. This form of exercise sees an explosive concentric contraction immediately follow an eccentric contraction (Wilk & Voight, 1993).

Fitness – A group of traits in individuals relating to their aptitude to perform physical activity. Fitness can be achieved through performing regular physical activity (Charles et al., 1998).

Speed – Like velocity, speed is the shortest time necessary for an individual or entity to cover a certain distance, but unlike velocity, speed does not specify the direction the entity needs to move in (Harman & Garhammer, 2008).

Agility – A change in speed or direction by the entire body (Sheppard & Young, 2006).

Power – The ability to complete an all-out effort in the fastest possible time (Knuttgen & Komi, 1992).

Rugby – A team sport played with an oval ball. The objection is for one team to score more points than the opposition. This can be done through scoring a try by grounding the ball beyond or on the opposition's try line or by kicking it through the upright posts and over the crossbar. The ball can be taken forward (towards the opposition's try line), by being passed, carried, or kicked (Oxford Dictionary).

1.10 Structure of the Thesis

The thesis consists of five chapters.

Chapter 1 is an introduction to the study. It explains the basis and objectives for this research and provides a motivation or rationale for why it was deemed important to the researcher. An account of the problem under investigation is given, as well as the aims and objectives and the relevant research questions. Important terms are also clarified in this chapter.

Chapter 2 provides a critical overview of literature related to this study.

Chapter 3 provides an outline of the research design and an explanation of the various practices used to answer the questions raised in the study and to address the objectives stated.

Chapter 4 presents the results of this research.

Chapter 5 discusses the study's results and draws conclusions based on the results found.

CHAPTER TWO

LITERATURE REVIEW

2 Introduction

Rugby is a team sport consisting of eight forwards and seven backline players. The game is played on a rectangular surface and lasts for 80 minutes. The sport can best be described as a multifaceted, invasive ball sport consisting of spells of attacks and defence (Hughes and Barlett, 2002). Furthermore, it is a high-intensity contact sport played by men and women across the globe. It is one of South Africa's most popular sports. It remained an amateur sport until 1995 when restrictions on payments to players were removed (Miles, 1995). This new status brought about a completely new set of performance demands on both players and coaches from sponsors, the media and the public.

Since the aim of the current study is to test and compare the impact of line sprinting and plyometric training on the speed, agility and power of intermediate rugby players, this chapter envisages to review these different training methods and their possible impact on three key physical attributes of rugby players identified earlier. They need to be powerful, fast and agile to be able to stop, change direction, kick, pass, sidestep, outrun, jump high in lineouts, push in scrums, wrestle with opponents for ball possession and tackle while either attacking or defending

2.1 Speed, Power and Agility in Rugby

Three of the key physical attributes required for success in rugby is power, agility and speed (Gabbett et al., 2009). It is therefore imperative that these qualities be maximally developed in individual players to maximise overall performance in the sport of rugby. As is the case with many other sports, coaches, players and trainers turned to science and technology to maximally gain from the training and coaching methods they employ to continually improve and advance the levels of performance in the sport.

2.1.1 Agility

One of the key objectives of rugby players, especially backline players, is to evade the defence of the opposing team though highly developed evasive skills and qualities commonly referred to agility. Agility is a complex skill consisting of rapid multidirectional movements at high velocities and is considered a key feature and fundamental component of successful performance in an open skilled sport such as rugby (Wheeler, 2009). Gabbett et al. (2009) have found that effective team performance rests on well-developed physical traits, with agility being one of them. Another study (Sayers & Washington-King, 2005) reported that activities involving agility, such as sidestepping and other forms of evasive running, are key skills in rugby union. They went on to say that, ball carriers who possess good agility can complete these evasive running tasks and present accurate decision-making strategies when faced with defensive reaction from the opposition, enabling them to outmanoeuvre defenders and gain territorial or tactical advantage with the ball (Sayers & Washington-King, 2005).

Agility is defined as the ability to change direction rapidly (Alricsson et al., 2001; Baechle, 1994; Barrow & McGee, 1971). Recently, though, it has also been defined as a change in speed or direction by the entire body (Sheppard & Young 2006). However, agility does not just involve speed and a change in direction. Plisk (2008) is of the opinion that coordination and balance should be considered as key components of agility. There are numerous tests available that can be employed to assess an individual's level of agility. The T-test is a reliable field test that is most commonly used by coaches and sports people as a tool for the determination of their players' agility (Pauole et al., 2000; Semenick, 1990). According to Webb and Lander (1983), the L-Run test was specifically developed to be used by rugby players. However, according to some studies (Meir et al., 2001; Gabbett et al., 2008), the use of the L-Run test has become more common in rugby league in recent years compared to rugby union. The 5-0-5 Test is another test and uses timing gates to assess agility (Draper & Lancaster, 1985). The Illinois Agility Test is believed to be heavily influenced by the ability to sprint quickly over short distances, so its reliability as a test actual agility is affected (Hachana, Chaabène, Rajeb, Khlifa, Aouadi, Chamari & Gabbett, 2014). The test also takes longer to perform than the T-test – usually longer than 15 seconds – so fatigue is likely to set in. A modified, shorter version of the Illinois Test exists, but the original version is still the most commonly used and the shorter test is merely an alternative to the original (Hachana et al., 2014).

2.1.2 Speed

Reaching great sprint velocities over short distances is key for successful performance in a wide variety of team and field sports including soccer and hockey (Rienzi, Drust, Reilly, Carter & Martin, 2000). It is also considered a key success performance factor in rugby union (Duthie et al., 2006) and the employment of different training methods for the improvement of sprinting speed is therefore critical.

Like velocity, speed is defined as the shortest time in which an individual or entity covers a given distance, but unlike velocity, speed does not specify the direction the entity needs to move in (Harman & Garhammer, 2008). According to Plisk (2008), the speed component should be further broken into deceleration, acceleration and the ability to maintain maximal speed. All speed tests make use of timing equipment (stopwatch and electronic timing gates) and are performed on an even surface. Popular lower-body speed tests include the 20, 30, 40, 50, 60 and 80-metre sprint tests (Busquets et al., 2016).

In their study which focused on sprint patterns in rugby union during competition, Duthie, Pyne, Marsh and Hooper (2006) stated that speed is an important performance component in field sports, and that, over shorter distances especially, it is key to success. They further explain their interpretation of how straight-line sprinting in a rugby game differs from regular straight line sprinting since attackers try to avoid defenders through side-stepping and swerving, and these activities, which happen consistently during a single game, make sprinting in rugby "qualitatively and quantitatively different from straight-line sprinting" (Duthie et al., 2006). They concluded that, despite these differences in the actual act of sprinting, rugby coaches, strength, and conditioning professionals still aim to get their players sprinting in a straight line as fast as possible (Duthie et al., 2006).

According to Duthie et al. (2003), rugby union forwards spend four percent of their time in the game sprinting, while backline players far surpass that and spend 25 percent of their game time sprinting.

These figures show the importance of sprinting speed in rugby as a key determinant of success in both attack and defence. A study by Agar-Newmand and Klimstra (2015) also reported that superior sprinting ability has been linked to a lower risk of injury.

Free sprint training i.e. sprint training, which excludes the use of any external equipment, is the most commonly used method used in sprint training programmes and has been found to increase running speed over short distances (Kristensen, van den Tillar & Ettema, 2006; Spinks, Murphy, Spinks & Lockie, 2007)

2.1.3 Power

While strength is the maximal force you can apply against a load, power is the ability to complete an all-out effort in the fastest possible time (Knuttgen & Komi, 1992). Power is one of the key fitness components for success in many sports. In rugby, power is an important performance component as it is needed to perform a large number of game-specific activities (such as scrums, lineouts, rucks, mauls, tackles and jumps – in the lineout or when contesting for the ball in the air).

Numerous tests can be employed to determine lower-body power output. The vertical jump, standing long jump, standing triple jump, drop jump, three-hop test and the two-hop test are some of the more popular measurers of lower-body power output.

The standing long jump was chosen for this study, as it is one of the more sport-specific actions given the goal of rugby – to move forward horizontally. This exercise mimics horizontal power output and movement (Spinks, Murphy, Spinks & Lockie, 2007).

2.2 Physical Fitness Characteristics of Rugby Players

The sport of rugby is characterised by its fast pace, vigorous and aggressive contest for, and retention of the ball through powerful physical engagement. These intense bouts of physical effort are alternated with rest periods differing in duration, sometimes due to play taking place up front (such as scrums and lineouts, occurrences during which the backline players remain out of action for a short period. During a match, speed is a performance component regularly used at either maximal or sub-maximum velocities. Power and agility are also crucial factors, as these components are needed for quick changes in direction to evade a defender, for example, and other activities such as lifting and jumping in the lineouts, tackling, shoving in scrums, and competing at rucks. Hence, speed, agility and power are important performance components in rugby, differing in importance among the different positions (Duthie et al., 2003).

2.3 Introduction to Plyometric and Sprint Training

2.3.1 Sprint Training

Harman and Garhammer (2008) defined speed as the shortest time necessary for an individual or entity to cover a certain distance, while Thomas et al. (2010) define the component as the ability to perform any movement in the shortest period of time.

Speed is especially important for backline players, as these players often have to sprint longer distances (up to 70 metres) to score tries. As the game continues to evolve, with forwards often drifting into play out wide away from some of the tight phases, speed – or mobility – has become a common goal for players outside the backline as well.

Sprint training involves repetitive full sprints over varying short distances (10m – 100m). Studies have shown that this method of repetitive speed work can improve muscle-power production. However, no research articles have produced positive results on the effects of line sprinting alone on agility (Mero et al., 1992; Enoksen et al., 2011).

2.3.1.1 Components of Speed

Speed consist of a number of different components. Acceleration, maximal velocity and speed endurance are three phases that are each trained in a specific way (Barr, Shephard & Newton, 2013).

The study describes acceleration as a very important factor in rugby given the high number of shorter-distance sprints players perform during a game, while maximal velocity is another major factor seeing as players often hit their maximum speed during games.

This study incorporated acceleration training into the intervention programme in the form of sprints performed over a very short distance – 10 metres – and a short distance – 20 metres. Maximal speed or velocity was trained by including 40- and 100-metre distances. For testing purposes, however, only 40 -and 80 metre distances were measured as one of the major focuses of this study was speed (maximal speed) and not acceleration, although it was included as a training or intervention distance to ensure a greater chance of improving overall maximal sprinting speed.

2.3.1.2 Sprint Training Recommendations

Various methods are recommended to enhance speed, with a number of equipment or training styles involved in each method. One study by Cissik (2005) describes one of these methods, assisted sprints, as one way of achieving higher velocities outside the individual's current capabilities. This is done by training the neuromuscular system to be able to maintain these increased velocities by itself (Dintiman & Ward, 2003). High-speed treadmill sprinting, towing and downhill sprinting are all examples of assisted sprinting that can be used as appropriate training methods to improve sprinting performance.

Given the explosive and high-intensity nature of sprint training, at least two days should be allowed to pass between sessions. While the main goal with assisted sprint training is to improve stride frequency, an individual who performs this type of training will take both longer and faster strides.

Behrens and Simonson (2011) found that of the three methods of assisted sprinting; assisted towing, high-speed treadmill sprinting, and downhill sprinting, the method that would result in the greatest improvement is assisted towing. This is because the other two options present a number of challenges ranging from cost (this particularly applies to high-speed treadmill sprinting) and discrepancies to which angle of slope would be the most suitable (downhill sprinting) and because assisting towing is the most sport-specific method. In addition, while performing assisted towing, the individual will incorporate both the acceleration phase and transition to maximal velocity. With downhill sprinting, on the other hand, the acceleration phase is difficult to achieve due to the physical forward lean.

The main goal of resisted sprinting is to increase the strength of the hip extensors, which in turn improves sprinting velocity, without any drastic changes in sprinting form (Faccioni, 1994). The study also states that incorporating resisted sprinting into an individual's training technique can lead to improvement in acceleration and maximal velocity. This is because more muscle fibres will be recruited through a greater neural activation network, which will, in turn, lead to greater stride length. Resisted sprinting can include activities such as uphill sprinting, sprinting with weighted vests and towing.

Strength training is another method of improving sprint performance. Through strength training, the size of the muscle fibres improve, while the individual's ability to generate power and general strength of the individual also improves. The exercises that are prescribed should however be similar to the actual sport in order to obtain maximum benefits (Alcaraz, Palao & Elvira, 2009).

Exercises that contain similar characteristics to the sport has the greatest ability to translate into on-field improvements as well, not just in a gym setting. Engaging the correct muscles and training functionally are key factors, and it needs to be considered whether the activity (in this case, sprinting) is unilateral or not, or horizontal or vertical.

Young, Benton, Duthie and Pryor (2001) determined that exercises like squats are good for improving shorter-distance sprints and speed out of the blocks, while exercises like the Romanian deadlift and strongly engage the gluteal and hamstring muscle groups, which makes this type of exercise more appropriate for maximal speed or maximum-speed sprinting.

Hip strength is also plays a crucial role in sprinting ability as speed improves as hip strength improves (Duthie et al. 2006). This is because the hip extensors are responsible for forward drive and the execution of concentric and eccentric actions during the contact phase.

The hip extensors produce the greatest muscle movements during sprinting and are active during the start of the sprint with an increase in muscle activity as running speed increases (Duthie et al. 2006).

Cissik (2005) also suggested that weight training should be combined with plyometric training. The results further indicated that the specificity of training is also important when taking part in a plyometric programme, and that exercises that require movement in a horizontal plane should be preferred, as sprinting is a horizontal movement (Cissik, 2005). Exercises, like broad jumps, standing long jumps and hurdle hops have the greatest potential for bringing about improvements in performance (Rimmer & Sleivert, 2000) and lyometric exercises that involve muscle velocities that closest resemble sprinting (and forward motion) will have the best effect on sprinting ability.

Training Recommendations

Rey, Padrón-Cabo, Costa, and Lago-Fuentes (2019) found that training resisted sprinting ability only once per week during the in-season was sufficient in improving 20-metre sprint performance and repeated sprinting ability in male soccer players.

Speed involves two components; stride length and stride frequency. Rimmer and Sleivert (2000) recommended that resisted sprinting training should be used to lead to improvements in stride length, while stride frequency can be improved by means of assisted sprinting. The study also explains that weight training can lead to improvements in power output, which is an important consideration when aiming to enhance acceleration and stride length. They specify that exercises that are sport-specific will result in the most significant transfer, the same way that exercises that mimic sprinting will lead to better improvements. One example of this is how sprint and plyometric training combined produce a replication of the movements involved in sprinting, which, in turn, leads to greater sprinting velocity.

In their study, which focussed on the effects of resisted sprint training on acceleration, performance and kinematics in soccer, rugby union, and Australian rules football players, Spinks et al. (2007) stated that resisted sled training and assisted towing are the most sport-specific protocols to lead to improvements in sprint speed. Both of these methods should be done on a level, flat surface and sprint form should still be maintained. They also say that, however, discrepancies exist when it comes to choosing the optimal slope that should be used when incorporating this training regime, and that it can be rather difficult finding a slope that would be appropriate to train on or one that would provide a suitable training surface (Spinks et al. 2007). They go on to explain that the kinematics of uphill sprinting and downhill sprinting activities are different compared to sprinting on a level platform (Spinks et al. 2007). High-speed sprint training on a treadmill is also suggested as a possible training method, but this method could result in a difference in kinematics as the 'ground' moves by itself, meaning the individual does not have to focus on propelling themselves forward at all.

Spinks et al. (2007) further discussed the importance of the musculature around the hips and hamstrings as the most important factors to consider when performing strength training to improve speed. While higher levels of strength lead to greater force production, it should also be considered that combining high-resistance low-velocity and low-resistance high-velocity actions in the training programme lead to the most significant improvements in sprinting speed.

Spinks et al. (2007) also address explosive weightlifting exercises that are high-resistance and high-velocity as a means of improving sprint performance, but state that using all three methods could lead to the most significant improvement in sprint speed.

Lastly, the effectiveness of plyometric training, when done alone or when combined with strength training, in order to improve speed, acceleration in particular, is also included.

Ultimately, Behrens and Simonson (2011) concluded that all variations of all the training techniques discussed above – plyometrics, resisted –and assisted towing and strength and high-velocity power training - should be incorporated in a sport-specific programme to improve speed.

2.3.2 Plyometric Training

The development and introduction of plyometric training is accredited to Dr Verkhoshanky, who referred to it as “shock” training (Chu, 1998). Because of the perceived success of plyometric training, it was considered a crucial component of any programme targeting the development of leg power (Young, 1991)

Given the dynamics of rugby, the proven benefits of plyometric training in relation to gains in power and speed has seen it become an increasingly relevant training technique within the sport.

Plyometric training incorporates dynamic resistance exercises to condition the body, and lower body plyometric training typically includes jumps and hops. These exercises increase muscle power through exploiting the muscles' lengthening and shortening cycles. For plyometric to be performed, a muscle needs to undergo quick stretching (eccentric phase) before undergoing quick shortening (concentric phase).

During regular plyometric training, the nervous system becomes trained to react rapidly to the stretch-shortening cycle. This, in turn, results in higher power output as well as faster speed of movement.

Plyometric exercises range from low intensity to high intensity. Lower intensity, lower body drills include exercises like double-leg hops, while a higher intensity, plyometric training programmes could include exercises like depth jumps (Faigenbaum & Chu, 2017).

As with any other type of training, the potential for injury is exacerbated if the programme involves an intensity, volume and frequency too high for the abilities of the athlete (Faigenbaum & Chu, 2017).

2.3.2.1 Plyometric Training Frequency

While the ideal frequency of plyometric training sessions per week to achieve maximal adaptations in performance-related components has until fairly recently been unresolved, there are various studies that have aimed to determine the optimal training frequency and volume.

A study conducted by Chaabene, Garcia-Pinillos, García-Ramos et al. (2018) compared the difference in effects of eight weeks of in-season plyometric jump training consisting of one session versus two sessions per week in women soccer players. They used a single-blind randomised controlled trial. The participants (*N*= 23; age, 21.4 ± 3.2 years) were assigned at random to one of three groups – a group that performed only one session per week (PJT-1,*n*= 8), a group that performed two sessions per week (PJT-2,= 8) and a control group (CON,*n*= 7) (Chaabene, Garcia-Pinillos, García-Ramos et al., 2018).

Prior to their normal soccer training, and afterwards as well, participants performed drop jumps, counter-movement jumps, maximal kicking velocity tests, the Meylan test, the Yoyo test and the 15-m linear sprint test.

The study's results presented a significant improvement in all tests for group 1 and 2. The control group presented no significant changes to their pre-intervention results ($p > 0.05$; 0.5–4.2%, $d = 0.03$–0.2) (Chaabene, Garcia-Pinillos, García-Ramos et al., 2018).

These results infer that a higher frequency of plyometric training holds no additional benefits for the fitness of women soccer players (the group that performed plyometric training twice a week didn't produce more significant results than the group that only followed the plyometrics programme once a week). Thus, they concluded that plyometric jump training performed once a week in addition to soccer-specific training is sufficient to improve fitness in women soccer players (Chaabene, et al., 2018).

There is limited information on the effect of progression in the plyometric training of rugby players in terms of number of sets and repetitions. Pienaar (2009), in her study on plyometric training in rugby players, concluded that constant modification in training programme activities would probably bring about muscle overload and more prominent changes in speed, agility and power.

2.3.2.2 Plyometric Training Volume and Intensity

There is also debate surrounding which intensity is best to induce maximum adaptation. Badillo, Izquierdo and Sáez de Villarreal (2008) assessed the effects of various plyometric training frequencies linked to a number of different training volumes on speed, vertical jumping ability and maximal strength. The study included 42 students who were assigned at random to one of four groups.

These groups consisted of a control group, a group that performed drop jumps once a week, a group that performed drop jumps twice weekly, and a group that performed drop jump four times weekly. The drop jumps were performed from three different heights (20, 40 and 60 cm).

After the seven-week intervention, the tests used to determine if any improvement had occurred included 20-m sprints, maximal strength tests, and the height achieved during drop jumps and counter-movement jumps (Badillo, Izquierdo & Sáez de Villarreal, 2008).

There was no significant difference in any of the variables between the different groups before training commenced. The control group produced no differences of significant value in any of the variables following the intervention. The group that performed plyometric training twice weekly produced similar results in ump training to the group that performed plyometric four times a week, but they produced a higher training efficiency (~12% and 0.014% per jump compared with ~18% and 0.011% per jump) (Badillo, Izquierdo & Sáez de Villarreal, 2008).

The two groups that performed a low and moderate number of training sessions per week showed similar improvements in jumping contact times, 20-m-sprint time, and maximal strength compared with high training frequencies, finding that there are no added benefits to performing higher-volume plyometric training compared to moderate-volume plyometric training. The fact that short-term plyometric training incorporating a moderate volume of jumps and training frequency led to greater training efficiency compared with a high-frequency plyometric programme also supports moderate over high training volume and frequency (Badillo, Izquierdo & Sáez de Villarreal, 2008).

To summarise, this study makes use of moderate-intensity plyometric and sprint training protocols, performed at moderate volume and frequency, to determine which training protocol will produce the most significant improvements in speed, lower-body power output and agility in intermediate male rugby players.

Plyometric Training Intensity Guidelines (Ebben, 2008)

- Those aiming for a high-intensity plyometric workout should opt for single-leg exercises as opposed to double-leg drill
- The higher the jump (from the ground) or the higher the height of the box (if box jumps are performed, for example), the higher the intensity of the activity

- Adding weights to plyometric training does not increase the intensity of the workout due to ground reaction forces. This is because when extra weight is added, an individual is less likely to achieve a greater vertical or horizontal jumping. Intensity is always determined by jumping height or distance, so exercises performed with additional weights will often be of only moderate intensity
- When arms reach overhead while performing jumps, particularly when trying to reach up to a goal, the jump height will be higher, which will see the individual perform at a higher intensity
- Plyometric exercises performed during this study were of a moderate intensity, with no added weights used.

2.4 Muscle Adaptation with Plyometric and Sprint Training

2.4.1 Muscle Fibre Classification

Muscle fibres also play a key role in an individual's ability to excel in certain activities. These fibres are composed of sarcomeres – units that holds the myofibrillar proteins myosin and actin. Muscle contractions occurs when these proteins interact. A number of classification methods exist to categorise different muscle fibres based on their physiological aptitudes and myosin structures. In the past, there were only two classifications for muscle fibres. These groupings were based on their speeds of shortening.

Scott, Stevens and Binder-McLeod (2001) state that most researchers place all muscle fibres into the traditional three groups (I, IIA, or IIB), while explaining that seven fibre types are recognised in humans. They further explain that fibres are categorised differently based only on staining intensities. This is due to differences in pH sensitivity rather than differences in the relative hydrolysis rates of ATPases (Scott et al., 2001).

Types IC, IIC, IIAC, and IIAB - which have intermediate myosin ATPase staining characteristics – have more recently also been identified as muscle fibre types (Scott et al., 2001).

The slowest fibre, Type IC, is more similar to Type I fibres due to their staining characteristics, whereas Type IIAC is more similar in stains Type IIA. Type IIAB fibres have intermediate staining characteristics between type IIA and IIB fibres (Scott et al., 2001).

To summarise, Scott et al. (2001) ranked the seven muscle fibre types in humans, in this order: Types I, IC, IIC, IIAC, IIA, IIAB, and IIB, ranging from slowest to fastest.

2.4.2 Characteristics of Muscle Fibre Types

Where rapid, powerful actions or movement is concerned, fast-twitch muscle fibres play the primary role. These muscle fibre types are therefor of great importance when it comes to sports or any physical activity that requires an individual to produce quick, powerful movements or cover various distances in the shortest amount of time.

Fast-twitch muscle fibres are capable of generating energy to produce these powerful actions, and this courtesy of the high rate of cross-bridge turnover associated with Type II muscle fibres (Wilson, Loenneke, Jo, et al. 2012). A high activity level of myosin ATPase, electrochemical transmission of action potentials, and a quick rate of calcium release and uptake also contribute to the rapid rate at which these muscle fibre types can generate energy (Wilson, Loenneke, Jo et al. 2012).

Compared to slow-twitch muscle fibres, the intrinsic shortening speed and tension development is significantly (three to five) faster. The short-term glycolytic system and fast-twitch muscle fibres' reliance there its energy system allows this type of muscle fibre to be activated quickly.

Slow-twitch muscle fibres, on the other hand, rely on ATP resynthesis to generate energy, and this is largely done through the aerobic system. Their calcium-handling ability is not as fast as with fast-twitch fibres, they have a comparatively lower activity level of myosin ATPase, and their glycolytic capacity is more developed than that of fast-twitch muscle fibres (Wilson, Loenneke, Jo et al. 2012).

The greater glycolytic capacity of slow-twitch muscle fibres, their high concentration of mitochondrial enzymes and the fact that they have a larger quantity of mitochondria mean that this muscle fibre type takes longer to fatigue and is therefore better equipped to sustain aerobic metabolism. It also makes this muscle fibre type more suited for endurance activities.

The third type – Type IIa – is seen as intermediate as shortens rapidly, yet it also has a rather well developed capacity for aerobic and anaerobic energy transfer.

Another reported type - Type IIb – has the most superior anaerobic potential. It can be described as the “true” fast glycolytic fibre. Type IIc fibre is a rarer fibre type, and is somewhat undifferentiated. It is possible that this type of muscle fibre is fibre contributes to motor unit transformation (Marieb, 2000).

2.4.3 Training-Induced Muscular Changes

In a study by Kubo, Ishigaki and Ikebukuro (2017), the effects of isometric and plyometric training programmes on muscle and tendon stiffness under passive and active conditions were assessed. This study was the first to determine the effects of plyometric and isometric training on these components.

A number of previous studies have shown that the mechanical properties of the muscle-tendon complex change after plyometric training (Kubo et al., 2007; Spurrs et al., 2003).

Kubo et al. (2007) was one of them. This study reported that 12 weeks of plyometric training led to a significant increase in ankle joint stiffness and jump performance (under active conditions, a stiffer muscle is more desirable under as it is capable of storing more elastic energy within the tendons during stretch-shortening cycle exercises).

Kubo et al. (2007) had participants partake in training for 12 weeks, three times per week. They performed plyometric training with the one leg and isometric training with the other. Each participant’s left and right legs were allocated a training protocol in a random manner. The measurement of one-repetition maximum for plyometric training and a maximal voluntary contraction for isometric training were conducted every four weeks to adjust the training load.

Post each training session, 1RM and maximal voluntary contraction significantly increased by 37.7±11.3% for plyometric training and 27.6±4.0% for isometric training, respectively (both $P<0.001$).

Foure et al. (2009), though, reported no significant changes in tendon stiffness after a plyometric training programme was introduced. Other studies, however, added to the conflicting past results of this topic when they found significant increases (Burgess et al., 2007, Foure et al., 2010, Wu et al., 2010). Spurrs et al. (2003) determined that musculotendinous stiffness in the ankle joint - measured by the oscillation technique - significantly increased after just six weeks of plyometric training, while running economy and three-kilometre running performance both showed improvement.

Kubo et al. (2005) and Wang et al. (2012) investigated stiffness and hysteresis of tendons during ramp isometric contractions, and found that the strain rates of tendons were notably different compared to that seen during running and jumping. This prompted Kubo et al. (2007) to investigate tendon properties during ballistic contractions in order to explain changes in tendon properties and performance brought on by plyometric training.

According to the study's results, the muscle thickness of the plantar flexors showed significant increases following plyometric training (5.7±2.6%), while isometric training showed a 5.5±2.3% improvement (both $P<0.001$). No significant difference was found in the relative increase in muscle thickness between plyometrics and isometric training ($P=0.804$). Maximal voluntary contraction significantly increased by 4.4±5.0% in the plyometric leg ($P=0.013$)

and 22.1±14.2% with the isometric one ($P<0.001$). The increase in maximal voluntary contraction was significantly greater with isometric training than with plyometric training ($P=0.001$).

Kubo et al. (2007) revealed that plyometric training more beneficial than isometric training relating to active muscle stiffness during fast stretching and the extensibility of tendon structures during ballistic contractions. It can therefore be deduced that plyometric training is an appropriate training protocol when the goal is to enhance the extensibility of tendon structures during ballistic contractions. Plyometric is also a worthwhile training protocol to enhance active muscle stiffness during fast stretching.

Carey, Cole and Dawson et al. (1998) determined the changes in performance, muscle metabolites, enzymes and fibre types after short sprint training. Their study involved nine fit male participants who performed 16 outdoor sprint sessions over a six-week period.

Thirty to 80 metre distances were covered at 90-100 percent maximum speed, with between 20 and 40 sprints performed during each session. Sprint (10 and 40 m times), sustained sprint (supramaximal treadmill run), repeated sprint (six 40 m sprints, 24 seconds recovery between each sprint) and endurance tests (VO2 max) formed part of the intervention, and these tests were performed before and after normal training. Muscle biopsy samples of the vastus lateralis were taken to examine changes in enzyme activities, metabolites and fibre types.

Following training, there were significant improvements in the 40-m time ($P < 0.01$), supramaximal treadmill run time ($P < 0.05$), repeated sprint performance ($P < 0.05$) and VO_{2max} ($P < 0.01$). There were no changes in resting muscle concentrations of ATP and phosphocreatine did not change. Phosphorylase activity increased ($P < 0.025$) and citrate synthase activity decreased ($P < 0.01$), but there were no significant changes in myokinase and phosphofructokinase activities. There was a significant increase in the proportion of type II muscle fibres ($P < 0.05$). The results found showed that six weeks of short sprint training could improve endurance, sprint and repeated sprint ability in fit, male individuals, while significant increases in the proportion of type II muscle fibres are also possible with short sprint training over a short period of training.

2.5 Effects of Plyometric Training on Sprint Performance

Rimmer and Sleivert (2000) set out to determine the impact of a sprint-specific plyometric programme on sprinting performance. Their study, which was conducted over an eight-week period, reported that the plyometric group experienced significant improvements in sprint times over the 10m distances (pre 1.96 +/- 0.10 seconds, post 1.91 +/- 0.08 seconds, p = 0.001) and 0 to 40m distances (pre = 5.63 +/- 0.18 seconds, post = 5.53 +/- 0.20 seconds, p = 0.001), while the sprint group did not experience significant improvements over either distance (pre 1.95 +/- 0.06 seconds, post 1.93 +/- 0.05 seconds) or (pre 5.62 +/- 0.14 seconds, post 5.55 +/- 0.10 seconds) (Rimmer & Sleivert, 2000). They also stated, however, that while the plyometric group's results showed more significant improvement than the sprint group, the significance of the improvements of the plyometric groups did not differ significantly from that of the sprint group.

Findings on the effects of plyometric on sprinting are not consistent, however, it has generally been agreed that exercises and drills that are more specific to any action or movement will better benefit the athlete (this could be due to increased familiarity with the movement) (Delecluse, Van Coppenolle, Williams et al., 1995).

A systematic review conducted by Sáez de Villarreal, Requena and Cronin (2012) on the effects of plyometric training on sprint performance, found that the combination of different types of plyometric training and incorporating greater horizontal acceleration is beneficial in optimising sprint enhancement. They also stated that there are no additional benefits to be gained from adding weights to plyometric training as this actually leads to a drop in intensity in the exercises performed (Sáez de Villarreal et al., 2012).

Enoksen et al. (2011) assessed the effects of 40-m repeated line sprinting on repeated sprint speed endurance, maximal sprinting speed, vertical jump and aerobic capacity in young elite male soccer players. Results from the study indicated that the participants had produced a statistically marked improvement in performance from pre -to post-test in the following items - 20- to 40-m top speed (−0.05 seconds), 40-m maximum sprint (−0.06 seconds), 10 × 40-m repeated sprint speed (−0.12 seconds), and CMJ (2.7 cm) (Enoksen et al., 2011)

Thomas et al. (2009) assessed the effects of two plyometric training techniques - depth jumping and counter movement jumps - on agility and power in youth soccer players. Following the intervention programme, both groups showed improvement in vertical jump height ($p < 0.05$) and agility times ($p < 0.05$). There was, however, no significant difference found relating to sprint performance. There were no differences between the treatment groups ($p > 0.05$), thus finding that both protocols are worthwhile training regimes for improving power and agility in young soccer players.

Juhász, Karsai, Meszler, Tollár and Váczi (2013) did a study on the effects of a short-term in-season plyometric training program on agility, knee extensor strength and power in male soccer players. Results indicated that plyometrics consisting of high impact unilateral and bilateral exercises induced great improvements in lower-body power and maximal knee extensor strength, while smaller improvements in soccer-specific agility were observed (Juhász et al., 2013).

Mujika, Santisteban and Castagna (2009) studied the impact of short-term sprint and plyometric training on elite, junior soccer players. The intervention was conducted in-season. The study set out to assess and compare two different short-term sprint and power training protocols on vertical counter-movement jump height, 15-m speed and agility in 20 male elite junior soccer players. The outcomes of the study favoured contrast training over line sprinting in the short term when the goal is to achieve improved sprint performance during the in-season relating to soccer specifically (Mujika et al., 2009).

A study conducted by Potteiger et al. (1999) determined the changes in power production and muscle fibre characteristics after a plyometric and aerobic training programme done over a three-week period concluded that the increased power output following a plyometric training program could partially be linked to muscle fibre size.

2.6 Effects of Plyometric Training on Maximal Power Output and Jumping Ability

Plyometric drills with minimum ground-contact time and its effects on maximal lower-body power output were assessed by Makaruk and Sacewicz (2010). They also sought to determine the training protocol's effect on jumping ability. Forty-four non-training participants formed part of the study. The research group found that the plyometric training led to increases in the relative maximal power output ($p \leq 0.001$) in counter-movement jumps and drop jumps, while the five-hop test distance length did not change significantly ($p > 0.05$).

Markovic, Jukic, Milanovic, et al. (2007) assessed the impact of line sprinting on dynamic athletic performance and muscle function. They also equated it to the effects brought on by standard plyometric training. In doing so, they discovered that plyometric and sprint groups showed significant improvement in squat jump and counter-movement jump height approximately 10 and 6%), drop jump performance (15.6 and 14.2%), and standing long jump distance (3.2 and 2.8%). All the effect sizes were moderate to high and ranged between 0.4 and 1.1.

Ross, Ratamess, Hoffman, et al. (2009) used 25 male athletes to assess the effects of treadmill line sprinting and resistance training – both independent and combined – on power output and maximal sprint velocity. The combined group showed significant improvement in 30-m sprint times. All groups produced improved results in treadmill sprint velocity. The sprint -and resistance-training group and sprint-only groups showed a greater increase than resistance training-only group.

2.7 Types of Plyometric Exercises

A myriad of plyometric exercise exists. Examples of plyometric exercises include the following;

- Jump-in-place (jump and land on the same sport (Young1991));
- Standing jumps (single horizontal or vertical jumps (Young, 1991));
- Bounding (amplified striding (Young, 1919);
- Multiple hops and jumps;
- Depth jumps (jumping from different heights followed by immediate take off after landing – the touch and go action must be stressed (Young 1991);
- Box drills (consists of a combination of hops and jumps with depth jumps (Young, 1991).
- Squat jumps (jump straight up from a squat position, upon landing go straight back into squat position ready for next jump.

2.8 Effects of Sprint Training on Maximal Power Output and Jumping Ability

Lockie, Murphy, Schultz et al. (2012) conducted research on the effects of different speed training protocols on sprint acceleration kinematics and muscle strength and power in field sport athletes. They discovered that the changes in strength and power were specific to the protocol. All three groups – the plyometric, free-sprint training and resisted sprint training groups showed improvements in reactive strength index (this was shown in their 40-m drop jump performance), while the free sprint training group also showed an improvement in horizontal power. This was measured by the five-bound test.

2.9 Summary

Chapter two gives an in depth overview of the literature relating to sprint and plyometrics training on speed, agility and power. The review of the literature showed that both sprint and plyometric training have positive developmental consequences for speed, agility and power, which are key performance indicators for a sport such as rugby.

CHAPTER THREE

METHODS

3.1 Research design

This study made use of a quasi-experimental research design, as it did not include a control group. Quasi-experimental research designs, like experimental designs, test causal hypotheses (White & Sabarwal, 2014). The effect of the treatment or intervention is assessed by means of pre-specified pre- and post-tests (White & Sabarwal, 2014).

3.2 Experimental approach to the study

The aim of this study was to determine which training regime, line sprinting or plyometric training, would deliver the biggest improvement in speed, peak power, agility and the ability to exert power over a specified period in intermediate rugby players. Participants were assessed on these three, pre - and post the eight-week intervention period.

3.3 Participants

The participants of the study included 22 club level rugby players, aged 18-25 years. They trained at least three times a week and played league or friendly matches once a week. The players were assigned at random to either the line sprinting group or the plyometric group (11 players per group). A requirement for participants was for them to be healthy and injury free.

Participants were informed about the experimental risks and were required to fill out a health questionnaire to ensure none of them had any chronic illnesses or major signs and symptoms suggestive of coronary artery or pulmonary disease.

3.4 Testing

Both groups were tested prior to the commencement of the training intervention. This served as the baseline speed, agility and power output data for the study. Post-tests were conducted at the conclusion of the eight-week intervention period to determine whether the training methods brought about changes in the speed, agility and power output of the players and which method produced the biggest improvements. Participants were allowed three attempts for each pre -and post-test, with the best of three used for research purposes.

3.4.1 Speed

Sprinting speed over distances of 40– and 80 metres were tested using electronic timing gates before the commencement of the study and after the intervention period. The timing gates were placed at either line of the sprint (start and the finish lines).

These distances were tested based on their relevance in rugby union. Cunniffe, Proctor, Baker and Davies (2009) found that the average sprint in a game is 20 metres long. This sprinting distance is covered 30 times in a match, on average, while jogging at a fast pace, covering a distance of 20 metres, occurs 90 times in a single match.

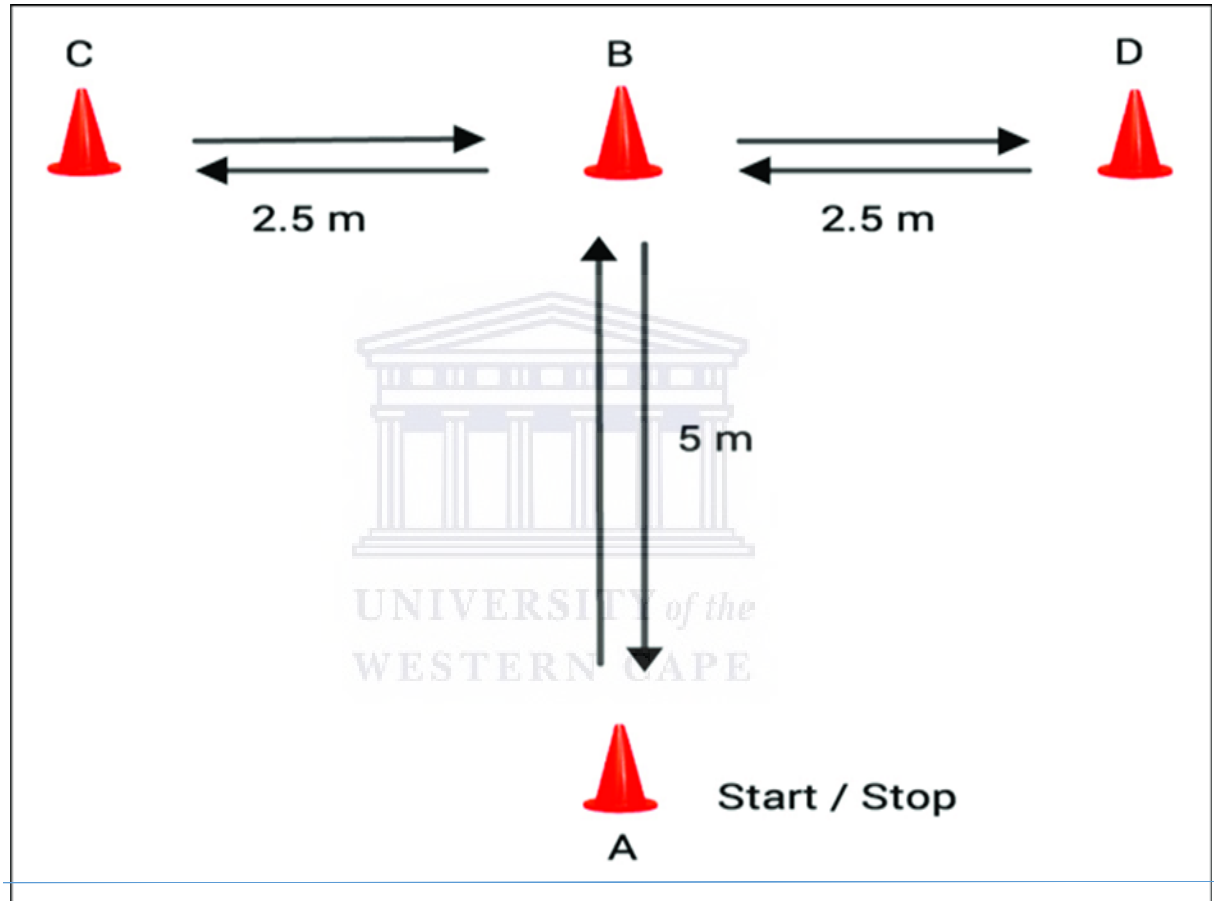
Tries of 80 or so metres virtually only occur when a player scores a breakaway try that originates in close proximity to his own try line, or when an opposing player needs to chase down and defend such an attacking player.

Rugby games are characterised by intense bursts of speed mainly executed by backline players at either maximum or sub-maximum velocities over distances of up to 70 meters (Bompa & amp; Claro, 2009). Eighty metres is around the maximum distance a rugby player would have to cover in a single piece of play, as the entire field of play (in length) can be 100 metres at most (World Rugby lawbook, 2019). Therefore, this distance was used as one of the two distances that were measured pre –and post intervention in this study, whereas the other distance – 40 metres – was decided on as anything less (like 10 metres, for example) would have fallen more in the acceleration category as opposed to maximum speed.

3.4.2 Agility

The T-test was used to measure agility. According to Garhammer; Lacours, Madole, Pauole, Ralph and Rozenek (2000), this test is highly reliable as it measures a variety of performance components (including agility, lower-body power and leg speed). Pauole et al., 2000 and Roozen, 2004 also stated that the T-test is one of the most accurate measurers of agility founded on recognised criteria data for males and females and because of the reported validity and reproducibility of the tests. Thus, it can be useful when distinguishing between those competing in sports at low and higher levels.

The T-test was performed on a non-slip surface, with cones marking the parameters. Electronic timing gates were placed at the starting point (which is also the finish point) to record the participants' time. This test includes forward, lateral, and backwards running, and the markers (cones) are placed in the formation as illustrated below (Figure 1).



Source: Researchgate.net (2013)

Figure 1. Agility test illustration

The test starts at the first cone (A). When ready, participants sprint to the second marker (B) before reaching down with their right hand and touching the base of the marker. They then move to marker C by shuffling sideways, before using their left hand to touch the base of the cone. The participant then shuffles sideways, to the right, to Cone D, where they touch the base with the right hand. The participant then shuffles back to cone B, before back paddling back to Cone A as fast as they can. Their time is recorded as soon as they move through the speed gates at the starting point. It is important that participants' feet do not cross while shuffling.

Participants were allowed three attempts during both pre– and post-intervention testing, with the best result used for research purposes.

3.4.3 Power

The standing long jump test was used to measure lower-body power output (Reid, Dolan & DeBeliso, 2017). It is popular tool for the measurement of lower body power output because it is easy to administer, it can be done in many different locations (good field test) and it is cheap. Reid, Dolan and DeBeliso (2017) found the standing long jump to be highly reliable with an interclass reliability coefficient of ICC=0.99 (Standard Error Measurement = 0.04).

During this test, the participant stood behind a line clearly marked on the ground. Their feet were slightly apart. The participant jumped as far as possible, taking off on both feet, and landed on both feet as well. They used a swinging motion of the arms and bending of the knees to provide forward drive.

The participant landed on both feet without falling backwards and, as with the other tests, three attempts were allowed, with the best of three used for inclusion and analysis in the current research. The measurement was taken from the marked line (for take-off) to the nearest point of contact upon landing (the back of the heels).

3.5 Training Intervention Programmes

Sprint Training Programme Design

Cissik (2015) identifies running technique and form as a major part of the line sprinting. Stride length and frequency of strides are also raised as factors that could influence, while sprints covering varying distances and intensities are also underlined. These guidelines, however, are directed at track athletes specifically.

In rugby, unless a player is defending a ball carrier or chasing a kick, for example, maximum speed reached with the ball is a bigger focus than straight-line sprinting without possession.

Plyometric Training Programme Design

Plyometric training programmes can be designed using a number of different design variables (Ebben, 2008).

Chmielewski, Myer, Kauffman and Tillman (2006) suggested the following training variables to consider when designing a plyometric programme.

Intensity

Intensity refers to the total amount or percentage of effort required by an individual in order to perform an activity.

The intensity of a plyometric exercise is determined by the type of movement that is performed. One-legged jumps, for example, are of a higher intensity than two-legged jumps.

It is crucial that these variables are considered when designing a plyometric-based programme for conditioning or rehabilitation purposes.

Volume

The term volume refers to the total amount of activity or work performed in a single cycle or training session.

When it comes to plyometric training, volume is often determined by taking into account the number of repetitions, sets and the load of the exercise, for example, the number of jumps or throws performed.

Chmielewski et al. (2006) suggests that 50-foot contacts in a training session would be classified as being of a low volume, while more than 200-foot contacts per session would be considered high volume, which would result in the intensity of the session being lower.

Volume should be increased gradually, dependent on the individual's progression, in order to lower the risk of over-training or injury due to performing above your athletic ability.

Frequency

Frequency refers to the number of training sessions performed during a single training cycle.

Recovery

Recovery is a vital part of every training programme, especially given the demands of plyometric training.

Chmielewski et al. (2006) further explain that longer recovery times are needed between plyometric training sessions, suggesting that the recommended time that should pass between sessions is 48 to 72 hours, while the rest period between sets should be five to 10 times more than the amount of time it takes to perform a set, as followed in this study.

Specificity

Specificity is also one of the recommendations of Chmielewski et al. (2006).

Under this point, it is recommended that a plyometric programme should be designed and applied based on the sport of the participant and position in order to ensure that maximum effect is gained from the programme.

In this study, players were not divided into a group based on whether they were a back or a forward. No front-row players formed part of the plyometric group, but forwards who do use jumping activities often during a match – like locks and flankers – did. Backline players like wings, fullbacks and fly halves – all players who often have to contest for possession of the ball in the air – were divided between the sprint and plyometric groups.

A number of Measurements or Determinants of Plyometric Intensity are Available.

Ebben (2008) suggests that the intensity of a plyometric training programme depends more on the specific exercise performed as opposed to ground-contact time.

Assuming all plyometric exercises are performed maximally:

- Single-leg plyometric activities are of a higher intensity than a similar exercise performed on both legs
- Jumps in place involve the highest knee-joint reaction forces, adding to the intensity of the activity
- The higher the distance from which the individual jumps or the higher the distance they jump onto, the greater the intensity of the exercise
- Exercises or jumps that are performed with added weight – whether it is handheld or in the form of weighted vests or ankle weights – lower the intensity of an exercise and usually result in a moderate-intensity activity due to ground-reaction forces. When it comes to plyometric drills, intensity is determined more by the height of the jump than the added weight. Additional weight results in a lower jumping height, making the plyometric activity less intense than it would have been had no extra weight been added

- If the individual reaches their arms overhead while performing a jump, especially when the goal is to reach an object above the head, the activity will result in a higher jump, making it higher in intensity.

Jensen & Ebben (2005) also suggest an Approximate Highest to Lowest Level of Intensity Plyometric Exercises:

- Single leg jumps
- Depth jumps that are performed from a height that is similar to the individual's maximal vertical jump height
- Pike jumps and tuck jumps
- Maximal jumping that involves reaching for an overhead goal
- Depth jumps and low box jumps
- Weighted jumps
- Squat jumps
- Sub-maximal jumps (in place)
- Sub-maximal jumps (in place)

This study used the above as a guide to select plyometric exercises that would fit a moderate-intensity programme. Relating to volume, Chmielewski et al. (2006) recommended the following guidelines be followed based on the physical fitness of the participant:

Table 1: Plyometric exercise volume (foot contacts) based on athletic ability.

Beginner	Intermediate	Advanced
80-100	100-120	120-140

Furthermore, when looking at volume determined through foot contacts, it can also be determined based on exercise intensity.

Table 2: Plyometric exercise volume (foot contacts) based on exercise intensity**.**

Low	Moderate	High	Very High
400	350	300	200

Given the physical condition of the participants, their limited involvement in sport competitions and their limited knowledge and engagement with plyometric and sprint training, an exercise programme of a moderate intensity was considered sufficient for producing improvements in the speed, agility and power output. This is also a precautionary measure against the risk of injury associated with the overloading effect brought about by high intensity exercises. A health questionnaire was also completed to determine whether there were any pre-existing conditions present that would make participation in this study a risk.

Both groups followed their respective training programmes twice weekly. Both groups performed a warm-up with a light three-minute jog followed by dynamic stretches for five minutes.

The intervention was done on Monday and Thursday afternoons. For the line sprinting, a standard rugby field (70 metres in width by 100 metres in length) was used, with clear markings to indicate the distance of the sprint. During training, participants performed short-distance sprints (10, 20 -and 40 metres) and longer-distance (100-metre) sprints.

These distances were used during the intervention period to ensure that the components of speed – acceleration, maximum speed and speed endurance – all of which are important in rugby were incorporated into the training programme.

Three maximal sprint sets of each distance were performed, with varying repetitions as the intervention progressed, with a three-minute rest period between sets throughout the study.

For the plyometric training, activities were performed in a gym setting where shock-absorbing surfaces were available to avoid any strain or injury during sessions. The participants performed four lower body plyometric exercises – squat jumps, box jumps (60 and 80 cm), lateral single-leg hops and depth jumps (80 cm) - with varying repetitions and three sets, and three minutes rest between sets.

Table 3: Plyometric training programme

Week	Plyometric group
	Exercise / Reps / Sets
1	Squat jumps / 8 / 3
2	Squat jumps / 8 / 3
3	60cm box jumps / 8 / 3
4	80cm box jumps / 8 / 3
5	Single-leg hops / 8 / 3
6	Single-leg hops / 8 / 3
7	80cm depth jumps / 8 / 3
8	80cm depth jumps onto 60cm box / 8 / 3

Weeks 1 & 2: Squat Jumps

The squat jump was performed as follows: Participants stood with their feet approximately shoulder-width apart. They then squatted down with their weight on their heels. When they hit the bottom of your squat, they drove hard through your legs and heels as they jumped straight up pushing off from their toes at the last moment of contact with the floor. They landed softly, and then use the momentum from landing to go right into your next squat (this constituted 1 jump).

Weeks 3 & 4: Box Jumps

The box jump was performed as follows: Participants stood with their feet shoulder-width apart. They then bent into a quarter squat, swung their arms back and then swung them forward to help gain an explosive take-off off the ground. They aimed to land on the box as softly as possible, while mimicking the take-off position upon landing was also prioritised – with their feet flat and the knees slightly bent. The participants then jumped back down from the box before resuming the next repetition.

Weeks 5 & 6: Single Leg Hops

The single-leg hops were performed as follows: Participants stood on one slightly-bent leg, with the other leg bent at a 90-degree angle and their hands resting on their hips. Following the lines drawn on the surface, participants then hopped over it from side to side, focusing on landing softly, with the knee properly aligned with (and not extending over) the toes. Each crossing of the line constituted one single-leg hop.

Weeks 7 & 8: Depth Jumps

The depth jumps were performed as follows: The intensity of the exercise is largely dependent on the height from which you drop. Participants dropped down from 80-cm boxes to perform this exercise. Participants stood with their feet shoulder-width apart and arms hanging by their sides, relaxed, before jumping off the box and landing on their feet, with their heels also briefly touching the ground. They then immediately jumped off both feet as high as they possibly could. During this exercise, it was important that participants minimised ground-contact time (amount of time their heels were on the ground after landing before performing the jump). This constituted one repetition.

For progression, in the final week, participants performed the same movement, only this time they had a specific goal as opposed to just jumping as high as possible after dropping down from the box. Upon landing on both feet simultaneously and with both heels touching the ground, participants then leaped up onto a 60-metre high box. To maximise the height they reached during this action, participants swung their arms back as soon as their feet touched the ground and swung them forward upon take-off. This movement constituted one repetition.

Rest: In between each set, participants rested for 3 minutes.

Table 4: Line sprinting programme

Week	Sprint group
	Exercise / Reps / Sets
1	10m sprint / 5 / 3
2	10m sprint / 5 / 3
3	20m sprint / 5 / 3
4	20m sprint / 5 / 3
5	40m sprint / 4 / 3
6	40m sprint / 4 / 3
7	100m sprint / 3 / 3
8	100m sprint / 3 / 3

Weeks 1 & 2: 10-metre Sprints

The 10-metre sprints were performed as follows: Participants lined up behind a line and, from a standing start, they sprinted to marker 10-metres away as fast as possible as soon as they were signalled to do so. They walked back slowly after each sprint. This constituted one repetition. Five repetitions were performed.

Weeks 3 & 4: 20-metre Sprints

The 20-metre sprints were performed as follows: Participants lined up behind a line and, from a standing start, they sprinted to marker 20-metres away as fast as possible as soon as they were signalled to do so. They walked back slowly after each sprint and commenced the following repetition upon the signal. This constituted one repetition. Five repetitions were performed.

Weeks 5 & 6: 40-metre Sprints

The 40-metre sprints were performed as follows: Participants lined up behind a line and, from a standing start, they sprinted to a marker that was 40-metres away as fast as possible as soon as they were signalled to do so. They walked back slowly after each sprint and commenced the following repetition upon the signal. This constituted one repetition. Four repetitions were performed.

Weeks 7 & 8: 20-metre Sprints

The 100-metre sprints were performed as follows: Participants lined up behind a line and, from a standing start, they sprinted to marker 100-metres away as fast as possible as soon as they were signalled to do so. They walked back slowly after each sprint and commenced the following repetition upon the signal. This constituted one repetition. Three repetitions were performed.

Rest: In between each set, participants rested for 3 minutes (three to five minutes rest between sets, or rest at a ratio of one to five, is adequate for full phosphagen recovery when taking part in power training; Kraemer, 1992).

Both groups cooled down for 10 minutes with static stretches.

3.6 Statistical Analysis

SPSS V25 was used to do the statistical analysis. Data are presented as means and standard deviations. To assess whether there are differences between the speed, power and agility pre- and post-tests results of the two training protocols groups, a paired samples t-test was used. An independent samples t-test was used to compare the improvements in the speed, power and agility between the two groups. The level of significance was set at $p<0.05$. Box plots were produced for average and maximum heart rates to illustrate the spread of the scores and the differences between pre- and post-tests. Effect sizes were calculated to quantify the size of the differences between the pre- and post-tests. Effect sizes were interpreted using Cohen's guidelines (1992) (0.2=small; 0.5=medium; 0.8=large and 1.3=very large).

3.7 Ethics

Concerning ethics considerations, permission to conduct this research was obtained from the University of the Western Cape's Biomedical Research Ethics Committee (REFERENCE NUMBER: BM17/1/17).

3.8 Informed consent

Participants were invited to a briefing meeting, where the aims and objectives of this study were explained. During this meeting, the procedures and protocols involved in the testing were explained orally and in writing by means of an information sheet (APPENDIX A). The testing protocols were also explained in detail. Participants were assured that measurements would be conducted in a secure environment by trained testers.

Throughout the briefing meeting, participants were encouraged to ask questions relating to the research study. These questions were truthfully answered by the researcher to ensure all participants were fully informed before deciding whether to take part in the study. All recruited participants who agreed to participate in the research were requested to sign a consent form (APPENDIX B).

3.9 Autonomy

Autonomy means that the patient has autonomy of thought, intention, and action when making decisions regarding health care procedures. Therefore, the decision-making process was free of coercion or coaxing. To ensure the participants made a fully informed decision, the researcher ensured that participants understood all risks and benefits of the procedure as well as the likelihood of success.

3.10 Confidentiality

Participant's personal information are kept confidentially by ensuring that their identity remain anonymous and data secured in a locked filing cabinet in my supervisor's office. Furthermore, any information collected from the testing will only be used for the purpose of this research study. Participants' identities will not be disclosed at any time, and no personal information or names were required for this study. Articles or reports emanating from this research will not divulge the identities of participants at any time.

3.11 Non-maleficence

It is requirement that research procedures employed in the study does not harm the participants involved. This study will employ the "do no harm" principles. The researcher will ensure that the potential risks of the study is minimised by employing correct training and testing techniques.

3.12 Beneficence

Beneficence requires that the procedure be done with the intent of doing 'good' for the participant involved. The intention of the research was to identify the most beneficial training methods for rugby players to enhance their performance. The research benefitted not only the participants in the present study, but also all who participate in sport where speed, power and agility are key determinants of success.

3.13 Justice

Both the burdens and the benefits of any new or experimental treatments must be distributed equally among all groups in society. The research will be published to inform the broader sporting and scientific communities of the benefits of the training methods under investigation.

3.14 Anonymity

Anonymity is the quality or state of being unknown to most people. The researcher will ensure that information accessed from participants will not be made known to anybody including co-participants in the study. Results will only be published as group data.

3.15 Voluntary Participation

All participants participated in this study voluntarily and were fully informed about all procedures and risks involved in research. All participants gave their consent to participate

3.16 Scientific integrity

1. The researcher ensured that practices and procedures employed in the research were compliant with the ethical procedures. The research proposal was initially submitted to the departmental research committee at the University of the Western Cape in the Faculty of Community Health Sciences.
2. The researcher liaised with participants regarding the most convenient time for assessment and testing. The researcher further ensured that all

participants were aware of their right to access the findings of the study at the Department of SRES at the University of the Western Cape upon completion of the study.

3. The researcher ensured that proper techniques and correct protocols were employed while conducting tests, including accurate calculations and the calibration of equipment.

CHAPTER 4

RESULTS

4.1 Introduction

The aim of this study was to test and compare the impact of line sprinting and plyometric training on the speed, power and agility of intermediate rugby players. Twenty-two participants voluntarily participated in the project. They were randomly divided into a line sprinting (n=11) and a plyometric training group (n=11). The two groups were pre-tested, after which they completed an eight-week line sprinting or plyometric intervention-training programme. The training programmes were followed by the post-tests. The results of the pre- and post-test are presented in this chapter.

4.2 Normality

There are many fields in which small sample sizes are common practice. In addition to ethical issues, sample sizes are often influenced by the demands of intervention programmes (Morgan, 2017). The final sample size of the current study was significantly impacted on by participant attrition mainly due to an extended and demanding intervention programme.

A research study's statistical power is directly influenced by its sample size (Morgan, 2017). There are different assumptions that are made when deciding on the appropriate statistical procedure. The assumption of "normality" is one of the key assumptions on which the use of parametric statistics is based, as their validity depends on it (Ghasemi & Zahediasl, 2012). Normality is one of the concerns with small sample sizes. There are various tests that can be used to assess normality. The current study assessed normality both visually and by using the Shapiro-Wilk test, which is available on SPSS software. The frequency distribution (histogram), stem-and-leaf plot, boxplot, P-P plot (probability-probability plot), and Q-Q plot (quantile-quantile plot) were used for checking normality visually. Table 5 shows the results of the Shapiro-Wilks tests while the Q-Q plots provide a visual impression of the normality of the scores. As can be seen from the significance levels, none of variables for both the sprint and plyometric groups are significantly different from a normal distribution ($p>0.05$). We can therefore assume that the pre- and post-test-data for both groups are normally distributed. The Q-Q plots in which the dots follow the trend line, support these assumptions of normality (see Figures 2 and 3).

Table 5: Shapiro-Wilk test results of pre- and post-test for the sprint group

	Shapiro-Wilk		
	Statistic	df	Sig.
40m Sprint (sec) Post-Test	.925	11	.365
40m Sprint (sec) Pre-Test	.942	11	.541
80m Sprint (sec) Post-Test	.958	11	.743
80m Sprint (sec) Pre-Test	.972	11	.910
Agility Test (sec) Post-Test	.908	11	.228
Agility Test (sec) Pre-Test	.946	11	.592
Standing Long Jump (cm) Pre-Test	.929	11	.403
Standing Long Jump (cm) Post-Test	.964	11	.823
40m Sprint (sec) Post-Test	.973	11	.916

Table 6: Shapiro-Wilk test results of pre- and post-test for the plyometric group

	Shapiro-Wilk		
	Statistic	f	Sig.
40m Sprint (sec) Post-Test	.906	11	.220
40m Sprint (sec) Pre-Test	.932	11	.433
80m Sprint (sec) Post-Test	.967	11	.860
80m Sprint (sec) Pre-Test	.960	11	.776
Agility Test (sec) Post-Test	.919	11	.307
Agility Test (sec) Pre- Test	.902	11	.196
Standing Long Jump (cm) Pre-Test	.983	11	.981
Standing Long Jump (cm) Post-Test	.978	11	.955
40m Sprint (sec) Post-Test	.963	11	.809

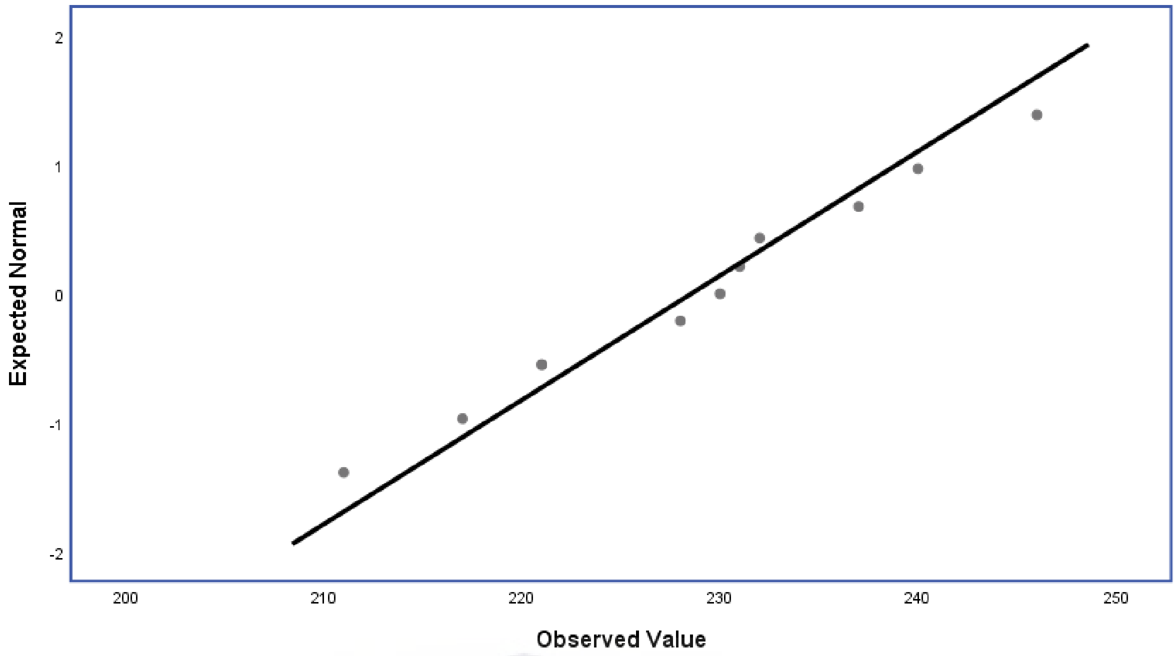


Figure 2: Normal Q-Q Plot for the standing long jump of the post-test of the sprint group

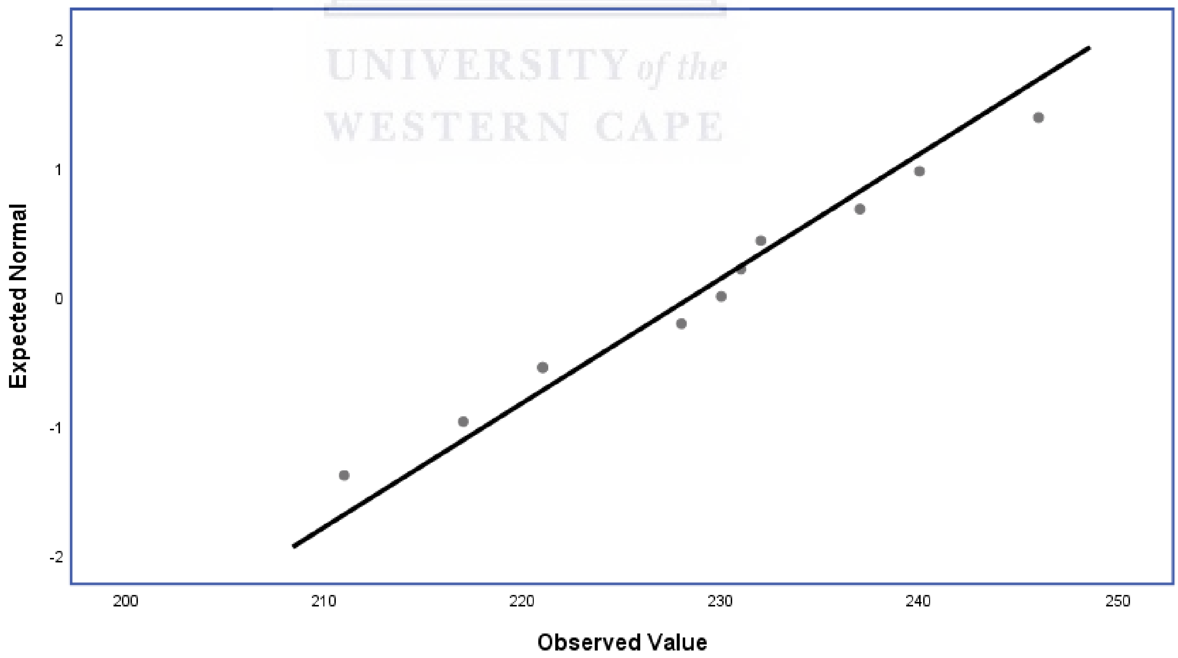


Figure 3: Normal Q-Q Plot for the standing pre-test standing long jump of the sprint group

4.3 Descriptive statistics for sprint and plyometric groups

Tables 7 and 8 contain descriptive data of the sprint and agility test times and standing long jump distances achieved by the sprint and plyometric groups respectively both pre- and post-intervention. Twenty-two subjects (eleven per experimental group) completed the intervention programme, and none reported any training-related injury over the entire intervention period.

Table 7. Descriptive statistics for the 40m and 80m sprint tests, leg power and agility of the line sprinting group (n=11)

	Minimum	Maximum	Mean	Std. Deviation	*Effect Sizes
40m Sprint (sec) Post-Test	6.02	6.65	6.2773	.15774	1.98
40m Sprint (sec) Pre-Test	6.40	7.07	6.6527	.21758	
80m Sprint (sec) Post-Test	10.90	13.30	12.0527	.76379	.367
80m Sprint (sec) Pre-Test	11.01	13.99	12.3709	.95572	
Agility Test (sec) Post-Test	9.50	11.98	10.7573	.87151	0.345
Agility Test (sec) Pre-Test	9.87	12.21	11.0545	.84856	
Standing Long Jump (cm) Pre-Test	211.00	246.00	228.5455	10.40542	0.407
Standing Long Jump (cm) Post-Test	212.00	241.00	224.6364	8.69796	

*Effect Sizes Interpretation (Cohen, 1992)

(0.2=small; 0.5=medium; 0.8=large and 1.3=very large).

Table 8. Descriptive statistics for the 40m and 80m sprint tests, leg power and agility of the plyometric group (n=11)

	Minimum	Maximum	Mean	Std. Deviation	*Effect Sizes
40m Sprint (sec) Post-Test	6.40	7.43	6.9073	.36070	0.364
40m Sprint (sec) Pre-Test	6.42	7.43	7.0300	.31122	
80m Sprint (sec) Post-Test	11.71	14.28	12.9255	.84319	0.269
80m Sprint (sec) Pre-Test	11.72	14.42	13.1482	.81300	
T-Test (sec) Post-Test	11.59	14.96	12.8045	1.03612	1.013
T-Test (sec) Pre-Test	12.50	15.08	13.7464	.81904	
Standing Long Jump (cm) Pre-Test	189.00	239.00	214.0000	17.97220	0.261
Standing Long Jump (cm) Post-Test	184.00	241.00	209.2727	18.16090	

*Effect Sizes Interpretation (Cohen, 1992)

(0.2=small; 0.5=medium; 0.8=large and 1.3=very large).

The effect sizes that were calculated to quantify the differences between pre- and post-intervention are also contained in Tables 7 and 8. The results show one very large effect for the sprint group and one large effect for the plyometric group. All the other effects were between small and medium.

4.4 Comparisons between pre- and post-test means of the two groups

Except for standing long jump (p=.038) (Table 9), the two groups showed no differences in the pre-test for all variables. The two groups only differed in terms of the standing long jump (p=.017) and 40m sprint (p=.012) at the post-test level (Table 9).

Table 9. Comparisons of the variables of plyometric group and the sprint groups at pre-test and post-test

	Sig	t
40m Post-Test	.012*	-5.308
40m Pre-Test	.346	-3.295
80m Post-Test	.694	-2.544
80m Pre-Post	.637	-2.055
Agility Post-Test	.486	-5.015
Agility Pre-Test	.944	-7.570
Leg Power Pre-Test	.038	2.323
Leg Power Post-Test	.017	2.531

*p<.05

4.5 Changes in pre- and post-intervention performances for the line sprinting and plyometrics groups

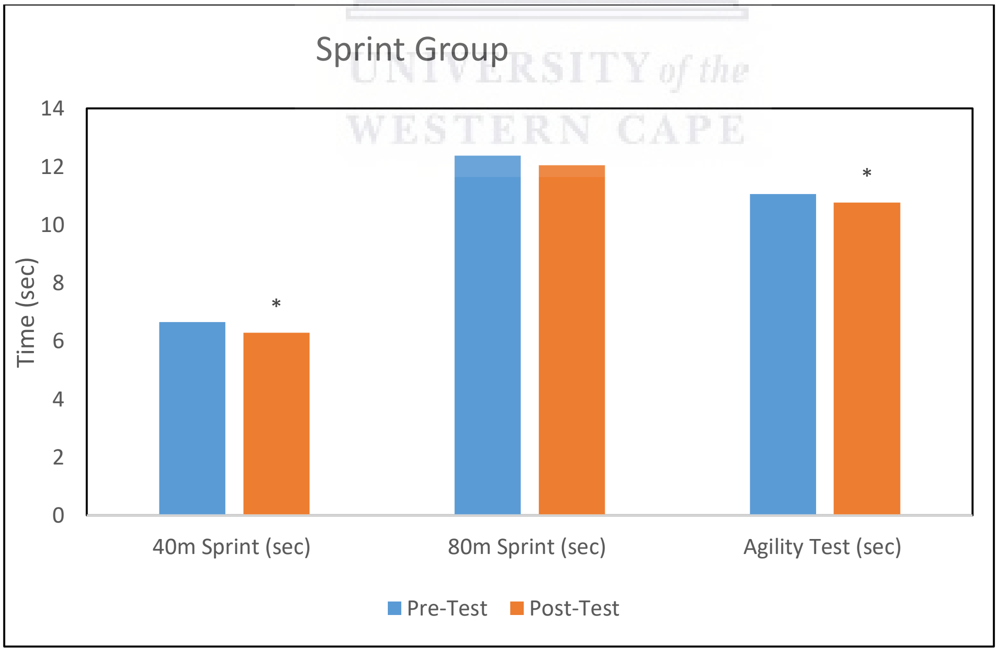
The sprint group improved significantly in their performances for three of the four performances measures. The only variable, which did not show significant improvements, is the 80m sprint (Table 10 and Figure 4). The plyometric group showed improvements in two categories i.e. agility and the standing long jump (Table 11 and Figure 5).

Table 10: Changes in pre- and post-intervention performances for the line sprinting group

	Mean	t	df	Sig
40m Pre-Test - 40m Post-Test	-.37545	-5.632	10	.000*
80m Pre-Test - 80m Post-Test	-.31818	-2.044	10	.068
Agility Pre-Test - Agility Post-Test	-.29727	-5.477	10	.000*
SLJ Pre-Test – SLJ Post-Test	3.90909	4.348	10	.001*

SLJ=Standing Long Jump

P<0.5



*p<.05

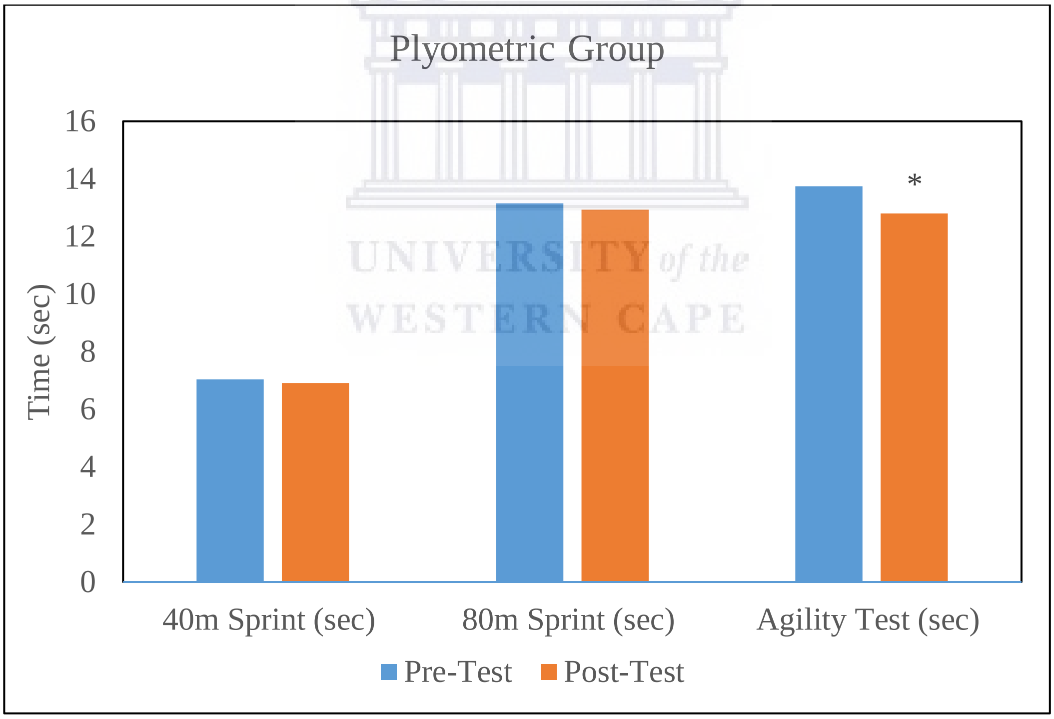
Figure 4: Pre- and post-test results for the sprint group

Table 11: Changes in pre- and post-intervention performances for the plyometric group

	Mean	t	Df	Sig
40m Pre-Test - 40m Post-Test	-.12273	-1.528	10	.157
80m Pre-Test - 80m Post-Test	-.22273	-2.083	10	.064
Agility Pre-Test - Agility Post-Test	-.94182	-5.316	10	.000*
SLJ Pre-Test – SLJ Post-Test	4.72727	3.436	10	.006*

SLJ=Standing Long Jump

*p<.05



*p<.05

Figure 5: Pre- and post-test results for the plyometric group

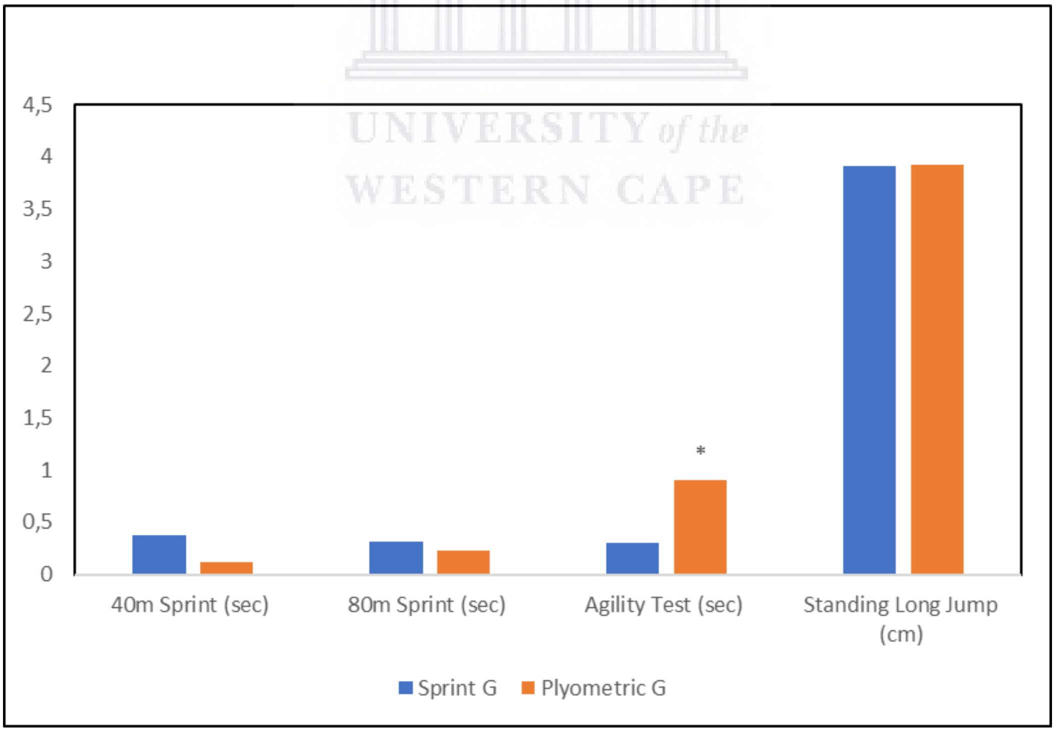
4.6 Comparison of the mean changes between the two groups

Table 12 and Figure 6 illustrate the comparison between the mean changes between sprint and plyometric training. Only significant difference was found for agility where the plyometric group outperformed the sprinting group.

Table 12: Comparison of the mean changes between the sprint and plyometric group

	Mean	T	Sig
40m Sprint Test	.2527	2.421	**.908**
80m Sprint Test	.0954	.506	**.347**
Agility Test	.6027	3.027	**.001***
Standing Long Jump	.0909	.061	**.061**

*p<.05



*p<.05

Figure 6: Comparison of improvements in performance categories sprint- and plyometric groups

4.7 Boxplots

The box plots in Figures 7-14 depict the differences in the median, minimum and maximum sprint and agility pre– and post-test times as well as the standing long jump distances of the sprint group. Figures 10-13 illustrate the same information for the plyometric group. From the box plots, it can be seen that there are two outliers for the 40-m sprint test times of the sprint group.

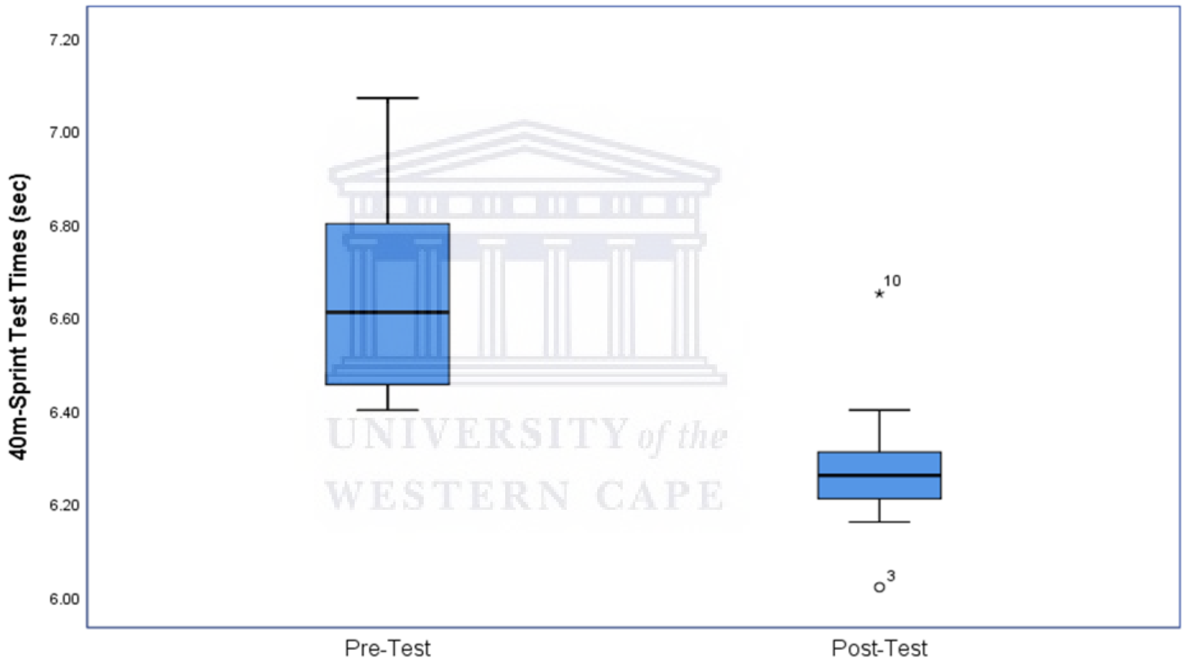


Figure 7: 40-m sprint test times for the line sprinting group

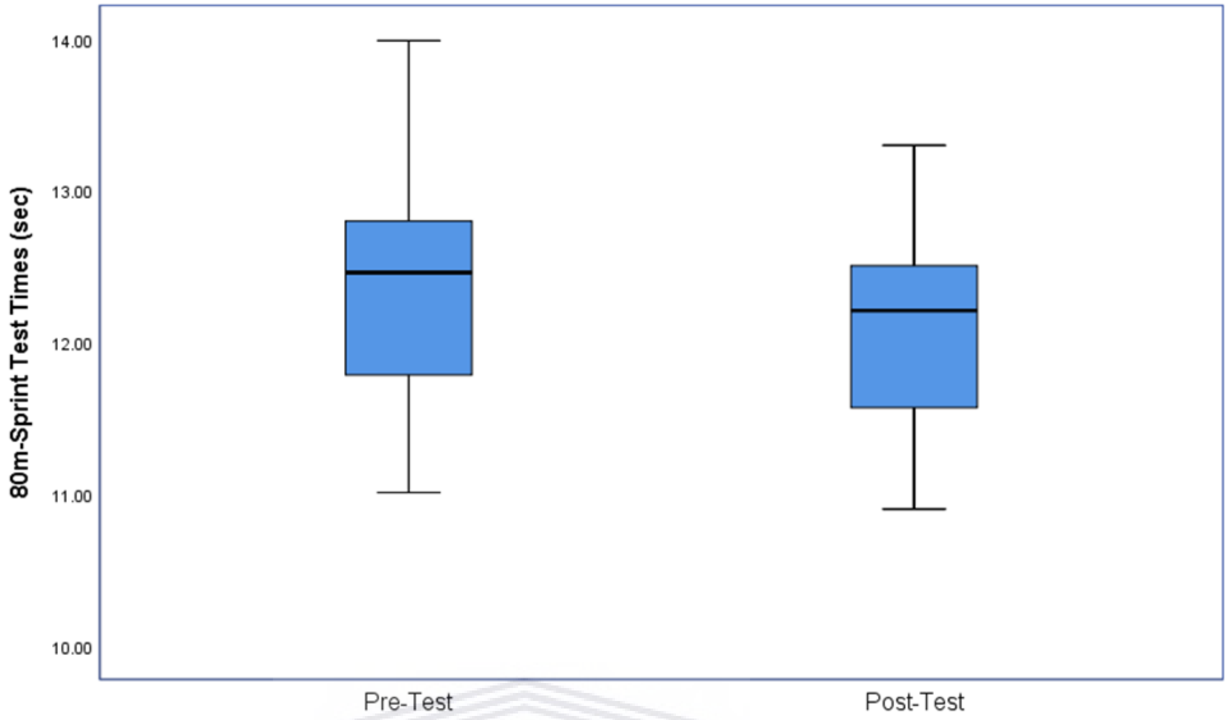


Figure 8: 80-m sprint test times for the line sprinting group

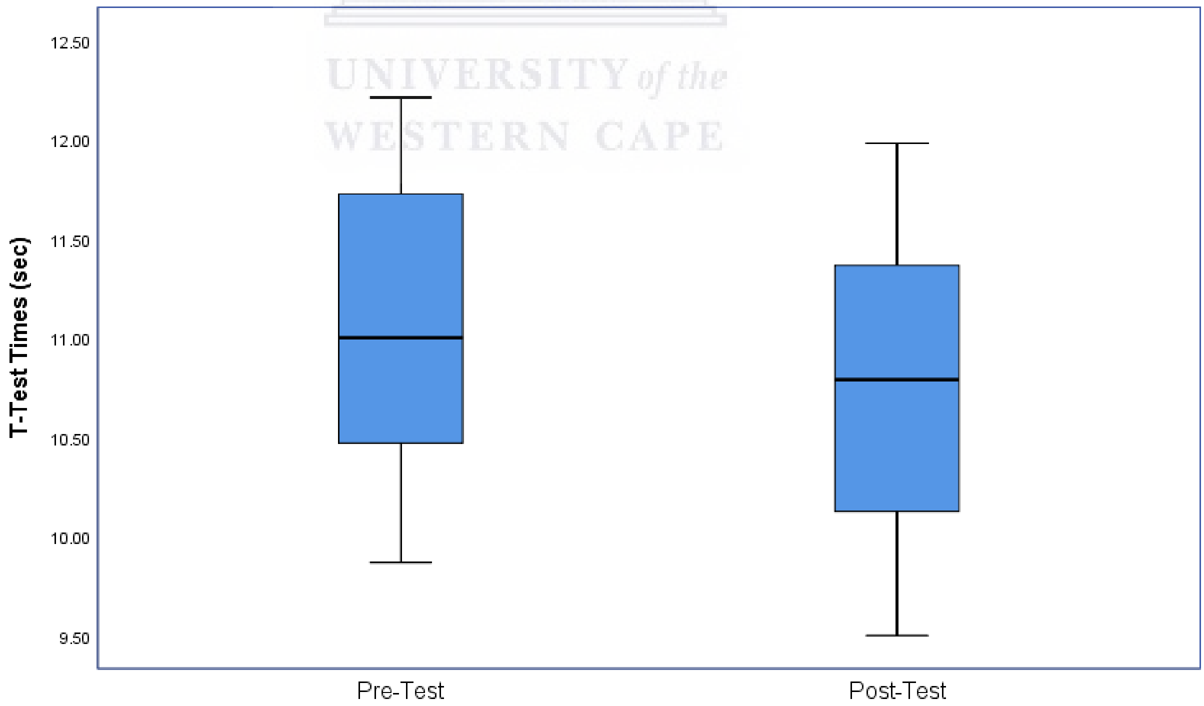


Figure 9: T-test times for the line sprinting group

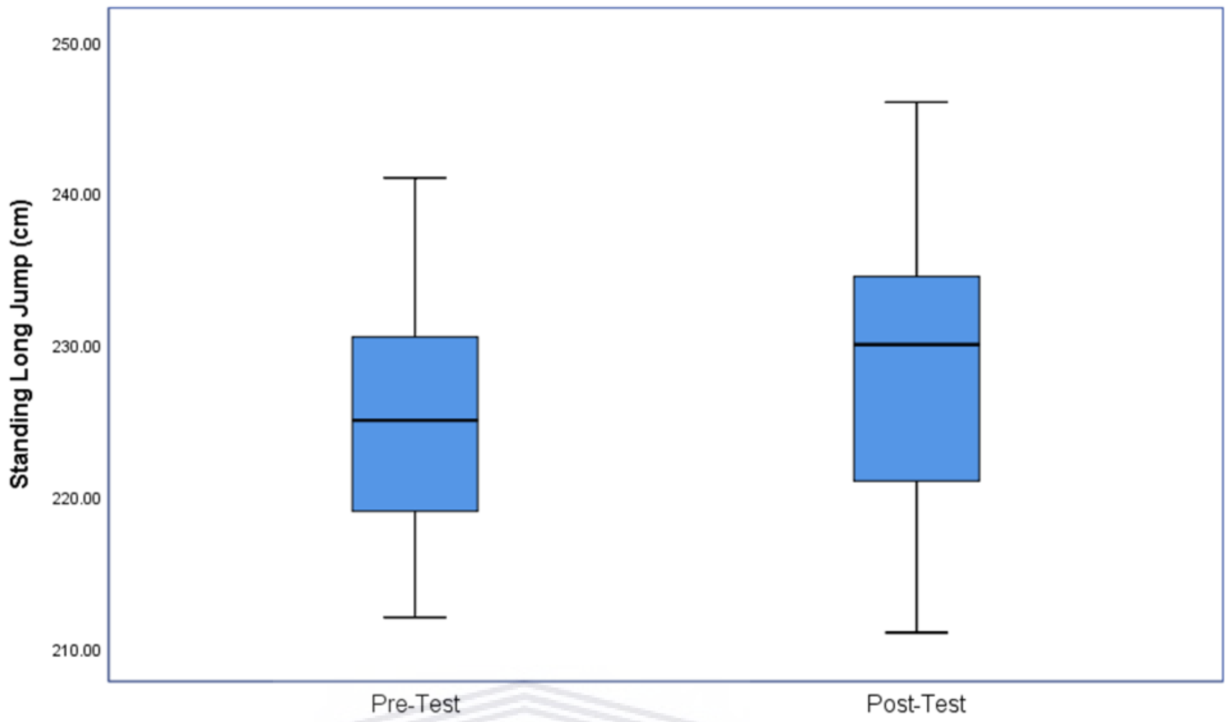


Figure 10: Standing long jump distances for the line sprinting group

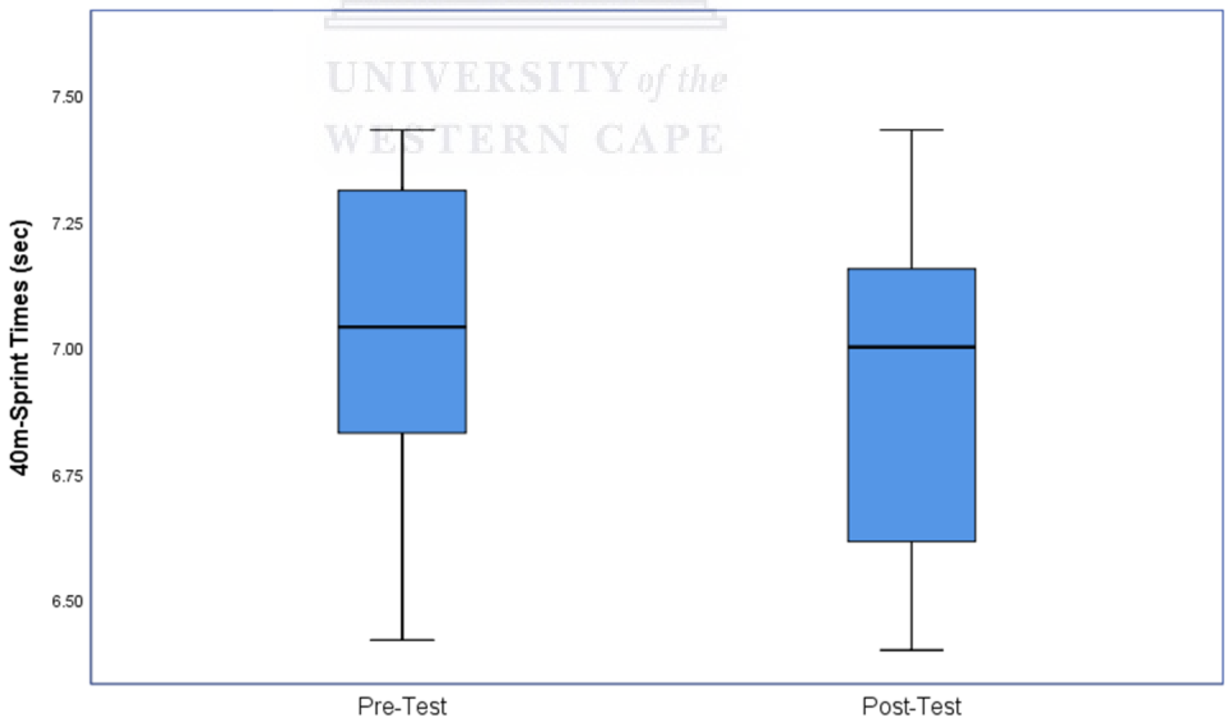


Figure 11: 40-m sprint test times for the plyometric group

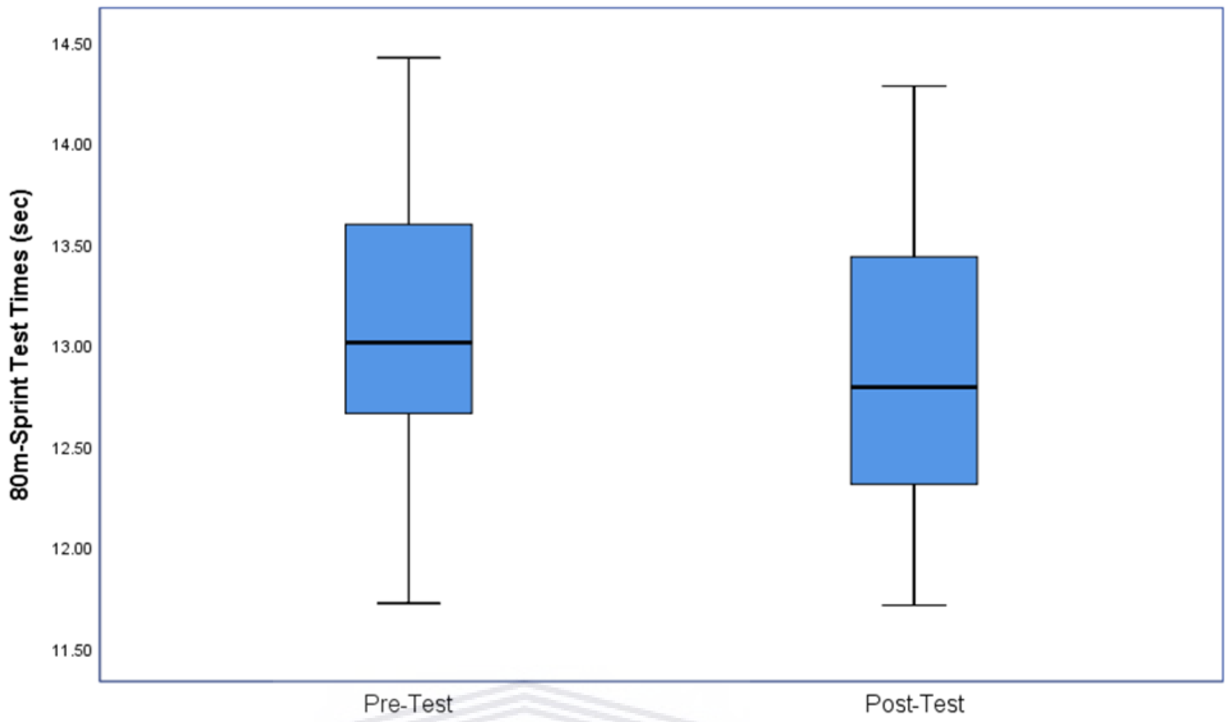


Figure 12: 80-m sprint test times for the plyometric group

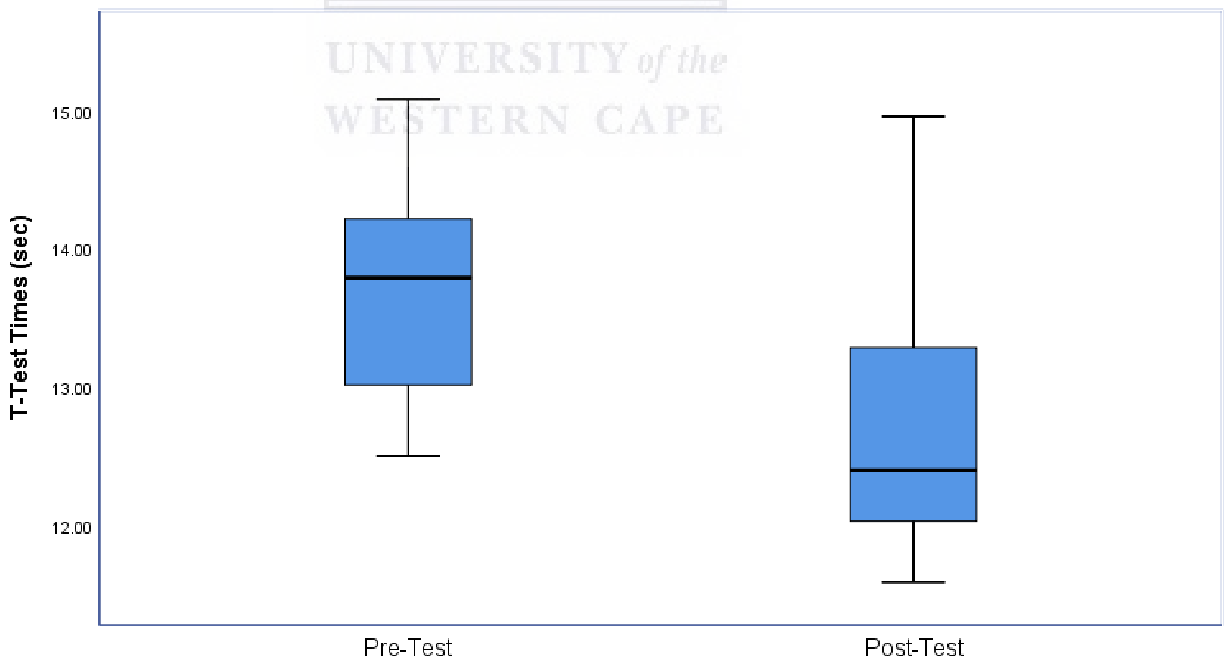


Figure 13: Agility T-test times for the plyometric group

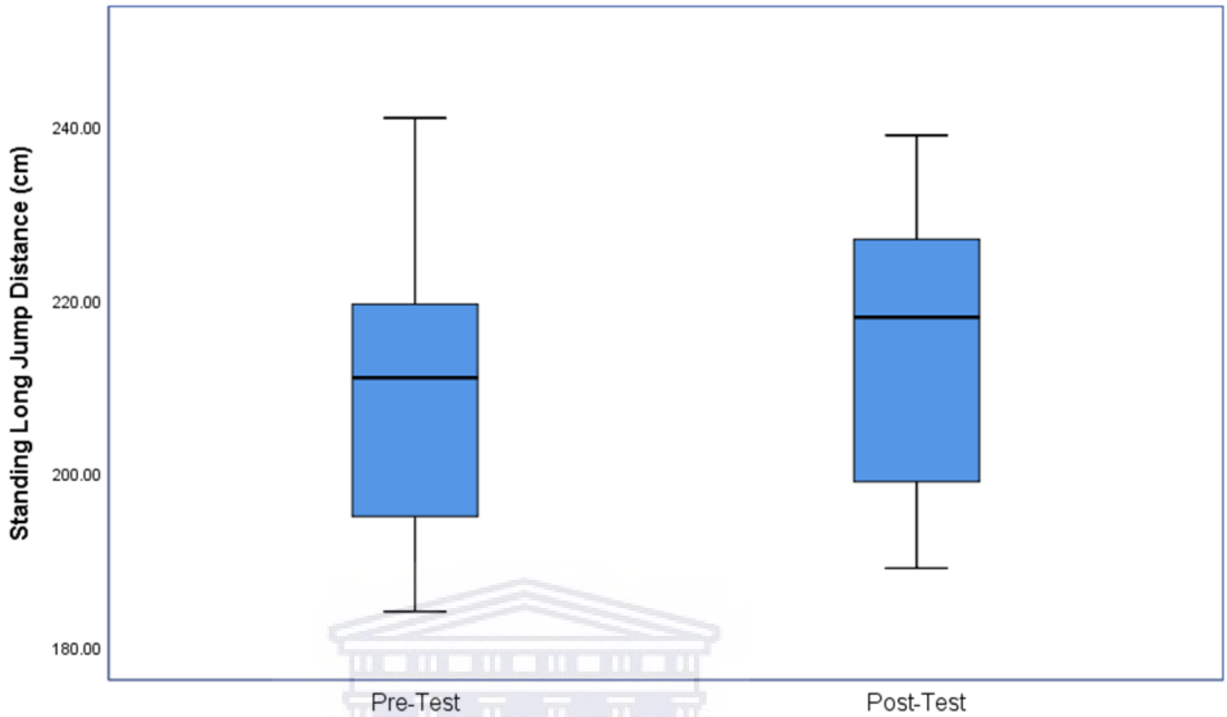


Figure 14: Standing long jump distances for the plyometric group

CHAPTER 5

Discussion and Conclusion

5.1 Discussion

Speed, power and agility are key determinants for success in rugby (Gabbett et al., 2009). It is therefore imperative for players and coaches to employ the most effective training methods to develop these physical attributes optimally to maximise their chances of success in the sport. There are various training methods that are used to develop these qualities including line sprinting and plyometrics. This study tested and compared the impact of line sprinting and plyometric training on the speed, power and agility of intermediate rugby players. It was hypothesised that both intervention protocols would improve speed, agility and power output. However, it was further hypothesised that line sprinting would result in greater improvements in the abovementioned components.

The line sprinting group improved significantly in their performances in the 40m sprint, the agility test and their standing long jump. These findings concur with previous research, which reported performance improvements in short-distance sprint speed, ranging from 10m to 40m, agility and jump performance after sprint training (Faigenbaum et al., 2007, Enoksen et al., 2011, Lockie et al., 2012, Markovic et al., 2007, Rimmer & Sleivert, 2000 and Ross et al., 2009). The only variable in which the sprint group did not show significant improvements is the 80m sprint (Table 10 and Figure 4).

Given the significant improvements seen in the line sprinting group over 40-metres, the standing long jump and agility T-test and not over 80m, it can be deduced that line sprinting training does not improve sprinting over longer distances.

The plyometric group showed improvements in agility and the standing long jump (Table 11 & Figure 5), but not in any of the sprint tests. The greatest improvements in the plyometric group were seen in the 40m sprint distance and the agility T-test, with the agility results showing the greatest level of improvements. The most significant improvement found in the plyometric group was the agility results. The findings of Chaabene et al. (2018), Juhász et al. (2013), Makaruk and Sacewicz, 2010, Potteiger et al. (1999) and Thomas et al. (2009) stated that short-term plyometric training results in improvements in agility and power output as seen in jumping performance. The results of the Thomas et al. (2009) research, which showed no significant improvement in sprint times after eight weeks of plyometric training, correlate with the results of this study.

Although it was hypothesised that line sprinting would bring about greater improvements in all performance measures this was not confirmed by the results of the study. The only difference in improvements between the two training methods was for agility where the plyometric group achieved greater improvements.

The improvements reported for agility, short sprints and power following the line sprinting intervention, could partly be the consequence of improved leg extensor strength and power. In contrast, it could be argued that the changes following plyometric training - which induced positive changes in jumping performance but not sprint performance - could be the result of the specificity of the plyometric exercises participants performed, which involved both vertical and horizontal components. Therefore, the positive results in jump performance for the plyometric group may have been the result of improved muscle coordination while the improvements in agility may be the result of familiarisation with the agility T-test and its movements as they did three repetitions for the pre-intervention tests, 8-weeks of intervention and then again three repetitions in the post-testing phase. Based on the findings of this study and others reported in the literature (Chaabene et al., 2018, Juhász et al., 2013, Makaruk & Sacewicz, 2010, Potteiger et al., 1999; Thomas et al., 2009), plyometric training appears to be an appropriate regime for improving certain performance components like agility and power. Line sprinting proved to be an effective form of training to improve sprint time over 40m, agility and horizontal jump performance.

While this study answered most of the pre-intervention research questions, some limitations exist that if addressed could further improve the reliability associated line sprinting and plyometric training and its effects on the speed, agility and power output in male intermediate rugby players.

The participants used for this study were limited to club level, aged 18 to 25. All participants were intermediate rugby players. Therefore, results of this study will only be applicable to such individuals.

Factors that could influence recovery time and subsequently the ability to perform at maximal intensity, such as diet, were not controlled. This could have led to certain participants consuming a diet that better aids protein re-synthesis, therefore resulting in more efficient muscle recovery and an improved capacity to perform the sprint and plyometric training. Other recovery methods such as active rest and water therapy were not controlled either.

The participants' extramural activities were not monitored either, meaning that participants could have taken part in physical activities that could perhaps have influenced their ability to maximally perform the prescribed exercises due to factors such as fatigue or muscle soreness.

For the sprint group, wind speed was not measured in this study, which could affect air resistance and sprint speed. A bigger sample would also have improved the credibility of the study. However, it was not practical due to the demands of the intervention programmes and player availability.

Only one researcher supervised the training intervention, therefore there was great consistency in how the intervention programmes and accompanying tests and exercises were applied, explained, demonstrated, observed and tested.

The fact that all the participants were from the same club was also a positive, as the chance of them being exposed to the same training regimes and recovery methods are higher. The agility benefits accrued through familiarity brought about by pre-intervention T-test trials, benefitted both groups equally since both groups experienced similar levels of exposure during the testing or drill phases. None of them was exposed to the T-test prior to the onset of the current research. It is therefore fair to conclude that although familiarity might have influenced the reported improvements in agility for both groups, the significant difference found in the levels of improvements between the two groups can be ascribed to the differential effects of the two intervention programmes.

Given the limitations of this study, this research can be extended to athletes from other sporting codes and participants from other levels of competition and age groups.

5.1 Conclusion

This study aimed to test and compare the impact of line sprinting and plyometric training on the speed, power and agility of club level intermediate rugby players aged 18 to 25 years. The results of this study therefore provides a more in-depth understanding of the effects of the two training methods on the variables in question.

The findings demonstrate that both sprint and plyometric training are effective in improving the agility and standing long jump distances or participants. Plyometric training proved to be more effective than sprint training in improving the agility performance of the participants but failed to improve the 40-m sprint times of the group. This is contrary to what was hypothesised and the hypothesis related to these outcomes are therefore rejected. Sprint training did produce significant improvements in the 40-m sprint times, which was not the case for the plyometric group. Neither the sprint nor the plyometric group produced significant improvements in the longer sprint test.

One of the key questions posed in this study is which of the two training methods has the biggest training effect on the variables investigated. Based on a comparison of the effect sizes of the two training method, this study concludes that except for the improvement in agility of the plyometric training group, the speed, power and sprint endurance training benefits of these two training methods do not differ. The hypothesis regarding comparative improvements is therefore rejected.

Future studies should include a third experimental group which combines line sprinting and plyometric training as well as a control group.

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APPENDIX A

INFORMATION SHEET

Project Title: A Comparative Study of the Effects of Sprint and Plyometric Training on the Speed, Agility and Power Output in Male Intermediate Rugby Players

What is this study about?

This is a research project being conducted by Wynona Louw at the University of the Western Cape. I am inviting you to participate in this research project because you are an affiliated club rugby player and fulfil the requirements. The purpose of this research project is to assess which training programme, sprint or plyometrics, will produce the most significant improvements in speed, agility and power output.

What will I be asked to do if I agree to participate?

Depending on which group you are in (sprint or plyometrics group) you will be asked to follow a training program for eight weeks. Your speed, agility and power will be tested before the commencement of the respective program. Normal every day activities can be performed while following the program. You will be retested after the eight-week period

Would my participation in this study be kept confidential?

The researcher undertakes to protect your identity and the nature of your contribution. To ensure your anonymity, your name will not be recorded and access to research material will be limited to the researchers and the supervisor.

To ensure your confidentiality, all recorded data will be stored and locked in the supervisors office and will only contain ID codes (no names). All data that is stored on laptops (including video materials) will be password protected. If we write a report or article about this research project, your identity will be protected. All video materials will only be viewed by the researchers for analytical purposes.

What are the risks of this research?

There may be some risks from participating in this research study. Much like any activity or assessment there are risks which can be described as both expected and unexpected. Possible expected risks of an emotional and psychological nature may include feeling self-conscious, embarrassed, or anxiety due to having fears of predicted negative outcomes. Unexpected risks include physical aspects such as increased heart rate and blood pressure, fatigue, discomfort and physical injury (e.g. strains and sprains) during assessments.

What are the benefits of this research?

The benefits to you include participating in a study which could improve the available knowledge and science underpinning your sport. Participating could improve your knowledge as to what procedures can be performed to improve and assess the relevant performance components. This research is not designed to help you personally, but the results may help the investigator learn more about the best method to improve speed, agility and power output in intermediate male rugby players. We hope that, in the future, other people might benefit from this study through improved understanding and knowledge.

Do I have to be in this research and may I stop participating at any time?

Your participation in this research is completely voluntary. You may choose not to take part at all. If you decide to participate in this research, you may stop participating at any time. If you decide not to participate in this study or if you stop participating at any time, you will not be penalised or lose any benefits to which you otherwise qualify.

What if I have questions?

This research is being conducted by Wynona Louw of the SRES department at the University of the Western Cape. If you have any questions about the research study itself, please contact Wynona Louw at 081 079 0903.

Should you have any questions regarding this study and your rights as a research participant or if you wish to report any problems you have experienced related to the study, please contact:

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BIOMEDICAL RESEARCH ETHICS ADMINISTRATION

Research Office

New Arts Building,

C-Block, Top Floor, Room 28

This research has been approved by the University of the Western Cape's Senate Research Committee. (REFERENCE NUMBER: BM17/1/17)

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APPENDIX B

CONSENT FORM

Title of Research Project: A Comparative Study of the Effects of Sprint and Plyometric Training on the Speed, Agility and Power Output in Male Intermediate Rugby Players

The study has been described to me in language that I understand. My questions about the study have been answered. I understand what my participation will involve and I agree to participate of my own choice and free will. I understand that my identity will not be disclosed to anyone.. I understand that I may withdraw from the study at any time without giving a reason and without fear of negative consequences or loss of benefits.

Participant's name ………………..………………………….

Participant's signature…………………………………….

Date………………………

APPENDIX C:

Health Questionnaire

PATIENT'S NAME:

DOB:

DATE:

HEALTH CARE PROVIDER'S NAME:

Please read the questions below carefully, and answer each one honestly. Please check YES or NO.

❑ Yes ☐ No Has your health care provider ever said that you have a heart condition and that you should only do physical activity recommended by a health care provider?

❑ Yes ☐ No Do you feel pain in your chest when you do physical activity?

❑ Yes ☐ No In the past month, have you had chest pain when you were not doing physical activity?

❑ Yes ☐ No Do you lose your balance because of dizziness or do you ever lose consciousness?

❑ Yes ☐ No Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?

❑ Yes ☐ No Is your health care provider currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?

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

Excerpted from the Physical Activity Readiness Questionnaire (PAR-Q) © 2002. Used with permission from the Canadian Society for Exercise Physiology.

APPENDIX D

Test Protocol Sheet

Intervention:	**T-test (Agility)**			**Long Jump (Leg Power)**			**Sprint (40 m) (Speed)**			**Sprint (80 m) (Speed)**		
Sprint Group	**1st**	**2nd**	**3rd**	**1st**	**2nd**	**3rd**	**1st**	**2nd**	**3rd**	**1st**	**2nd**	**3rd**
SG1												
SG2												
SG3												
SG4												
SG5												
SG6												
SG7												
SG8												
SG9												
SG10												
SG11												
SG12												
SG13												
SG14												
Plyometric Group												
PG1												
PG2												
PG3												
PG4												
PG5												
PG6												
PG7												
PG8												
PG9												
PG10												
PG11												
PG12												
PG13												

APPENDIX E:

Training Programme/Intervention

Week	Plyometric group	Sprint group
	Exercise / Reps / Sets	*Exercise / Reps / Sets*
1	Squat jumps / 8 / 3	10m sprint / 5 / 3
2	Squat jumps / 8 / 3	10m sprint / 5 / 3
3	60cm box jumps / 8 / 3	20m sprint / 5 / 3
4	80cm box jumps / 8 / 3	20m sprint / 5 / 3
5	Single-leg hops / 8 / 3	40m sprint / 4 / 3
6	Single-leg hops / 8 / 3	40m sprint / 4 / 3
7	80cm depth jumps / 8 / 3	100m sprint / 3 / 3
8	80cm depth jumps onto 60cm box / 8 / 3	100m sprint / 3 / 3

Rest: In between each set (both plyometrics and sprint), participants rested for 3 minutes.

Both groups cooled down for 10 minutes with static stretches.

APPENDIX F: Ethics Extension

MINUTES OF THE ABOVE MENTIONED COMMITTEE HELD ON FRIDAY,

03 AUGUST 2018 IN THE DVC BIG BOARDROOM, ADMIN BUILDING, LEVEL 2

PRESENT

Prof N Myburgh (Chairperson), Prof B van Wyk, Prof H Schneider, Dr A Jeftha,

Dr R Mulder, Prof L Wegner, Mr G Paulse and Mr M Wareley.

In attendance: Patricia Josias, Committee Officer

9 ***APPLICATIONS FOR RENEWAL AND AMENDMENT OF ETHICS***

9.1 Ms WA Louw (SRES)

Study project:	A comparative study of the effects of sprint and plyometric training on the speed, agility and power output in intermediate rugby players
Registration number:	BM17/1/17
Ethics:	*The request for renewal, amendment and change of title was approved*

Appendix F: Ethics Approval Letter

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19 January 2017

Ms W Louw
SRES
Faculty of Community and Health Sciences

Ethics Reference Number: BM17/1/17

Project Title: A comparative study of the effects of sprint and plyometric training on the speed, agility and power output in male intermediate rugby players

Approval Period: 15 December 2016 – 15 December 2017

I hereby certify that the Biomedical Science Research Ethics Committee of the University of the Western Cape approved the scientific methodology and ethics of the above mentioned research project.

Any amendments, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval. Please remember to submit a progress report in good time for annual renewal.

The Committee must be informed of any serious adverse event and/or termination of the study.

Ms Patricia Josias
Research Ethics Committee Officer
University of the Western Cape

PROVISIONAL REC NUMBER -130416-050