

**PHYSICAL FITNESS OF ELITE WOMEN'S RUGBY UNION PLAYERS OVER A
COMPETITION SEASON**

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A full thesis submitted in fulfillment of the requirements for the degree



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DECLARATION

I hereby declare that “Seasonal variations in the physical fitness of Elite Women’s Rugby Union Players” is my own work, that it has not been submitted before for any other degree in any other university, and that the sources I have used have been indicated and acknowledged as complete references.

Nceba Mzimkulu Hene

February 2011

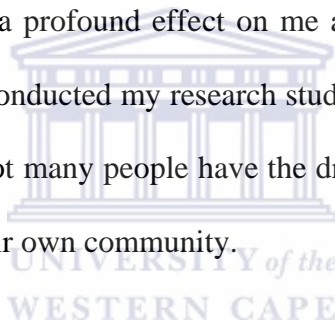
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I would like to acknowledge the support of the South African Rugby Union and Management of the Women's National Rugby Team, especially Mahlubi Puzi who has provided me with a platform to grow as a Biokineticist. Not many professionals get an opportunity to work with a National team from inception and to fulfill their childhood dream of representing their country at a World Cup.

The players have not only had a profound effect on me as a professional but also as a man hence it was only fitting that I conducted my research study on this group of players. I admire their passion for the game, as not many people have the drive to pursue and live their passion despite being stigmatised by their own community.



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Finally, I would like to thank my parents (Peter and Bongiwe) for their continuous love and sacrifices they have made in order for me to have a great childhood and education.

ABSTRACT

The primary aim of this study was to investigate the changes in physical fitness characteristics of elite women's rugby union players over the duration of the season. Thirty two elite female rugby players who were identified as members of the South African Rugby Union High Performance Squad were assessed on three separate occasions (pre-season, mid-season and post-season) throughout the competition season. The players were sub-divided into two positional categories consisting of 17 forwards and 15 backs. On all testing occasions, players underwent anthropometric (stature, body mass and sum of 7 skinfolds) and physical performance measurements (sit-and-reach, vertical jump, 10m and 40m speed, 1 RM bench press; pull-ups; 1 min push-ups and multi-stage shuttle run test). A two-factor analysis of variance evaluated differences in the physical fitness variables between and within playing positions over the competition season.

There were statistical differences ($p < 0.01$) between positional groups, as forwards had a greater body mass, higher sum of skinfolds and larger body fat percentage than backs. In terms of explosive leg power, maximum speed (40m sprint times), muscular and aerobic endurance, backs obtained superior performance values. In contrast, no significant differences were detected between forwards and backs in terms of stature, flexibility, acceleration (10m sprint times) and upper body strength (1 RM bench press and pull-ups).

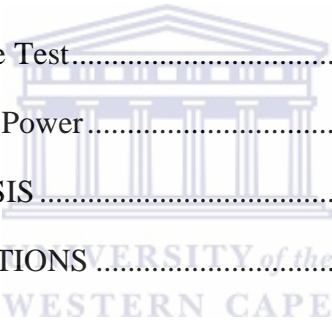
In both positional groups, no significant changes were determined in the sum of skinfolds, vertical jump height, 1 RM bench press, 1 min push-ups and multi-stage shuttle run test scores between pre-season and mid-season. Whereas, sprint times (10m and 40m) significantly decreased for both forwards and backs, regardless of the significant decrease in percent body fat during the same time period. Although a significant increase in speed was observed, there were no significant changes in the other physical fitness characteristics measured. Based on the results achieved, further studies are required to determine the appropriate training stimulus to enhance the physical fitness characteristics of elite women's rugby union players during the early phase of the season without compromising speed.



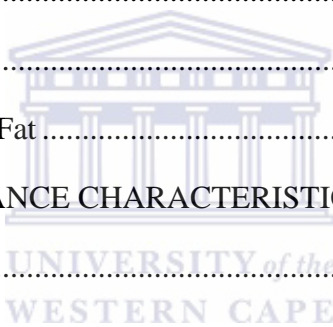
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CHAPTER ONE

STATEMENT OF THE PROBLEM

1.1 INTRODUCTION

Female participation in rugby has been described as that of a ‘domestic worker’ (Chandler & Nauright, 1999; Thompson, 1988). The role of females in rugby has been one of doing endless chores for their sons and husbands such as - transporting them to games and practices, cleaning their rugby gear, preparing meals and attending to their injured bodies and egos. Hence, the role of women within the rugby sphere has been traditionally one of provision rather than as an active participant (Haynes & Miller, 2001).

Over the past two decades, rugby union has grown unexpectedly as a female participative sport throughout Australia, Great Britain, Canada, USA, New Zealand and many other Western and Asian countries. Chu, Leberman, Howe, and Bachor (2003), identified the prime reason for women participation in a male dominant sport, as being the physical nature and love for the sport.

With the emergence of structured international competitions, women’s rugby has also increasingly found its way into the limelight as matches have been played at rugby “fortresses” such as Murrayfield (Scotland); Twickenham (England) and Ellis Park (South Africa) as curtain raisers to International Men’s rugby matches. With the 2009 Women’s Rugby World Cup and 2009 Rugby World Cup Sevens (Men and Women) being broadcasted

live on pay TV channels, this has provided women with the platform to showcase their talent to a global audience.

In 2000, when South African Rugby Union (SARU), the custodians of the game in South Africa accepted women's rugby into the rugby fraternity, there were less than 10 clubs playing on a social basis in the middle class communities. At present, rugby is being played in 143 rugby clubs throughout South Africa, with 15 129 registered players within towns, suburbs and rural districts (International Rugby Board, n.d). In 2003, SARU launched the Inter-Provincial League, where games were played once a month. Such domestic competitions serve to provide a pathway for players to develop physical and technical skills so as to cope with the physical demands at international level (Duthie, 2006).

Rugby is a field-based team sport, eliciting a variety of physiological responses as a result of repeated high-intensity sprints and high frequency of contact (Duthie, Pyne, & Hooper, 2003). Time-motion analysis is an objective and yet non-invasive method of quantifying the demands of rugby and for providing information that is applicable in the designing of physical conditioning and testing programmes (Deutsch, Kearney & Rehrer, 2007). Of interest to coaches is the difference in movement patterns between forwards and backs in competitive rugby (Deutsch, Kearney, & Rehrer, 2002; Deutsch, Maw, Jenkins & Reaburn, 1998). In rugby, high intensity activity accounts for 12-14% of game time for the forwards and 4.5-6% for backs (Deutsch et al., 2007; Duthie et al., 2003). This difference between backs and forwards was largely as result of the greater involvement of forwards in static exertion (rucking, mauling and scrummaging) and higher sprinting efforts by the backs (Deutsch et al.,

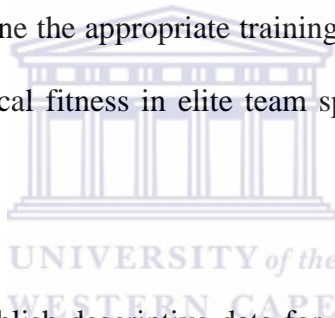
2007). Static exertion requires great strength, while intense running involves acceleration and maximal speed and when performed over an extended duration or repeatedly, both static exertion and sprinting will require muscle and aerobic endurance. Detailed analysis of the occurrences of these activities, will assist coaches to prepare highly effective training sessions and sport scientist to develop specific physiologic tests to examine the preparedness for competition (Deutsch et al., 1998, 2007).

Competitive success in male rugby union is related to anthropometric profiles (Duthie, Pyne, Hopkins, Livingstone, & Hooper, 2006a; Hawes & Sovak, 1994) and physical capacities of players such as strength (Mayes & Nutall, 1995; Quarrie & Wilson, 2000; Tong & Wood, 1995), speed (Duthie et al., 2003; Quarrie, Handcock, Waller, Chalmers, Toomey, & Wilson, 1995) muscular power (Carlson, Carter, Patterson, Petti, Orfanos & Noffal, 1994; Deutsch, Kearney, & Rehrer, 2002) and aerobic fitness (Deutsch et al., 1998; McLean, 1992; Scott, Roe, Coats & Piepoli, 2003). Hence, scientifically evaluating players with regards to the anthropometric and physical characteristics plays an integral role in monitoring and developing these physical fitness components among modern rugby players (Du Plessis, 2007). A number of studies have investigated the physical fitness characteristics of sub-elite and elite female rugby union players (Kirby & Reilly, 1993; Quarrie, Handcock, Waller, Chalmers, Toomey & Wilson, 1995). There is however, presently a lack of information on the characteristics on contemporary elite female rugby union players. These studies have suggested that, as in men's rugby, female players are most often selected for positions based on their anthropometric and physical characteristics.

Rugby union players have a diverse range of physical attributes, and a distinct physique will naturally orient a player towards a particular position over others (Quarrie, Handcock, Toomey & Waller, 1996). Backs players for whom sprinting is important for attacking and cover defending, have a lean physique unlike forwards who are heavier, taller, and have a greater proportion of body fat as the physique is more suitable for dominating scrums, tackles, rucks and mauls (Rienzi, Reilly & Malkin, 1999). In addition, forwards also demonstrate greater absolute power and strength so as to defend as well as retain turn over possession. When body mass is taken into account, there is a reversal of these results (Duthie et al., 2003).

In the professional era, playing rugby is virtually a year-round endeavor. The capacity of elite players to acquire and maintain a good level of physiological fitness during pre-season and in-season, respectively, has become paramount (Caldwell & Peters, 2009). Studies conducted on male rugby players (Duthie et al., 2006a; Gabbett, 2005b; Tong & Mayes, 1995) show that the greatest improvement in strength, flexibility, aerobic fitness and reduction in skinfold thickness occur in the earlier stages of the season before returning to baseline values or being maintained during the competition. Reduction in muscular power and maximal aerobic power and increase skinfold thickness may also occur towards the end of the rugby season due to low training loads and high match loads and injury rates (Gabbett, 2005a). However, with women's rugby being an amateur sport, fitness may either increase or decrease in some players over a season due to level of competition and quality of training sessions or social circumstances.

From the time men's rugby union became professional worldwide in 1995, the science examining the sport and its participants has developed rapidly to meet the increased demand for knowledge of the requirements of the game and the characteristics of players (Nicholas, 1997). As a result of the physical demands of the game, the anthropometric and physical characteristics of elite players have become highly developed. However, little is known about the optimal way to enhance physical fitness in female rugby players, and to what extent aerobic power, speed, muscle strength and power should be trained during the competition season. The finding of different magnitude of changes in physical fitness during the season in elite female rugby players will have important implications for team selection and highlighting the need to determine the appropriate training strategy and periodisation required to elicit improvements in physical fitness in elite team sports (Granados, Izquierdo, Ibáñez, Ruesta, & Gorostiaga, 2008).



The aim of this study is to establish descriptive data for elite South African women's rugby union players and to determine the changes in anthropometric and physical characteristics of the players within a competition season.

1.2 STATEMENT OF THE PROBLEM

As far as it can be ascertained, no study published has monitored the physical fitness levels of women's rugby union player throughout a competitive season. Several studies have described the anthropometric and physical characteristics of women's rugby union players; however all of these studies have been limited to a single fitness testing session performed either at pre-season, mid-season or post-season.

Hence, the purpose of this study is to monitor the changes in physical fitness characteristics of elite women's rugby union players over the duration of a competitive season. The data could be used by the coaching staff, sport scientists and medical practitioners to determine the effectiveness of intervention programs in the attainment or maintenance of fitness levels throughout the season.

1.3 AIM AND OBJECTIVES

The aim of this study was to assess the physical fitness of elite senior women's rugby union players over a competition season. In order to meet the primary aim of this study, the following objectives are relevant:

- To investigate seasonal variations in physical fitness of an elite women's rugby union player during a competition season between pre-season, mid-season and post-season.
- To identify which of the following anthropometric and physical characteristics are significantly different between forwards and backs, of an elite South African women's rugby union player during a competition season:
 - anthropometric measures such as:
 - stature
 - body mass
 - skinfold
 - percentage body fat
 - physical measures such as
 - flexibility
 - vertical jump

- 10 and 40 m speed
- 1 RM bench press
- pull-ups
- 1 minute push-ups
- aerobic power

1.4 RESEARCH HYPOTHESIS

For this study, it was hypothesised that:

- There will be a significant improvement in the body mass, sum of seven skinfolds, percentage body fat, flexibility, vertical jump, 10m and 40m speed, 1- RM bench press, pull-ups, 1 minute push-ups and predicted maximum oxygen uptake between pre-season, mid-season and post-season.
- There will be no significant change in the body mass, sum of seven skinfolds, percentage body fat, flexibility, vertical jump, 10m and 40m speed, 1- RM bench press, pull-ups, 1 minute push-ups and predicted maximum oxygen uptake between mid-season and post-season.
- There will be a significant difference between the forwards and backs for the following physical fitness characteristics: body mass, sum of seven skinfolds, percentage body fat, flexibility, vertical jump, 10m and 40m speed, 1- RM bench press, pull-ups, 1 minute push-ups and predicted maximum oxygen uptake.

1.5 SIGNIFICANCE OF THE STUDY

Rugby union is a contact team sport played by both sub-elite and elite male and female competitors. The increase in women's participation in competitive games is reflected in the growing popularity of Women's Rugby Union (Kirby & Reilly, 1993). The acceptance of the women's rugby by SARU, culminated in the participation of the Springbok Women's Team in the 2006 Women's Rugby World Cup. Up to now there has been little attention given to the women's game in South Africa by researchers, unlike men's rugby in which has been studied by various research groups (Duthie et al., 2003).

According to Holmyard and Hazeldine (1993), the seasonal nature of rugby union imposes varied physical stresses on the player which may compromise their physical development. With this mind, the scientific investigation on physical testing of these fitness qualities will attempt to assist in the monitoring of a players physical fitness during the season. Furthermore, the knowledge generated in this study will assist in the development of intervention programs for women's rugby union players. From a practical perspective, such research could be utilised by coaches in structuring periodised plans so as to facilitate effective training to improve individual and team performance. In addition, it may provide conditioning coaches with realistic performance guidelines based on the different phases on the competition season.

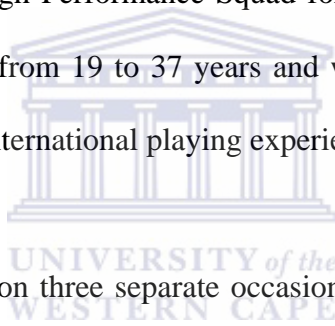
1.6 LIMITATIONS OF THE STUDY

The sample size of this study is relatively small however it is comparable to anthropometric and physical studies for women's rugby players in club, provincial and international level

(Gabbett, 2007; Quarrie et al., 1995; Kirby & Reilly, 1993). In an attempt to obtain a homogenous sample size of senior elite women's rugby union players, only participants that have been selected for the SARU high performance squad will be studied. Although it may have been advantageous to include a greater sample size, the researcher deems it more important to study a representative sample of elite women's rugby players.

1.7 SCOPE OF THE STUDY

The sample consisted of 32 elite female rugby players who were identified as members of the South African Rugby Union High Performance Squad for the 2010 Women's Rugby World Cup. The players' ages ranged from 19 to 37 years and were defined as "elite" because the majority of these players have international playing experience.



The participants were assessed on three separate occasions throughout the 2009 competition season. The first data collection process took place in May, pre-season, then in July, mid-season and in October, post season. All physical assessments were conducted on the first day of the national training camps after medical assessments were done on each player by the medical staff. All measurements and assessments were done in-doors so as to limit any interference from environmental conditions. On all testing occasions, the fitness testing protocol was specifically completed in the following order: stature, body mass; skinfolds; sit and reach; vertical jump; speed; bench press; pull-ups, push-ups and multi-stage shuttle run so as to increase reliability and accuracy.

1.8 TERMINOLOGY

Forwards:

Classified as players numbered 1 to 8 and referred to as “ball winners” (Duthie et al., 2003). Within the forwards, players 1 to 3 are referred to as the “front row”, while 1 to 5 are commonly known as the “tight 5”. The “second row” is formed by the locks (players 4 and 5). The “loose forwards” are players 6 to 8, and also referred as the “back row”.

Backs:

Classified as players numbered 9 to 15 and referred to as “ball carriers” (Duthie et al., 2003). Within the backs, “half backs” players 9 to 10, while 9 to 13 are commonly known as the “inside backs”. The “midfield backs” (centers) are 12 and 13, and “outside backs” are 11, 14 and 15.

Physical fitness:

Defined in this study as a combination of anthropometric and physical performance characteristics.

Anthropometric characteristics:

Defined as the measurement of the dimensions of the human body (Maud & Foster, 2006) and for this study, measurements of stature, weight and skinfolds to determine body composition.

Physical performance characteristics: Defined in this study as the outcome of measurements of the following fitness components: muscle strength and endurance, anaerobic and aerobic endurance, flexibility, speed, and power.

Scrum: The scrum is a way to restart play after a minor infringement or a stoppage. A scrum is formed in the field of play when eight players from each team, bound together in three rows for each team, close up with their opponents so that the heads of the front rows are interlocked. This creates a tunnel into which a scrum half throws in the ball so that front row players can compete for possession by hooking the ball with either of their feet (SA Rugby, 2007).

Maul: A maul occurs when a player carrying the ball is held by one or more opponents, and one or more of the ball carrier's team mates bind on the ball carrier. A maul therefore consists of at least three players, all on their feet; the ball carrier and one player from each team. All the players involved must be caught in or bound to the maul and must be on their feet and moving towards a goal line (SA Rugby, 2007).

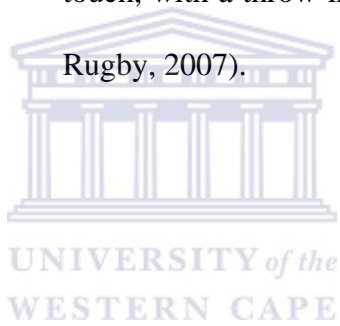
Ruck:

A ruck is a phase of play where one or more players from each team, who are on their feet, in physical contact, close around the ball on the ground (SA Rugby, 2007).

Line-out:

It is a way to restart play, after the ball has gone into touch, with a throw-in between two lines of players (SA

Rugby, 2007).



CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 INTRODUCTION

Rugby is a collision-based sport, which historically has been a male preserve. Success in the sport is extremely reliant upon the player's possessing an adequate level of strength, power, speed, endurance and as well as technical and tactical acumen. With the rapid growth in women's rugby, this chapter first explores the history of women's rugby and its competitive development in South Africa. The demands of rugby competition are described in terms of activity patterns so as to gain insight into the positional demands in rugby union. Thereafter, specific physical fitness characteristics are described in this chapter, which have shown to influence sporting performance. Finally, season changes in fitness over the course of the season as well as monitoring methodology used during training will be discussed.

2.2 WOMEN'S RUGBY UNION

South Africa is a country whereby rugby has a following of about ten million in a population of 44 million and played by both men and women at club, provincial and national level (SA Rugby, n.d.). In the 1990's, women's rugby in South Africa emerged in Johannesburg and Pretoria, with when it was played predominately by middle class females who had enough time and resources to establish teams. These players encountered gender stereotypes on a regular basis from some rugby men, although rugby in South Africa was founded on the

principle of a non-racial, non-political and democratic rugby community, so as to ensure the leveling of the playing fields on and off the field (SA Rugby, n.d.).

2.2.1 Women's Club Rugby

When the South African Rugby Union (SARU) accepted women's rugby into its fold in 2000, there were less than 10 clubs which were mainly situated at the Blue Bulls, Golden Lions and Falcons rugby union. Women's rugby achieved success in the early period and experienced an exponential growth due to SARU initiated campaigns through the Provinces to establish club rugby so as to dispel the stereotypes born of misconceptions about the sport. The recruitment drive resulted in the affiliation of 65 clubs in July 2001 and on National Women's Day (9 August 2001) the programme was officially launched in Pretoria. At the end of 2001, there were 91 clubs throughout the country which further increased to 123 by March 2002, with Eastern Province and Border region showing remarkably growth especially in the under-privileged communities. With the increasing numbers and competitiveness, women's rugby was now an established female sport in South Africa.

Women's rugby playing numbers declined between 2003 and 2006, as women faced the daunting task of managing clubs, raising funds and yet playing. In addition, senior players who had aspiration of representing the National Team retired after realising that they were not meeting the selection criteria.

After a few years of struggling for survival, rugby is now being played in over 143 amateur clubs (Figure 1). This resurgence in the women's games is due to an initiative by Mahlubi Puzi

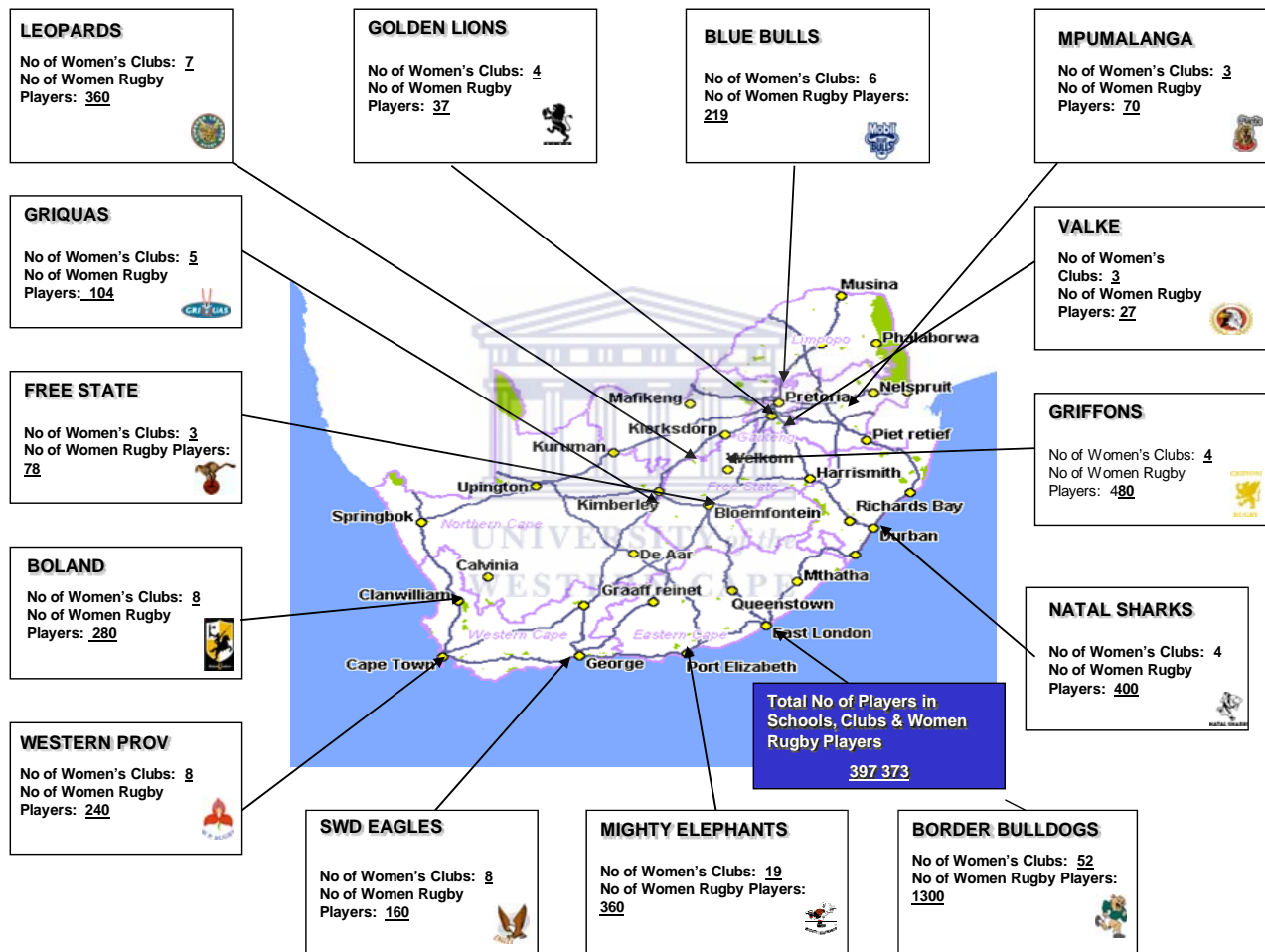


Figure 1: Map of South African Women's Club Rugby

(International Rugby Board, n.d)

Puzi, the South African Rugby Game Development Manager to attract young girls to the game through men's youth club so as makes the clubs more sustainable. Currently they are 15129 amateur female rugby players, comprising of 7167 senior female players, 4143 teen female players and 3819 pre-teen female players (International Rugby Board, n.d)

2.2.2 Provincial Women's Rugby

In August 2002, SARU staged the inaugural Inter-Provincial Tournament to give opportunity to a greater number of players to play representative rugby. This culminated in Falcons winning against Natal in a closely contested match on National Women's Day (09 August 2002). SARU then launched the Inter-Provincial League in 2003. In New Zealand, provincial rugby has been played since 1980 (Chester, Palenski, & McMillian, 1998), even though it was only accepted by the New Zealand Rugby Football Union in 1992 (Chu, Leberman, Howe, & Bachor, 2003). In South Africa, Provincial rugby is played once a month with the other three weeks dedicated to club rugby. Provincial games are played either in communities or as curtain raisers to provincial men's games in major stadiums so as to promote the game to a broader spectator base.

Blue Bulls and Eastern Province are the leading Provincial rugby teams as they both secured four and three consecutive Inter-Provincial titles between 2003-2006 and 2007-2009, respectively (SA Rugby, 2009).

2.2.3 International Women's Rugby

Men's Rugby Union has been an international sport since 1871, when England and Scotland contested the first international match (Quarrie & Hopkins, 2007). In the United States, the senior, U23 and U19 women's national team began participating in 1987, 1999 and 2002, respectively (Chase, 2006). The South African Women's Rugby team, commonly known as the Springbok Women's Team, played their inaugural test matches against Wales at the Adcock Stadium in Port Elizabeth and at Securicor Loftus Stadium in Pretoria in 2004, followed by a reciprocation outbound tour to Wales and England in 2005 whereby the team won its first international game against Wales (SA Rugby, 2005). The Springbok Women's team won their first home game and test series in June 2006 against Netherlands (SA Rugby, 2006).



In 2006, at the third official 2006 International Rugby Board Women's Rugby World Cup in Canada, South Africa participated as the Confederation of Africa Rugby (CAR) representative. The first recognised Women's Rugby World Cup was hosted by The Netherlands Rugby Board in 1998, which was won by New Zealand, who are the current three-time defending World Cup champions. Prior to this, World Tournaments were staged in Wales and Scotland in 1991 and 1994 respectively.

2.3 PHYSIOLOGICAL DEMANDS OF RUGBY COMPETITION

Rugby is typical of many team sports, with a range of work intensities, durations and recovery periods (McLean, 1992). Researchers have used measurements of physiological parameters

such as heart rate (Deutsch et al., 1998), blood lactate concentration (Deutsch et al., 1998; McLean, 1992); blood glucose (Jardine, Wiggins, Myburgh, & Noakes, 1988), muscle glycogen (Jardine et al., 1988) and haematological parameters (Banfi, Del Fabbro, Mauri, Corsi, & Melegati, 2006) to establish the physiological response to rugby. Due to the frequency of physical contact during competition, to collect blood samples poses logistical difficulty for researchers and players. Hence time-motional analysis is preferred, as it provides a non-invasive and yet effective method of quantifying the demands of rugby and also provides conceptual frame work for specific physical preparation of players (Deutsch, et al., 2002; Deutsch et al., 2007; Duthie et al., 2003; McLean, 1992; Roberts, Trewartha, Higgitt, El-Abd, & Stokes, 2008).



In rugby, time-motion analysis has been used extensively to establish movement patterns (Deutsch et al., 1998; Deutsch et al., 2002; Deutsch et al., 2007), distance covered and average velocities (Deutsch et al., 2002; Deutsch et al., 2007; Duthie et al., 2003; McLean, 1992; Roberts et al., 2008), levels of exertion and work to rest ratios (Deutsch et al., 1998; Deutsch et al., 2007; Duthie, Pyne, & Hooper, 2005; McLean, 1992) in order to quantify the time spent in different activities at different levels of competition and between positional groups (Duthie et al., 2003).

Hence, a detailed understanding of positional demands is necessary to inform the development of more position specific norms so as to match players to particular positions and for the implementation of training programs specific to the physical positional demands.

2.3.1 Movement Patterns

Time-motion studies have revealed that the 85% of the match is spent on low intensity activities (standing, walking, jogging and utility movements) and 15% in high intensity activities (cruising, sprinting, scrummaging, rucking, mauling, and tackling) (Duthie, 2007; Deutsch et al., 2007). These findings support the notion that rugby is of intermittent nature whereby short bouts of high intensity are interspersed with long periods of low intensity activity.

Studies of rugby union players reveal that forwards spent significantly more time in the high intensity phase than backs, because of their greater involvement in rucking, mauling and scrummaging (Deutsch et al., 2002; Duthie et al., 2003; Duthie et al., 2005). These findings were supported by a recent study by Deutsch et al., (2007) and Roberts et al., (2008), whereby forwards spent 12-14% total match time performing high intensity work, while corresponding value for backs were 4.5-6%. These findings reaffirm the notion that static and dynamic movements such as rucking, mauling, tackling are critical components in the game of rugby for forwards. Of high intensity activity, backs spend approximately two to three times more sprinting than forwards irrespective of playing conditions (Deutsch et al., 1998; Deutsch et al., 2007; Roberts et al., 2008).

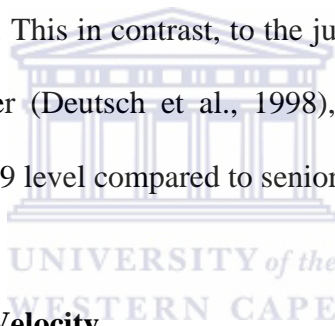
Movement analysis of elite male junior and senior internationals indicate that front row forwards spend more time standing still, with the trend for this time to decrease as one moves outwards among the different positional groups (Deutsch et al., 1998; Deutsch et al., 2007; Roberts et al., 2008). This breakdown of movement suggests that players carrying a greater

body mass passively recovery around the ruck area after an intense activity. The percentage of time spent walking reported for U-19 players (front forwards 14.7%, back row forwards 16%, inside backs 27.5%; outside backs 27%) was similar to Super 12 players (Deutsch et al., 1998). Conversely, there is greater use of jogging by forwards when compared with backs which suggests forwards continuously follow the ball to breakdowns given the proximity to the contest (Deutsch et al., 1998; Roberts et al., 2008).

2.3.2 Work-to-Rest Ratios

Across all rugby playing positions, players are required to repeatedly reproduce maximal sprints of short duration, interspersed with brief recovery periods over the duration of a match. Hence, work-to-rest ratios provide an objective means of quantifying the physiological requirement of an activity (Duthie et al., 2003). Work and rest periods have been defined as those when a player is involved in high intensity activities (running, sprinting, rucking, mauling or scrumming) and in low intensity activities (standing, walking, jogging and shuffling sideways or backwards) respectively (McLean, 1992). Work-to-rest ratios are calculated by comparing the mean duration of work periods against the mean duration of rest periods (Deutsch et al., 2002; Duthie et al., 2003; McLean, 1992). High-intensity efforts can sometimes follow each other in effort to retain possession, resulting in increased work-to-rest ratios and players having insufficient time for the replenishment of creatine phosphate stores between high intensity efforts, and thus a considerable reliance on anaerobic glycolysis during these subsequent work periods (Deutsch et al., 1998; Deutsch et al., 2007). This results in the need for longer periods of recovery between high intensity efforts (Meir, Newton, Curtis, Fardell, & Butler, 2001).

Analysis of work-to-rest periods in U-19 Australia male rugby players showed that forwards (1:1.4) maintained a higher work-to-rest ratio than backs (1:2.7) with the loose forwards (1:1.2) working more continuously than inside backs (1:3.6) (Deutsch et al., 1998). Similarly, McLean (1992) reported that most work-to-rest ratios during international match-play were in the range of 1:1 to 1:9 for backs and forwards combined which is the same with U-19 Australian players when positions are combined. These are considerably higher than the estimated mean work-to-rest ratios of 1:7.4 and 1:21.8 reported for New Zealand Super 12 forwards and backs respectively (Deutsch et al., 2007). The prolonged rest periods at the senior elite level of rugby union reflects the increase number of stoppages due to injuries, goal kicking and stringent refereeing. This in contrast, to the junior level, in which rest periods are short and work rates are higher (Deutsch et al., 1998), which suggests a less structured, continuous style of rugby in U-19 level compared to senior level.



2.3.3 Distance Covered and Velocity

Estimation on the distance covered during the course of a match indicates that backs cover more distance than forwards (Deutsch et al., 1998; Roberts et al., 2008). The total distance covered by both forwards (5581m) and backs (6127m) during a 80 minute rugby match at the elite level (Roberts et al., 2008) is in line with U19 age group level of forwards (4240m) and backs (5640m) during a 70 min match (Deutsch et al., 1998). The difference in total distance traveled by backs and forwards is attributed to a greater walking distance by backs (2351 vs. 1928 m) and as result of high intensity running (448 vs. 298m) (Roberts et al., 2008). Sprinting data show that outside backs (280 ± 185 m) sprint significantly greater total distances than inside backs (124 ± 78 m), tight forwards (144 ± 189 m) and loose forwards

(192 ± 203 m) (Roberts et al., 2008). The greater sprints performed by outside backs reinforces the generally accepted notion that as “finishers” they require a superior sprinting ability than other positional groups.

Furthermore, male forwards and backs achieved speeds in excess of 90% maximal velocity (V_{\max}) at $7.5\text{m}\cdot\text{s}^{-1}$ and $8.5\text{m}\cdot\text{s}^{-1}$, respectively (Duthie, Pyne, Marsh, & Hooper, 2006b). For forwards, many sprints commence from a standing start and typically lasted 2.5 seconds in which they covered a distance of 15m (Duthie et al., 2006b). This illustrates that conditioning coaches should train forwards from a standing position and test them preferably over ten meter splits (0 to 10 m and 10 to 20m), which can be classified as acceleration. When starting from a jogging speed, elite rugby union backs achieved 100% of V_{\max} in which they covered approximately 40m within five seconds. Hence, the assessment of speed for backs should include 0 to 10m and 30-40m sprint training from standing and moving starts as this will assess their acceleration and ability to attain speeds in excess of 90% of V_{\max} .

2.4 PHYSICAL FITNESS OF A RUGBY PLAYER

Rugby union is a high contact, dynamic sport in which athletes requires high levels of physical fitness, which is a composite of aerobic and anaerobic endurance, muscle strength and power, speed, agility and body composition. For this review, the anthropometric and physical performance characteristics will be compartmentalized in sections for ease of discussion.

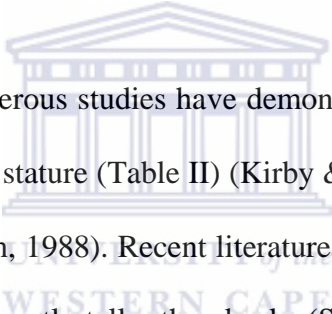
2.4.1 Body Mass

There has been a marked increase in the body mass of rugby players following the introduction of professionalism due to selection pressure towards physiques that best match the requirements of the sport (Quarrie & Hopkins, 2007). The 1999 Rugby World Cup lends support to this conception as the most successful teams had greater mass in the forwards (Duthie et al., 2006). A greater body mass confers an advantage in the contact phases of the sport, because of the great momentum players are able to generate (Quarrie & Hopkins, 2007). An increased focus on weight training and usage of nutritional supplements may also have contributed to the increase changes in body mass (Duthie et al., 2003).

Numerous studies have shown that there is a distinction between forwards and backs with respect to body mass of elite (Duthie et al., 2006; Meir & Halliday, 2005; Quarrie & Hopkins, 2007), amateur (Maud, 1983; Quarrie et al., 1995), adolescent (Deutsch et al., 1998; Durandt et al., 2006) and female rugby players (Gabbett, 2007; Kirby & Reilly, 1993; Quarrie et al., 1995; Schick, Molloy, & Wiley, 2008). Amongst the 2006 Women's Rugby Union players, the forwards (80.17 ± 10.10 kg) were significantly heavier than the backs (68.03 ± 10.10 kg) which is comparable to elite women's rugby league forwards and backs (74.5 ± 12.5 kg vs. 64.7 ± 7.6 kg) (Gabbett, 2007; Schick et al., 2008) (Table I). Differences in body mass have also been observed within the forwards and backs between U/16 and U/18 South African rugby union players (Durandt et al., 2006). Sixteen year old players weighing significantly less than the 18-year-old players (76.5 ± 8.2 vs. 84.9 ± 8.3 kg) with the props being the heaviest and scrumhalves the lightest in both age groups .

2.4.2 Stature

There is a clear distinction in stature (standing height) between male forwards and backs at junior (Durandt et al., 2006) and professional level (Duthie et al., 2003). Interestingly, a data analysis of New Zealand Rugby Players between 1972 and 2004 shows, that forwards have become slightly shorter whereas backline players have become taller (Quarrie & Hopkins, 2007). It has been speculated that the decrease in stature of the forwards coincides with the introduction of the law permitting lineout jumpers to be supported in the lineout as this law allows good lifters to overcome slight disadvantages in the stature of the jumper.



In contrast to male players, numerous studies have demonstrated that senior and school girl's forwards and backs have similar stature (Table II) (Kirby & Reilly, 1993; Quarrie et al., 1995; Sedlock, Fitzgerald, & Knowlton, 1988). Recent literature has shown that both elite women's rugby union forwards are significantly taller than backs (Schick et al., 2008). It would appear that players in the forwards need to be tall to contest aerial possession of the ball in line-outs.

2.4.3 Sum of Skinfolds

The majority of anthropometric assessments of rugby players have involved quantifying the body fat levels (Duthie et al., 2003). The calculation of percentage body fat is problematic, due to limitations in establishing percentage body from estimates of body density and skinfold measurements (Martin, Ross, Drinkwater, & Clarys, 1985) and the measurement error of different methods and prediction equations (Duthie et al., 2006a). Given these concerns, it is

Table I: Body Mass (kg) of female rugby player

		Body Mass (kg)	
		Mean ± SD	
		Forwards	Backs
Gabbett (2007)	Elite Rugby league	75.5 ± 12.5	64.7 ± 7.6
Schick, Molloy & Willey (2008)	Elite Rugby Union	80.2 ± 10.1	68.0 ± 7.5
Quarie et al., (1995)	Senior New Zealand	75.6	61.4
Kirby & Reilly (1993)	Senior England	68.9 ± 6.6	60.8 ± 5.7
Williams (1984)	Club United States	68.9 ± 6.1	60.7 ± 5.9
Sedlock, Fitzgerald, & Knowlton (1988)	Club	69.2 ± 9.3	54.1 ± 6.8

now common practice to monitor sum of skinfolds in elite rugby players in preference to estimating percentage body fat, as it can be used to monitor changes in peripheral fat stores over time (Jenkins & Reaburn, 2000).

The skinfold thickness is reported to significantly higher in forwards than backs for male professional rugby union players (forwards: 84 ± 19 mm vs. backs: 60 ± 13 mm), and elite female rugby league player (forwards: 141 ± 37.2 mm vs. backs: 114.8 ± 20.2 mm) (Duthie, 2006; Gabbett, 2007). It has been suggested that the higher percentage body fat in forwards may serve as protective buffer in contact situations or impact injuries (Bell, 1973), however, to date no conclusive evidence exists to support or refute this claim. The lower body fat values of the backs are a reflection of the higher speed requirements of these players. Body fat values for male backs are said to be similar to other team sports such as field hockey, soccer and touch rugby (Duthie, Pyne & Hooper, 2003). Excessive body fat should be avoided as it has shown to have negative impact on performance for two main reasons, First, Newton's second law ($a = F/m$) specifies that increases in fat mass (m) without an increase in muscle force (F) will reduce acceleration (a). Second, displacement of additional fat mass requires extra energy, which increases the relative physical cost of exercise (Duthie, 2006).

2.4.4 Speed

Speed is a component of fitness that is often assessed by sport scientist to indicate athletic ability (Logan, Fornasiero, Abernethy, & Lynch, 2000). Speed is the ability to cover distances in as short a time as possible and represents the maximum capabilities of an athlete in a

Table II: Stature (cm) of female rugby players

		Stature (cm)	
		Mean ± SD	
		Forwards	Backs
Gabbett (2007)	Elite Rugby league	169.0 ± 6.6	166.1 ± 5.4
Schick, Molloy & Willey (2008)	Elite Rugby Union	172.0 ± 6.7	165.6 ± 5.9
Quarie et al., (1995)	Senior New Zealand	166.7	164.1
Kirby & Reilly (1993)	Elite Rugby Union	168.5 ± 7.9	165.5 ± 3.9
Williams (1984)	Club	166.0 ± 5.4	164.9 ± 5.4
Sedlock, Fitzgerald, & Knowlton (1988)	Club	166.4 ± 4.6	162.2 ± 5.6

straight line (Baker & Nance, 1999). The ability to sprint is undeniable an important fitness component for rugby union (Nicholas, 1997). In rugby, sprints vary in terms of change of direction, methods of carrying the ball, and strategies to avoid contact with the opposition (Duthie et al., 2006b). Collectively, these factors make sprinting in rugby different from straight-line track line sprinting (Sayers, 2000). Despite these differences, elite rugby union coaches and conditioning staff still strive for their players to be able run quickly in a straight line (Duthie et al., 2003).

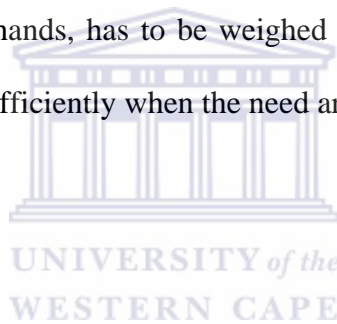
Speed consists of a number of components, all of which are independent qualities; namely acceleration, maximum speed and speed-endurance (Cronin & Hansen, 2005). Assessment of elite rugby players' speed has traditionally involved testing over a range of distances (10 to 100m) from both a standing and moving start (Duthie et al., 2006b; Carlson et al., 1994; Quarrie et al., 1995; Quarrie et al., 1996). Time motion studies have suggested that acceleration (0-10m) and to a lesser extent, maximal velocities (30-40m) are important qualities of sprinting for elite rugby players (Duthie et al., 2006b; Duthie et al., 2003). Sprint comparison among elite female sport athletes reported that Touch rugby players are fastest in acceleration and speed endurance (Table III).

Considering the importance of assessing and developing acceleration qualities of rugby players, coaches and conditioning staff need to be aware of the critical differences between track and rugby running techniques. Correct track sprinting technique is not ideal in rugby, as players need to change direction, carry a ball and prepare for contact (Sayers, 2000). Rugby players must sprint with low foot elevation and emphasis on fast feet or cadence rather than

Table III: Comparison of 10m and 40m sprint times among elite sportswomen

		Seconds	
		Mean ± SD	
		10-m sprint	40-m sprint
Gabbett (2007)	Rugby League	2.00 ± 0.11	6.46 ± 0.36
Tumilty (2000)	Soccer	1.87 ± 0.07	Not reported
Lawrence & Polgaze (2000)	Hockey	1.98 ± 0.07	6.04 ± 0.22
O'Connor (1997)	Touch Rugby	1.82 ± 0.09	5.71 ± 0.22

stride length like a track sprinter (Duthie et al., 2003). Rugby players tend to run with a closed, slightly slouched upper body posture with a significantly forward lean (to drive hard and protect possession) with the foot landing forward of the centre of gravity (to brace for impact or provide breaking force for change in direction), as compared to track athletes who run more upright and with feet landing under the centre of gravity (Sayers, 2000). Attacking players often have to sprint while carrying a ball which has the potential to reduce their arm drive, an important characteristic of sprinting. A study has shown that players can sprint fastest without the ball, while running with the ball under one arm is slower and running with the ball in both hands is the slowest (Grant et al., 2003). The negative effect of slowing down while holding the ball in both hands, has to be weighed up against the advantages of being able to distribute the ball more efficiently when the need arises.



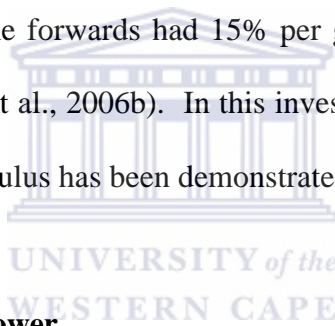
2.4.5 Agility

At present, there is no consensus among sport scientists for a clear definition of agility, although most practitioners classify agility as any movement involving rapid change(s) of direction (Bloomfield, Ackland & Elliot, 1994). In a more recent publication by Sheppard and Young (2006), agility is defined as a rapid, whole body, change of direction or speed in response to a sport specific stimulus.

Several researchers have advocated the use of agility tests on rugby union players such as Illinois agility run (Durandt et al., 2006), 505 test (Ellis et al., 2000), Agility run (Quarrie et al., 1995) and T-test (van Gent & Spamer, 2005). Although these studies reflect the time difference within positional groups (backs and forwards), there is no significant difference

between age groups (Durandt et al., 2006) and playing levels (Quarrie et al., 1995). If a test cannot discriminate between higher and lower performers within a sport, its utility in detecting training-induced changes is questionable (Gabbett, Kelly, & Sheppard, 2008). In addition, these tests are limited as the change of direction relies on preplanned movements which are not practical in a sport such as rugby. Furthermore, the aerobic and anaerobic test procedures that will be described in the upcoming paragraphs both involve a component of agility as they comprise several sharp turns within the tests.

While the majority of agility research has been devoted to preplanned change of direction speed tests, a study reported that during a Super 12 game, 16% of all the sprints involved a change of direction of which the forwards had 15% per game which is significantly greater than backs ($6 \pm 3.2\%$) (Duthie et al., 2006b). In this investigation, the ability of rugby player to respond to game specific stimulus has been demonstrated.

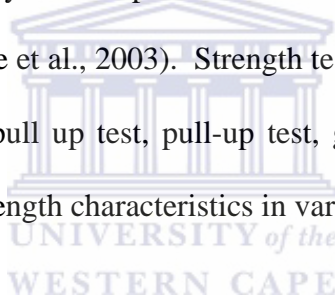


2.4.6 Muscle Strength and Power

Strength is defined as the ability to overcome or resist very high levels of force, especially against large external resistances, such as the body weight of opposing players (Baker, 2001b). Power is defined as the ability to generate high levels of force quickly (strength x speed or the speed at which strength can be manifested) (Baker, 2001b). Strength and power have been reported as important physical qualities necessary for successful participation in rugby union player, as is not only necessary to be strong to effectively tackle, push or pull opponents or resisting high level of forces during scrums, rucks and mauls but also to generate these high levels of strength with speed (Hrysomallis, 2010; Meir et al., 2001). Hence muscular power and strength are regularly evaluated by strength and conditioning staff and are

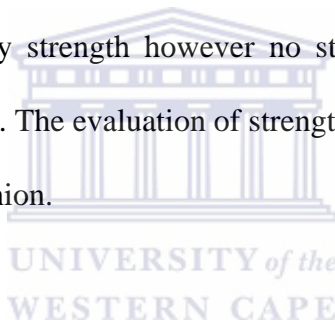
deemed important components of physical fitness by players and coaching staff (Crewther, Gill, Weatherby, & Lowe, 2009).

Testing of rugby players has greatly increased during the past decade, principally due to the increased professionalism in the sport and the consequent determination to improve player talent identification and performance level (Baker, 2001b). Numerous studies have examined the upper body strength of male rugby union players at various competitive levels and age groups (Du Plessis, 2007; Durandt et al., 2006; van Gent & Spamer, 2005; Crewther et al., 2009), however there is presently limited published information on the leg strength levels of elite rugby union players (Duthie et al., 2003). Strength test such as the one or three repetition maximum bench press, bench pull up test, pull-up test, grip strength and leg strength tests have been used to profile the strength characteristics in various rugby populations.



Crewther et al., (2009), reported significant differences in one repetition maximum (1 RM) box squat (197.7 ± 25.5 kg vs. 181.9 ± 16.8 kg) and bench press (143.6 ± 10.9 kg vs. 130.6 ± 17.9 kg) strength in forwards and back respectively at elite level. These findings are in line with previous research on international rugby union players (Cometti, Pousson, Bernardin, & Brullebaut, 1992). The positional difference in muscular strength can be partially explained by the larger body mass of forwards, and may also reflect the muscular adaptation which occurs as a function of the strength requirements of forwards to enable them to withstand and transmit the forces applied whilst scrumming (Quarrie & Wilson, 2000).

Durandt et al., (2006) indicate that a 16 year old (77.1 ± 11.8 kg) male elite rugby player lifted less weight than a 18 year-old male (95.3 ± 16.7 kg) in the 1 RM bench press test for upper body strength. The greater strength in 18 year olds was attributed to maturation, training discrepancies or a combination of the two (Durandt et al., 2006). Significant differences were also reported by Mayes and Nuttall (1995) between senior and U21 male Welsh Rugby Union players regarding their three- repetition maximum bench press of 98.7 ± 13.7 kg and 83.1 ± 14.4 kg respectively. These findings may be attributed, in part to neural adaptations that occur with long-term periodised strength training of professional rugby players (Baker, 2001a). It appears that rugby players require a high degree of muscularity combined with exceptional levels of upper and lower body strength however no study has investigated the muscular strength of female rugby players. The evaluation of strength could assist in the development of scientific knowledge in rugby union.



Power expression on rugby union players has been assessed by measures of vertical jump height (Carlson et al., 1994; Maud, 1983; Quarrie et al., 1995; Quarrie & Wilson, 2000; Tong & Mayes, 1995), squat jump and bench throw (Crewther et al., 2009). Investigations have commonly used the vertical jump test instead of the squat jump to assess muscular leg power as it equipment is portable and can be used on the appropriate surfaces. Research indicates that backs generally produce a superior vertical jump performance compared with forwards (Maud, 1983; Rigg & Reilly, 1988), while surprisingly, vertical jumping performance decreased as playing level increased. This is similar to a previous study on New Zealand senior female rugby union forwards players (Quarrie et al., 1995). However, it is contrast to studies by Kirby & Reilly (1996) and Gabbett (2007) on elite women's rugby union and

league players, respectively whereby no significant positional differences were found for the vertical jump test (Table IV). Such comparisons may be erroneous given the changes in vertical jump assessment over this period (e.g. chalk board versus Vertec) (Duthie et al., 2003).

Recently, Crewther et al., (2009) reported, that the absolute expression of squat jump and bench throw peak power was greater for the forwards than the backs when assessing lower and upper body muscle power respectively. After normalizing the power results using ratio scaling (power/body mass), the backs revealed superior performance in these tests, which is consistent with previous research in rugby union players (Maud, 1983). Ratio scaling has been criticised as it assumes a linear relationship between body size and performance, thereby penalizing heavier individuals and showing bias towards lighter individuals (Atkins, 2004; Jaric, Mirkov, & Markovic, 2005). There was no performance difference between the backs and forwards after allometric scaling using either the proposed or the derived exponents. The present study did have limitations, as scaling power values for body mass, using either the ratio or allometric methods, did not account for body composition differences between individual players (e.g. fat mass, muscle mass) (Crewther et al., 2009) and the regional distribution of body and muscle mass, which can vary between forwards and backs (Bell, Evans, Cobner, & Eston, 2005).

2.4.7 Muscle Endurance

Muscle endurance is dependent on the muscle being able to contract repetitively without developing fatigue. A combination of muscle strength, metabolic characteristics and local

Table IV: Comparison of Vertical Jump Height (cm) among female rugby players

		Position	n	Vertical Jump (cm) Mean ± SD
Quarrie et al., 1995	New Zealand Senior Rugby Union	Forwards	35	39.6 ± 5.60
		Backs	31	44.8 ± 8.30
Kirby & Reilly, 1996	England Senior Rugby Union	Forwards	20	35.4 ± 3.3
		Backs	19	36.9 ± 2.7
Gabbett, 2007	Australian Elite Rugby league	Forwards	16	35.1 ± 8.0
		Backs	16	35.7 ± 5.9

circulation in the muscle influence the endurance characteristics (Lambert, 2009). Rugby researchers have predominately assessed abdominal and upper body muscle endurance via the 1 minute sit-up and push-up test respectively (Durandt et al., 2006; Maud, 1983). A study on South African U16 and U18 elite male junior rugby players showed that 18 year old players completed more pushups (52 ± 15) than the 16-year-old players (41 ± 12) however no significant differences between playing position were demonstrated (Durandt et al., 2006). Although tests are performed within a group of players and descriptive analysis are provided, there are concerns over their standardization, reliability and validity (Duthie et al., 2003).

2.4.8 Aerobic Endurance

The trend towards more expansive game plans with constant recycling of possession and a decrease in set plays in Super 12 and international matches has placed greater aerobic endurance demands upon modern rugby players as compared to those of the era before professionalism (Scott et al., 2003). Aerobic endurance, also referred to as cardiovascular endurance or aerobic fitness, refers to the collective ability of the cardiovascular system to adjust to the physiological stress of exercise (Lambert, 2009). Cardiovascular fitness is usually measured in a laboratory or field setting. The most frequently employed laboratory protocols for assessing a rugby player's maximum oxygen consumption (VO_{2max}), are progressive, incremental exercise tests to exhaustion on either a treadmill or cycle ergometer (Scott et al., 2003). An athlete's VO_{2max} can be expressed either in absolute (liters per minute ($l \cdot \text{min}^{-1}$)) when power output is important or relative to body mass per minute ($\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) for activities where body mass should be considered (Duthie et al., 2003). Given the large body mass variation between backs and forwards, it suggested that researchers present these ratios

to allow accurate comparison (Duthie et al., 2003). Recent research examining the difference using modified Bruce protocol on a treadmill showed that the maximum oxygen uptake was higher in backs ($48.3 \pm 2.1 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) than forwards ($41.2 \pm 2.7 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) yet no significant difference in the exercise duration (Scott et al., 2003). This reaffirms the research finding that backs have superior oxygen uptake when expressed relative to body mass and that forwards have superior absolute $\text{VO}_{2\text{max}}$ values as compared to backs (Maud, 1983; Jardine et al., 1988).

Hawley and Burke (1988) reported a significant negative correlation between maximum oxygen uptake and time for continuous aerobic endurance tests such as the 3 km run test. This was attributed to pace setting, as athletes will often start too quickly, and consequently experience fatigue prematurely during the late stages of the test, hence the athlete's true aerobic capacity would be underestimated (Hawley & Burke, 1988). In addition, rugby players discipline does not require participants to run uphill or at the same pace. Hence, both laboratory and sustained running tests of $\text{VO}_{2\text{max}}$ are unsuitable for assessing the aerobic power of rugby players.

Rugby Union and Rugby League are sports which demand a high level of aerobic fitness, with players covering an average distance of 5.5 to 7 km during the course of game (Roberts et al., 2008). However, in these sports, players change both the pace and direction of running, and have to accelerate from a standing or walking start many times during a match (Hawley & Burke, 1998). For this reason, the multi-stage shuttle run test is widely used to predict aerobic fitness in a field setting. Kirby and Reilly (1993) reported mean $\text{VO}_{2\text{max}}$ values of 43.8 and

47.3 mL/kg/min for elite women's rugby union forwards and backs respectively. The estimated maximum oxygen uptake is similar to those of Senior New Zealand Women's Rugby Union forwards and backs of 44.75 and 54.48 mL/kg/min respectively (Quarrie et al., 1995). Interestingly, elite touch rugby union players had superior aerobic power at 50.3 ml/kg/min. A limitation of the multi-stage shuttle run test is that it provides no confirmation that maximum effort was given by the athlete (Duthie et al., 2003; Scott et al., 2003).

2.4.9 Anaerobic Endurance

A rugby match entails intermittent exercise with varying intensity, from all-out sprints to static pauses, high power outputs in accelerating into a sprint, jumping for the ball, or in winning possession of the ball in line-outs or scrums or in intercepting passes (Rienzi et al., 1999). Hence, a rugby player is required to continually produce short bursts of high intensity work with minimal loss of power (Nicholas, 1997). Exercise performance in sports that involve short bursts of intense exercise, such as sprinting or jumping, rely predominantly on the phosphagen and glycolytic energy system. Players rarely get sufficient time to recover completely and achieve full synthesis of the creatine phosphate (Spencer, Bishop, Dawson, & Goodman, 2005). Hence, the ability of the players to continue to produce high intensity efforts depends on the efficiency of the removal substance produced in the sprint, which inhibits peak performance (Wadley & Le Rossignol, 1998).

Laboratory research on the anaerobic performance of rugby players have largely focused on cycle ergometry or treadmill sprinting of short (<10 seconds) to moderate (30 to 40 seconds) duration to quantify players abilities (Maud, 1983; Quarrie & Wilson, 2000; Rigg & Reilly,

1988; Ueno, Watai, & Ishii, 1988). Forwards produce higher absolute peak and mean power outputs across a range of 7 to 40 seconds in comparison with backs (Maud, 1983; Rigg & Reilly, 1988; Ueno et al., 1988). When these results are expressed relative to bodyweight, the results are similar or slightly favour the backs over the forwards (Maud, 1983). Although the cycle ergometer is the most commonly used laboratory procedure for estimating an athlete's anaerobic power, most individuals may not have access to facilities or expertise to undertake such a test.

A more practical test may involve repeated sprint ability (Duthie et al., 2003). The repeated effort test protocol measures the ability of the players to resist fatigue while enduring similar demands, with respect to time and distance of sprint, as experienced in a game situation (Jenkins & Reaburn, 2000). Numerous exercise protocols have been used to investigate repeat sprint ability with differences in sprint duration (6 to 10 seconds), number of sprint repetitions (10 to 15), distance (30 to 40m) and recovery duration (30 to 60 seconds) (Dawson, Fitzsimmons, & Ward, 1993; Spencer et al., 2005). For repeat sprint ability to be relevant to performance in field-based team sports, the test variables need to be specific to the movement patterns (Spencer et al., 2005).

The five meter repeat sprint test (5-m RSP) measures the ability to resist fatigue during repeated short bouts of sprinting and was designed to test match-related fitness in a number of sports characterized by intermittent short duration high intensity bouts of activity, including rugby, field hockey, soccer and Gaelic football (Durandt, Tee, Prim, & Lambert, 2006). Hence, analysis of factors that influence the performance in the 5-m RSP have practical

implication for players, coaches and sport scientists. The 5-m multiple shuttle repeat sprint test (5-m RST) adopted by Welsh Rugby Union and modified by the Sport Science Institute of South Africa is used to determine player's match-related fitness (Boddington, Lambert, Gibson, & Noakes, 2001). The test consists of six 30 seconds repeat sprint bouts, interspersed with 35 seconds rest period. The participants performed 6 repeat shuttles of this protocol with a 35-second rest between bouts. The peak distance (greatest distance covered during a 30s shuttle), total distance (the total distance covered during the 6 x 30s shuttles), delta distance (the difference between the longest and shortest shuttle distance and fatigue index are recorded (Boddington et al., 2001). Factors determining success in the 5-m RST are multifaceted, and performance is best predicted by a combination of factors including body mass, strength and aerobic fitness. To cover a total distance in excess of 750m for the 5-m RST requires good basic speed, the ability to run at a pace and accelerate, and excellent aerobic system for a rapid recovery between runs (Hawley & Burke, 1998). Even though deemed important by rugby researchers, there is limited normative data on rugby players.

2.5 CHANGES IN PHYSICAL FITNESS OF OVER A COMPETITION SEASON

Professional athletes perform concurrent physical and technical training throughout the season in an attempt to elicit gains in many physical attributes required for optimal performance (Argus, Gill, Keogh, Hopkins & Beaven, 2009).. Physical fitness can provide a coach and the sport scientist with an objective and reproducible means of assessing an athlete/players training status, physical strengths and performance capabilities (O'Gorman, Hunter, McDonnacha, & Kirwan, 2000). Information gathered from these tests can assist the coaching

staff with regards to selection and making appropriate adjustments to an individual's training program.

2.5.1 Body Composition

In team sports such as rugby, hockey and soccer, body composition plays an important role in individual performance because excess body fat may influence speed, power and endurance. A number of investigations suggest that females participating in team sports report desirable changes in body composition (reduction in percentage body fat or skinfold thickness and or increase in lean muscle mass) during rigorous pre-season conditioning (Astorino, Tam, Rietschel, Johnson & Freedman, 2004; Clark, Reed, Crouse & Armstrong, 2003) primarily due to a high training volume (Burke, Gollan, & Read, 1986). During a competition season, players experience a minimal change in body composition (Granados, et al., 2008) as training emphasis is on tactical preparation for the upcoming match and conditioning sessions are predominately of a high intensity but for a short duration (Burke et al., 1986).

2.5.2 Speed

A study by Holmyard and Hazeldine (1993) on international rugby players showed that the greatest improvements in sprint performance occurred during the pre-season and the first half of the competition. No additional studies on professional rugby players were found to support the above findings. This is in contrast to a study done on junior and senior rugby league players whereby there was no significant change in 10m and 40m times after a 14 week pre-season training program (Gabbett, 2006). The progressive increase in training volume and

insufficient rest prior to the sprint test could be the contributing factors for the non-positive result.

2.5.3 Muscle Strength

An investigation by Granados et al. (2004) on the changes in upper and lower body strength during a female competitive field hockey season, reported no changes in upper and lower body strength, although the athletes were stronger during pre-season and in-season compared with post-season. This is consistent with findings by Baker (2001b), whereby professional rugby league players maintained upper and lower body strength in both elite and amateur rugby league players throughout a competition season. It has been suggested that a lack of strength gains in experienced athletes could be due to their greater strength training background (Baker, 2001b; Baker & Newton, 2006), concurrent training (Kraemer et al., 2004) and a decrease in resistance training volume (Argus et al., 2009; Koutedakis, 1995)

2.5.4 Aerobic Fitness

National male rugby players may exhibit significant increase in aerobic fitness during the preparatory phase of the season (Holmyard & Hazeldine, 1993; Gabbett, 2005a; Tong & Mayes, 1995) and no significant changes in aerobic power in the later part of the season (Holmyard & Hazeldine, 1993; Gabbett, 2005a). However, it has also been suggested there is no significant change in aerobic fitness of college female field hockey players over the entire season Astorino et al., (2004). The improvement in the aerobic endurance of National

male rugby players may be associated with greater training volume during field conditioning sessions. the greater conditioning volume (Gabbett, 2005a).

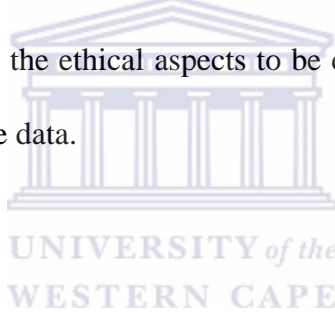
2.6 SUMMARY

Traditionally, the game of rugby union has been a male dominated sport. Acceptance of the female game by the International Rugby Board (IRB) has resulted in the emergence of a structured international competition being the World Cup. Rugby union is a contact sport in which players requires high levels of physical fitness which is a composite of aerobic and anaerobic endurance, muscle strength and power, speed and agility. With rugby union increasingly being played year round, a greater emphasis has being placed on the development and maintenance of physical fitness levels. Much research has been conducted with male rugby players, but very little with females. Therefore, the aim of this study is to contribute the knowledge of coaches by describing anthropometric and physical characteristics of an elite women's rugby union within a competition season.

CHAPTER THREE
METHODS AND PROCEDURES

3.1 INTRODUCTION

This chapter will outline the practicalities of the research employed and also discusses the research inventories and tests utilised to determine the outcome of this research study. Hence, the chapter commences with a detailed explanation of the research design adopted and of the participants recruited, then an explanation of the testing period, the description of the data collection process and procedures of each assessment included in the fitness test battery. The chapter concludes by describing the ethical aspects to be considered, as well as the statistical analysis to be used to analyse the data.



3.2 RESEARCH DESIGN

A quantitative approach was used in this study with the specific nature of the research being descriptive and comparative. The study was classified as descriptive as it aimed to achieve insight into the physical fitness of elite women's rugby players in South Africa over a competitive season.

3.3 PARTICIPANTS

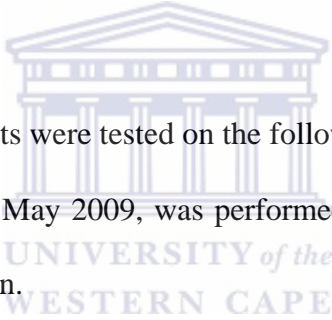
For the purpose of this study, 32 female rugby players selected for the South African Rugby High Performance Programme were recruited. These players were selected from the 2008 Inter-provincial competition by National Selectors appointed by the South African Rugby

Union. The players were sub-divided into the following positional categories: 17 forwards (five props, two hookers, four locks, six loose forwards) and 15 backs (nine inside backs and six outside backs). The forwards ages ranged from 19 to 37 years, while backs ages ranged from 19 to 34 years.

3.4 ASSESSMENT SCHEDULE

The 32 week season was from April 2009 to November 2009 and consisted of pre-season (from week 1 to 12) and in-season (from weeks 13 to 32) consisting of Provincial games and a four week overseas tour.

During the season, the participants were tested on the following three occasions:

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- The first test (T1) in May 2009, was performed two weeks after the beginning of the competition season.
 - The second test (T2) in July 2009, was performed at the middle of the competition season.
 - The third test (T3) in November 2009, was performed two weeks after the end of the Interprovincial League Finals, at which 20 of the players participated.

All the players involved in the study followed individual training programs based on the demands of their specific playing position.

3.5 DATA COLLECTION

The collection of physical fitness data occurred on three assessment periods during the season (pre-season, mid-season and post-season), of which coincided with the National training camps. All of the players were assessed on each test on the first day of each training camp.

On arrival at the training camp, players completed a detailed medical questionnaire and had a full medical examination by the team sport physician and musculo-skeletal screening by the physiotherapist. Players with medical conditions were excluded from participating in the physical assessment. Participants were familiarized with the testing protocol, although they had already been tested on several occasions for training program prescription purposes.

The participants were confirmed by the South African Institute for Drug Free Sport as not having taken any exogenous anabolic-androgenic steroids or other drugs or substances that could affect physical performance or hormonal balance. During the data collection process, assistants were used to help administer the testing. All of the assistants were qualified Biokineticist and also trained by the researcher prior to assisting in the physical evaluations.

3.6 TESTING PROTOCOL

The testing protocol consisted of anthropometric and physical measurements which were performed in the following order:

Anthropometric measurements

- Stature

- Body mass
- Skinfolds (biceps, triceps, subscapular, suprailiac, medial calf, front thigh and abdominal)

Physical measurements

- Flexibility (Sit and reach)
- Muscle Power (Vertical jump)
- Speed (10m and 40m sprint)
- Muscle strength test (1 RM Bench Press)
- Muscle endurance tests (pull-ups and 1 min push-ups)
- Aerobic endurance (Multi-stage shuttle run)

For measurements to be made as quickly and efficiently as possible, the participants were requested to present themselves in shorts, sports bra and without shoes for ease of access to all measurement sites.

3.6.1 Stature

The stature of each player was measured to the nearest 0.1 centimeter using a stadiometer (Seca Model 708, Seca Germany). The free standing technique was used for measuring stature as reported by Norton, Marfell-Jones, Whittingham, Kerk, Carter, Saddington, & Gore (2000). The player stood with her feet together and heels, buttocks, and upper part of the back touching the stadiometer. The head was in a Frankfort plane whereby the orbital was placed in the horizontal plane with the tragion. The participant was instructed to look straight ahead,

breathe in and stand as tall as possible then the platform of the stadiometer was lowered until it made firm contact with the vertex (top of the head).

3.6.2 Body Mass

Body mass was measured using a calibrated scale (Seca Model 708, Seca Hamburg, Germany) with accuracy to the nearest 0.1 kg. The players were weighed on a scale located on a hard and level surface. Participants were requested to remove their footwear and stand erect and still on the scale until the measurement was recorded.

3.6.3 Skinfolds

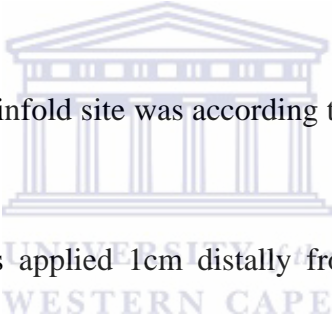
As an estimate of adiposity, skinfold thickness was measured at seven sites using a Harpenden skinfold calipers. The biceps, triceps, subscapular, suprailiac, medial calf, front thigh and abdominal were the sites selected (Ross & Marfell-Jones, 1991).

The skinfold-caliper reading was the measurement of the compressed thickness of a double layer of skin and the underlying subcutaneous tissue, which is assumed to be adipose tissue. The skinfold thickness was measured by grasping a fold of skin and the underlying subcutaneous tissue between the thumb and forefinger, 1 - 2 cm above the site that is to be measured. The fold was pulled away from the underlying muscle and the jaws of the calipers are placed on either side of the site, at a depth of approximately 1 cm. The skinfold was held firmly throughout the application of the caliper and the reading was taken when the needle became steady after the full pressure of the caliper jaws had been applied. The calipers were

held at 90 degrees to the surface of the skinfold site at all times. All measurements were recorded on the player's right side, irrespective of their dominant side. All measurements, according to specification, were taken three times, unless the first two measurements were the same. The median value was used if three measurements were taken. A complete data set was obtained before repeating the measurements for the second and the third time.

Thereafter, body fat was estimated as the sum of seven skinfolds (mm) and as a percentage of body mass according to Durnin and Womersley (1974). Body fat determination from skinfolds has a reliability ranging between 0.70 and 0.90 (American College of Sports Medicine, 2000).

The exact positioning of each skinfold site was according to the procedures described by Ross and Marfell-Jones (1991).

- 
- **Biceps:** The caliper was applied 1cm distally from the vertical fold raised by the tester's left thumb and index finger, at the marked mid-acromiale-radiale line on the anterior surface of the participant's right arm.
 - **Triceps:** The caliper was applied 1 cm distally from the vertical fold raised by the tester's left thumb and index finger, at the marked mid-acromiale-radiale line on the posterior surface of the participant's right arm.
 - **Subscapular:** The caliper was applied 1 cm distally from the skin fold raised by the tester's left thumb and index finger, in a position oblique to the inferior angle of the participant's scapula along the natural fold.
 - **Suprailiac:** The caliper was applied 1cm anteriorly from the oblique skin fold raised by the tester's left thumb and index finger, at the intersection of the border of the

participant's ilium (a horizontal line projected from the iliac crest mark) and a line from the spine to the anterior axillary border (armpit). The fold follows the natural fold lines running medially downwards at about a 45° angle from horizontal.

- **Medial Calf:** The caliper was applied 1cm distally to the left thumb and index finger, raising a vertical fold on the relaxed medial right calf at the estimated level of the greatest circumference.
- **Front Thigh:** The caliper was applied 1 cm distally to the skin fold raised by the tester's left thumb and index finger, on the anterior surface of the participant's right thigh, along the long axis of the femur, with the leg is flexed at 90° at the knee by placing the foot on a box. The mid-thigh position for this measure was measured as halfway between the inguinal crease and the mid-point of the anterior patella. In those participants where the fold was difficult to raise, the calipers were pushed to the muscle level and slightly retracted with the participant assisting by supporting the underside of the leg.
- **Abdominal:** The caliper was applied 1 cm inferiorly to the vertical fold raised by the tester's left thumb and index finger, on the participant's right side 5 cm lateral to, and at the level of, the omphalion (midpoint of the navel).

3.6.4 Flexibility

- **Sit-and-reach test**

The purpose of test was to determine the joint range of motion and flexibility of the muscles around the hip joint using a sit and reach box with the “zero” point being 26 cm. The sit-and-reach test was performed according to Ellis et al. (2000). A participant sat on the floor with

knees extended (straight), and bare feet against the vertical edge of the sit-and-reach box. The participant then flexed (bent) at the hip and reached forward, with one hand placed over the top of the other with palms facing down, fingertips overlapping and elbows straight. The participant was encouraged to lean forward as far as possible, sliding her hands along the ruler of the sit and reach box, exhaling gently as she moved. Full stretch was held for at least 2 seconds to avoid the effect of bouncing. The furthest reach of the middle fingertips was recorded. The best of three attempts was recorded to the nearest 0.5 cm. The sit-and-reach test has a test-retest reliability of 0.89 (Johnson & Nelson, 1979).

3.6.5 Power

- **Vertical Jump**

Explosive leg power was tested using the Vertec Jump Tester (Sports Imports, Columbus, OH). Vertical jump height was measured according to Logan et al. (2000). Participants were requested to stand with feet flat on the ground, extend their dominant arm and hand against the wall for the tester to measure the distance from the floor to the fingertips of the outstretched dominant arm. Thereafter each participant was instructed to jump as high as possible using a vertical countermovement with an arm swing and touch the highest vane possible of the Vertec Jump tester with their dominant arm. The depth and speed of knee flexion during the countermovement was self-determined. The take-off was from two feet, with no preparatory steps or shuffling. Vertical jump height was calculated as the difference between the standing reach height and the highest vane touched during the jump from three attempts. Vertical jump height was measured to the nearest half inch on the Vertec and then converted to centimeters.

3.6.6 Speed

- **10m and 40m speed**

The acceleration and maximum velocity of players over 10 meters and 40 metres, respectively was evaluated using an electronic sprint timer with photo-electric sensors (Newtest Oy, Oulu, Finland). The speed test was measured according to Durandt et al. (2006). Players underwent a 10 minute standardised warm-up (which consisted of low intensity running, a standardized stretching routine, some moderate to high intensity striding and acceleration sprints) to familiarise themselves with the intensity of the test. An electronic sprint timer was set at chest height and positioned at 10m and 40m intervals from the start line. The starting position was standardized for all players. The players started in a two point crouch position and with the front foot approximately 30cm from the start line, after which they sprinted maximally for 40m through the sensors, with the fastest 10m and 40m times for each player being recorded. Each player completed two maximal efforts separated by a 5-10 minute recovery period. They were instructed to run as quickly as possible over 40m distance and to not slow down before the finish line. Running velocity was measured to the nearest 0.01s, with the fastest 20m and 40m times from the two trials being recorded as their sprint scores.

3.6.7 Muscle Strength Test

- **1 RM bench press**

The 1RM bench press test is a standard test of upper body strength. The test reflects the maximum load that an individual can press once from the chest (Durandt et al., 2006). The player lay supine on the bench press machine with feet on the bench with hips and shoulders in contact with the bench. The player started the test by lowering the 20 kg Olympic bar in a

controlled manner to the center of the chest, touching the chest lightly and then extending upwards until the arms were in a fully locked position. A lift was disqualified if the player raised her buttocks off the bench during the movement, bounced the bar off their chest, extended her arms unevenly, or if the spotter had to assist the lifter.

A light warm-up set of 10 repetitions was performed using the 20 kg Olympic bar prior to testing. This was followed by 6-8 repetitions at approximately 30-40% of the estimated 1RM, based on the player's previous resistance training experience. A 2-minute stretching routine for the shoulders and chest was completed; thereafter six repetitions at 60% of the estimated 1RM were performed. The player was required to rest for 3-4 minutes before attempting their 1RM. If the 1RM was successful, the resistance was increased by 2.5% to 5% increments after a 5 minute rest period before attempting the next bench press. The final weight lifted successfully was recorded as the absolute 1RM in kilograms, and the relative bench press was calculated as 1RM/ (body weight). It has been demonstrated that the test-retest reliability of 1RM measurements amongst experienced male and female lifters ranges from 0.92 to 0.98 (Logan et al., 2000).

3.6.8 Muscle Endurance Test

- **Underhand pull-ups**

The pull-up test is widely used to assess body mass-related dynamic upper body muscular endurance. The underhand pull-up test was performed according to Durandt et al. (2006). An underhand grip was used with hands placed 10-15 cm apart. The player started from a hanging position (arms fully extended). The player's chin was required to reach above and touch the

bar on the ascent with arms fully extending (straightening) on the descent. A repetition was not considered valid if these requirements were not fulfilled. Being a maximal effort test, the player continued until she could no longer lift her chin to the bar. The maximal amount of valid pull-ups completed was from an extended arm position to where the chin touches the bar and back down. The reliability of the pull-up test is 0.95 (Vanderburgh & Edmonds, 1997).

- **1 min push-up**

The player assumed a prone position with her hands on the floor, shoulder width apart, elbows fully extended and a training cone placed below the chest. Keeping the back and body straight, the player descended until her chin touched the training cone and then ascend until elbows are fully extended (straightened). If the player did not adhere to these specifications, the repetition was not counted. The test was scored as the number of push-up correctly performed in one minute. Players were allowed to rest within the one minute period, in the extended arm position. The number of push-ups performed in one minute was recorded as their score (Jackson, Fromme, Plitt, & Mercer, 1994).

3.6.9 Maximal Aerobic Power

- **Multiple stage shuttle run test**

The purpose of the test is to estimate the aerobic endurance. The progressive multistage shuttle run was based on the protocol of Léger and Lambert (1982). Players were required to run back and forth on a 20m marked floor according to the pace determined by a pre-recorded sound signal. If they failed to complete the 20m distance in the required time for two consecutive laps they were withdrawn from the test. Players were allowed to voluntarily

withdraw from the test if they are unable to maintain the required pace. The score was recorded as the number of the last completed lap and the maximal aerobic power was then predicted (Léger & Lambert, 1982). The reliability and validity of measurement for the multistage fitness test is 0.95 and 0.90, respectively (Léger & Lambert, 1982).

3.7 STATISTICAL ANALYSIS

Descriptive statistics was used to analyse the test results and were expressed as means and standard deviations. Double entry was used to ensure accuracy of the data entry.

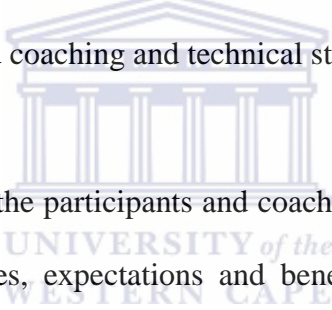
The main aim of this study was to determine whether there were differences in the physical condition (as measured by several different variables) of women (high-level) rugby players at three different points in the season: pre-season, mid-season, and post-season. A secondary aim was to know if there were differences between playing positions with regards to physical fitness. Hence, statistically, the model that was used for analysis was a two-factor analysis of variance (ANOVA) with one factor (position) being a between-participants factor with two levels and the second factor (test or time) being a within-participants factor with three levels. The responses within participants were dependent and the dependency was modeled using an unstructured correlation model.

The software SAS v9 (SAS Institute Inc., Cary, NC, USA) was used for analysis. Specifically the MIXED procedure was used for the analysis. An interaction term for Position and Test was included in the model. Pairwise comparisons were done using Least Squares Means. Due to the large number of tests being conducted, a more stringent level of significance of

0.01 was used rather than 0.05. For each outcome variable the residuals from the analysis of variance model were examined for outliers. Standardized residuals greater than 2.5 were noted and the analysis was re-run with outliers excluded. In most cases the results were not noticeably different when the outliers were excluded. The residuals were approximately normally distributed.

3.8 ETHICAL CONSIDERATIONS

Ethical clearance and permission was sought from the CHS and Senate Research Committees of the University of the Western Cape, The South African Rugby Union, and 2009-2010 Springbok women's rugby squad coaching and technical staff.



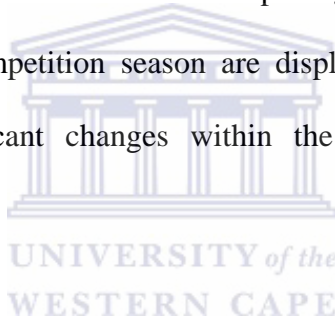
On arrival at the training camp, the participants and coaching staff were given an information package detailing the procedures, expectations and benefits for participating in the study (Appendix A). Prior to the fitness testing, players received a verbal briefing on the nature and content of the research (Appendix A). A written consent from each player was requested (Appendix B) and they were informed of their right to withdraw at any time from the study without prejudice. They were given the assurance that all data gathered in the data sheet (Appendix C) during their participation in the research study would be kept confidential and that their names will not be used in any publication that may arise from this research. Each participant had access to their own physical fitness results for their personal development.

CHAPTER FOUR

RESULTS

4.1 INTRODUCTION

This chapter describes the positional physical fitness results at each of the three testing periods over the competitive season. Measurement results of the tests are reported in terms of the mean scores achieved at each of the three different testing periods in the season. The descriptive data for the sub groupings (forwards and backs) at the three testing sessions are all contained in a table in Appendix D. The results depicting comparisons and changes for the positional groups over the competition season are displayed graphically. In addition, this chapter highlights the significant changes within the forwards and backs during the experimental period.

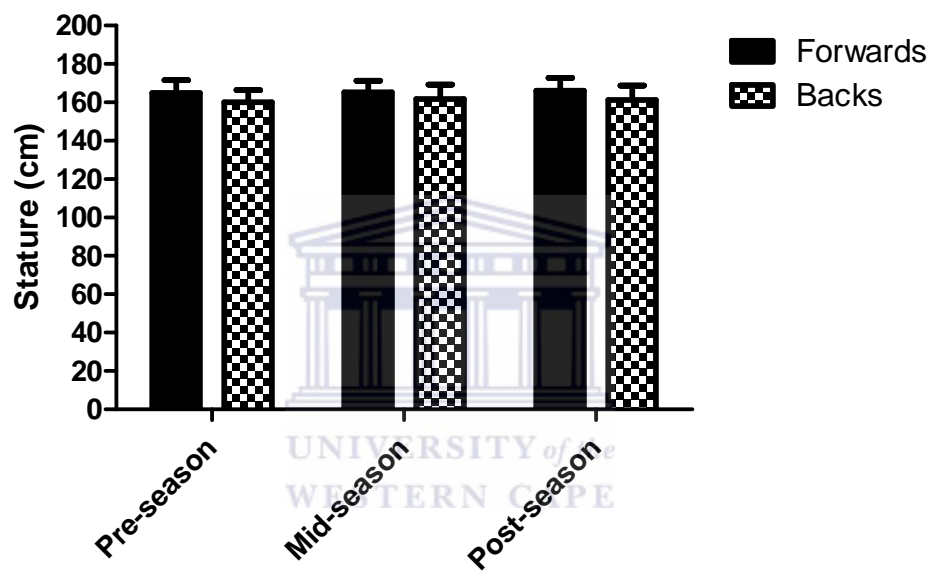


4.2 ANTHROPOMETRIC MEASUREMENTS

The anthropometric measurements conducted during the study consisted of body mass and body composition expressed as the sum of seven skinfolds, from which percentage body fat was calculated.

4.2.1 Stature

The positional stature results of the forwards and backs for the three testing sessions are outlined in Figure 2. There were no significant differences or changes in stature between or within the positional groups during three testing sessions. Although not statistically significant



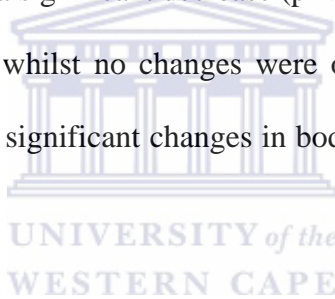
* significant at $p < 0.01$

Figure 2: Mean Stature (cm) by position over the three test sessions

the descriptive analysis indicated that forwards (164.9 ± 6.68 cm) in comparison were taller than backs (160.1 ± 6.39 cm).

4.2.2 Body Mass

The body mass comparisons between positional groups as well as changes within each position are presented in Figure 3. These data indicate that for each testing session, forwards had a significantly higher body mass than backs ($p < 0.01$). The highest body mass for backs (62.97 ± 5.96 kg) and forwards (79.51 ± 14.19 kg) were reported at pre-season and post-season, respectively. There was a significant decrease ($p < 0.01$) in body mass within the backs from pre-season to midseason, whilst no changes were observed from mid-season to post-season. However, there were no significant changes in body mass within forwards throughout the season.



4.2.3 Sum of Skinfolds

The data for the sum of the seven skinfolds between forwards and backs, and the mean score progressions within forwards and backs are reflected in Figure 4. The measured difference in skinfold thickness between forwards and backs in pre-season and mid-season, was 35.8 mm and 42.0 mm, respectively ($p < 0.01$). No significant differences were observed between backs and forwards at the end of the season. Within the forwards, skinfold thickness increased significantly between pre-season and the end of the season ($p < 0.01$), but no significant differences were reported from mid-season onwards. With respect to the backs, no significant changes were noted throughout the competition season.

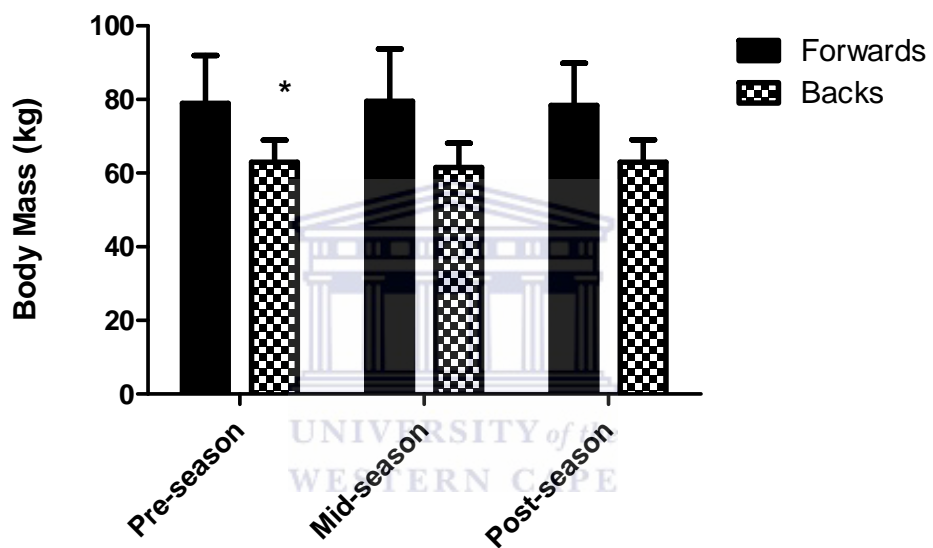
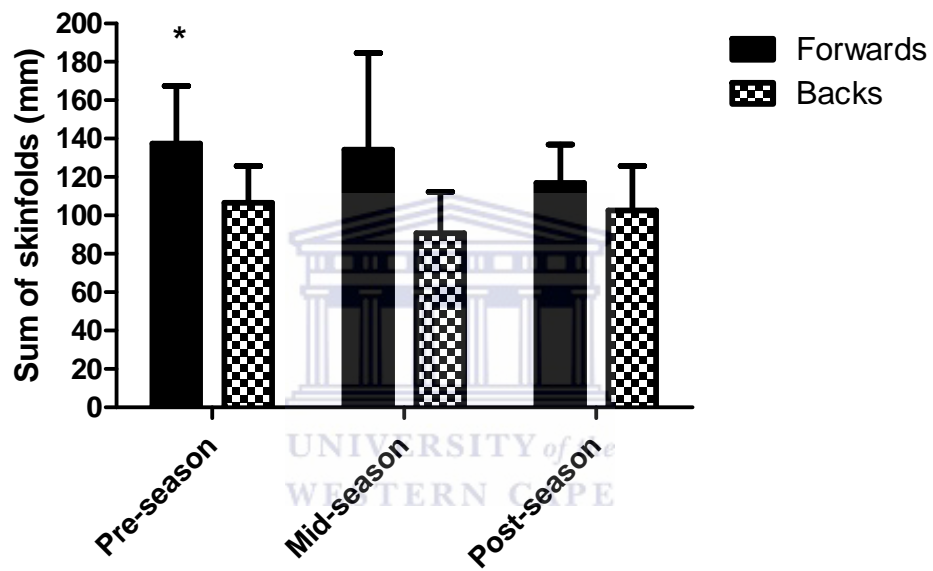


Figure 3: Mean body mass (kg) by position over the three test sessions



* significant at $p < 0.01$

Figure 4: Mean sum of seven skinfolds (mm) by position over three testing sessions

4.2.4 Percentage Body Fat

The positional body fat percentage results for the three testing sessions are outlined in Figure 5. Forwards had a greater body fat percentage than backs at pre-season ($p < 0.01$) and mid-season ($p < 0.01$) but no meaningful differences were reported post-season. Within backs, percentage body fat decreased significantly ($p < 0.01$) by 1.6% from pre-season (26.11 ± 3.81 %) to mid-season (23.81 ± 3.28 %) and increased by 2.9% ($p < 0.01$) from mid-season (23.81 ± 3.28 %) to post-season (27.33 ± 2.76 %). In addition, significant decreases ($p < 0.01$) of 2.24% from pre-season (30.81 ± 4.56 %) to mid-season (29.10 ± 5.60 %), and of 1.76 % from pre-season (30.81 ± 4.56 %) to post-season (29.24 ± 2.93) were observed within the forwards

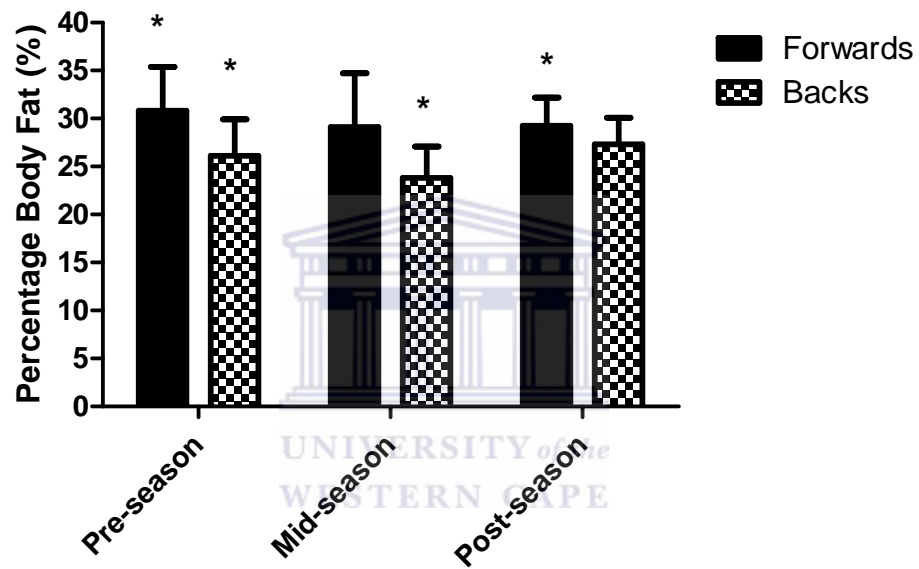
4.3 PHYSICAL PERFORMANCE CHARACTERISTICS

The physical performance characteristics tests included flexibility, explosive leg power, speed (10m and 40m), upper strength (measured by means of bench press and pull-up tests), upper body muscular endurance and aerobic endurance.

4.3.1 Flexibility

- Sit-and-Reach Test

The mean scores illustrated in Figure 6 represent the changes within positions and over the competition season. The sit-and-reach test did not show any significant differences in flexibility between or within backs and forwards throughout the experimental period.



* significant at $p < 0.01$

Figure 5: Mean percentage body fat (%) by position over the three testing sessions

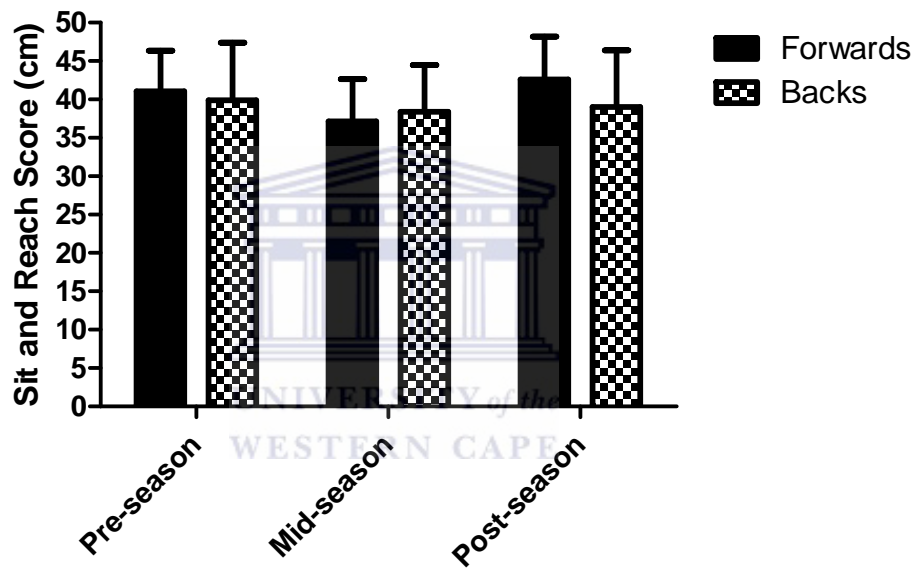


Figure 6: Mean Sit and Reach Score (cm) by position over the three testing sessions

Within forwards, there was a small decrease of 3.94 cm from pre-season to mid-season and a small increase of 5.45 cm from mid-season to post-season, with greatest flexibility being observed at post-season.

4.3.2 Muscle Power

- Vertical Jump

The vertical jump results for each testing session between and within positional groups are shown in Figure 7. The results indicate that backs produced a significantly ($p < 0.01$) superior vertical jump performance compared with forwards at pre-season (44.35 ± 5.06 cm vs. 37.50 ± 5.36 cm), mid-season (44.60 ± 5.23 cm vs. 38.40 ± 5.03 cm) and post-season (46.25 ± 2.92 cm vs. 39.25 ± 5.69 cm). Although the explosive leg power results were not significantly different within forwards and backs, there were progressive increases in vertical jumping height throughout competitive season for both positional groups.

4.3.3 Speed

- 10m sprint

The 10-metre sprint times achieved at the three testing sessions are depicted in Figure 8. Although backs were faster than forwards throughout the season, the difference was significant ($p < 0.01$) at pre-season and with the fastest sprint times recorded during post-season testing. Both positional groups were significantly slower in mid-season than in pre-season and significantly faster at end of the season than mid-season. In addition, forwards sprint times at the end of the season were significantly faster than pre-season.

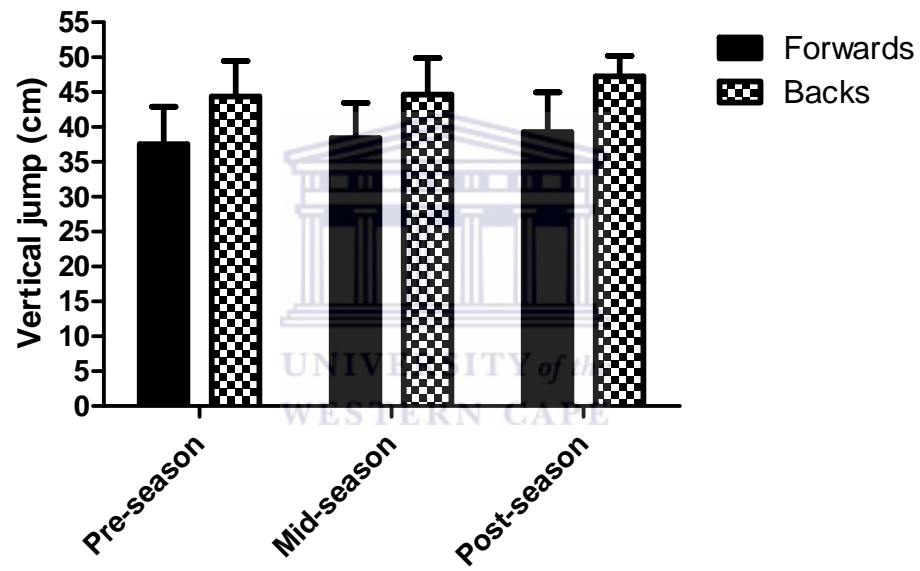
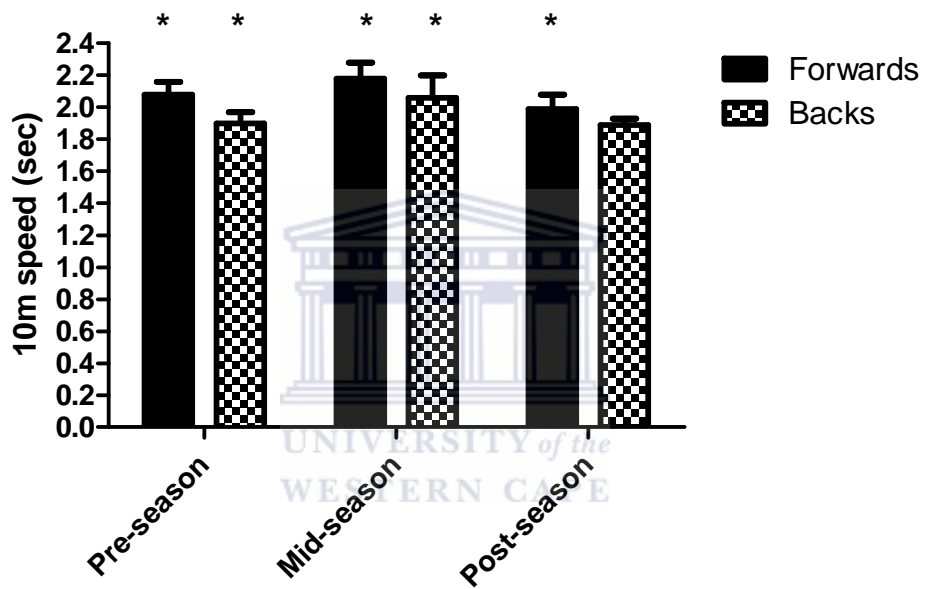


Figure 7: Mean vertical jump (cm) by position over the three testing sessions



* significant at $p < 0.01$

Figure 8: Mean 10m speed (sec) by position over the three test sessions

- 40m sprint

The mean 40m sprint results for forwards and backs for the three testing sessions during the study are depicted in Figure 9. Unlike the 10m sprint times, the backs were significantly faster than forwards over 40m throughout the season. As in the 10m sprint, backs are significantly slower ($p < 0.01$) at mid-season as compared pre-season (6.13 ± 0.78 sec vs. 5.96 ± 0.19 sec), then significantly faster ($p < 0.01$) from mid-season to post-season (6.13 ± 0.78 sec vs. 5.90 ± 0.07 sec). The forwards, maximum sprint times were non-significant between pre-season (6.51 ± 0.31 s) and mid-season (6.63 ± 0.16 s) but then a significant improvement ($p < 0.01$) was seen from mid-season (6.63 ± 0.16 s) to post-season (6.41 ± 0.29 s) and when comparing pre-season and post-season sprint times.

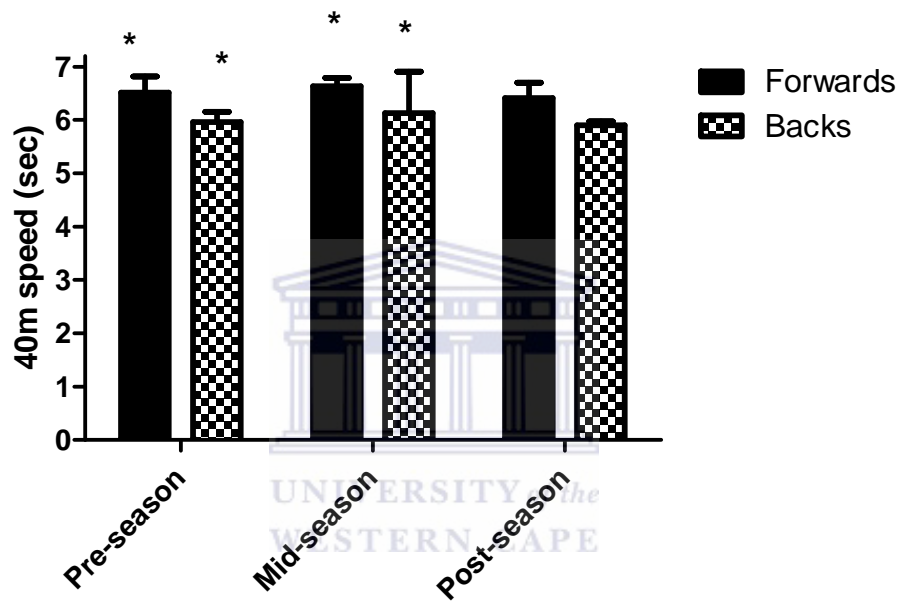


4.3.4 Muscle Strength

The bench press and pull-up tests were conducted to examine the upper body strength characteristics of the participants at the three testing sessions over the competitive season. The 1-RM bench press measurements were used to investigate differences in absolute and ratio scaled strength.

- Absolute Strength Results

Displayed graphically in Figure 10 are changes in 1-RM bench press data according to positional groups. There was no significant difference between forwards and backs at any period throughout the season.



* significant at $p < 0.01$

Figure 9: Mean 40m speed (sec) by position over the three test sessions

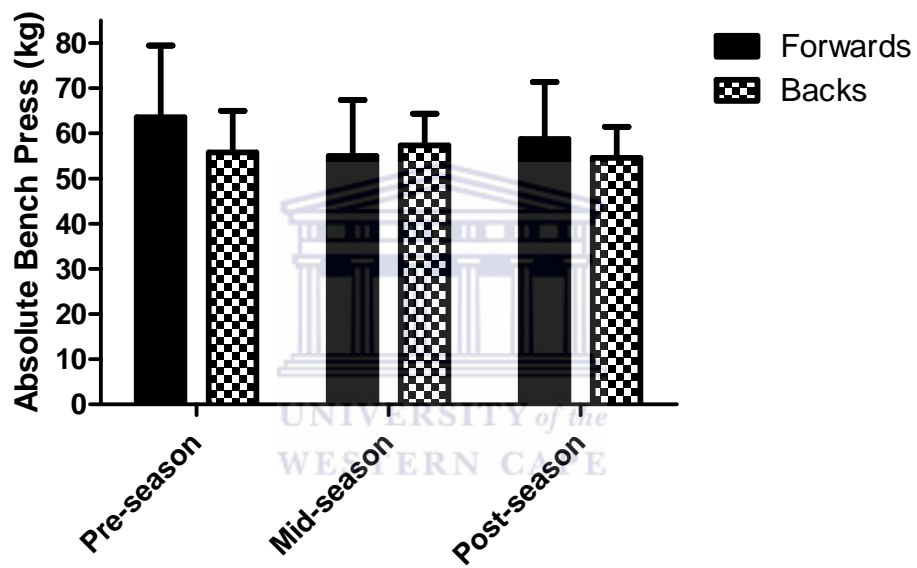


Figure 10: Mean Absolute Bench Press (kg) by position over the three test sessions

No difference was apparent within positional groups from pre-season to post-season. However, the backs and forwards were strongest at mid-season (57.33 ± 7.04 kg) and pre-season (63.57 ± 15.86 kg), respectively.

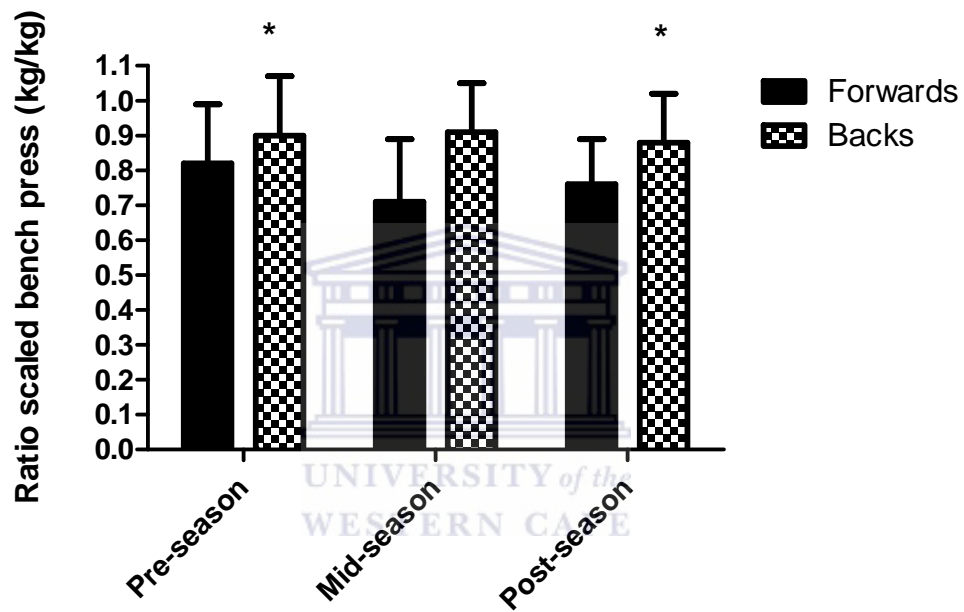
- Ratio scaled strength

When normalizing the 1-RM strength results using ratio scaling, significant differences ($p < 0.05$) between backs and forwards (0.91 ± 0.14 vs. 0.71 ± 0.18) were only observed in mid-season. As with absolute strength, no significant changes were observed in the scaled strength ratio within positional groups from the start to the end of the competition season (Figure 11).



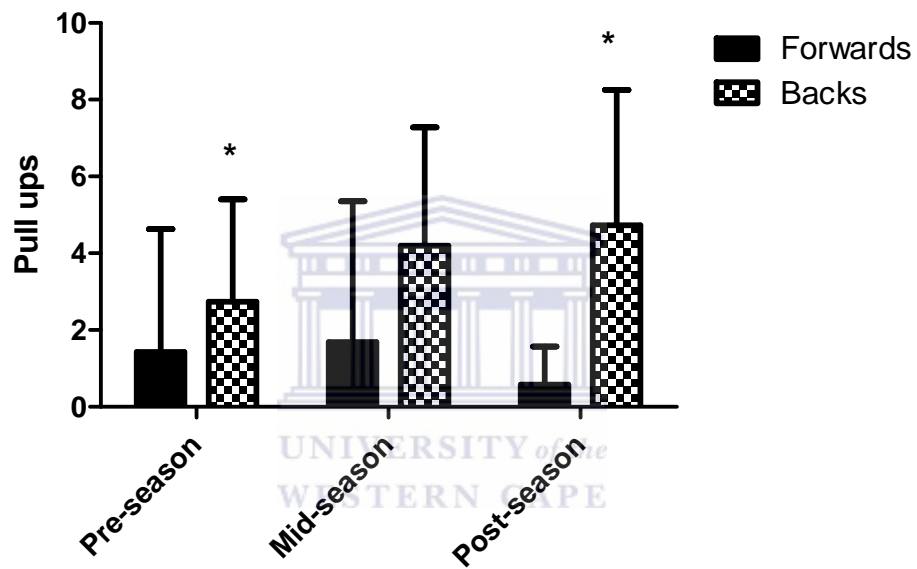
- Pull-ups

Mean pull-up testing results are presented in Figure 12. As with the 1-RM bench press test, non-significant differences were observed between forwards and backs at all three testing periods. On the exclusion of large residuals (same participant at pre-season and mid-season, which performed 12 and 13 pull ups, respectively), the analysis identified a significant difference ($p < 0.01$) between forwards and backs at pre-season, mid-season and post-season. Within the backs, a significant increase in the number of completed pull-ups were observed from pre-season to mid-season and between pre-season and post-season ($p < 0.01$). No significant difference was noted within forwards and even when the analysis was re-run with outliers excluded during the experimental period.



* significant at $p < 0.01$

Figure 11: Mean ratio scaled Bench Press by position over the three test sessions



* significant at $p < 0.01$

Figure 12: Mean number of pull-ups by position over the three test sessions

4.3.5 Muscle Endurance

- 1 minute push-ups

The 1 minute push-up test data illustrated in Figure 13 indicate that backs completed a greater number of push-ups at all three testing sessions but with significant positional difference only observed at the pre-season. Significant improvements in upper body muscle endurance for both backs and forwards were reported between pre-season and mid-season and as well as pre-season and post-season ($p < 0.01$).

4.3.6 Aerobic Endurance

- Multi-Stage shuttle run

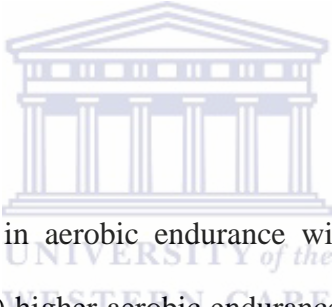
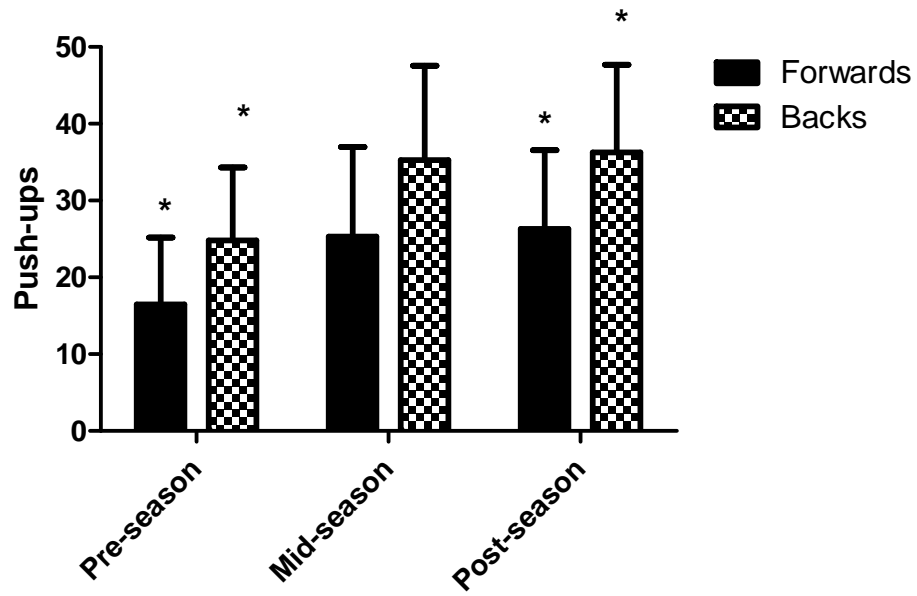
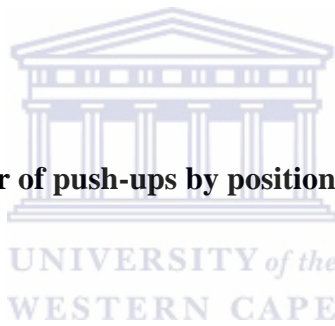


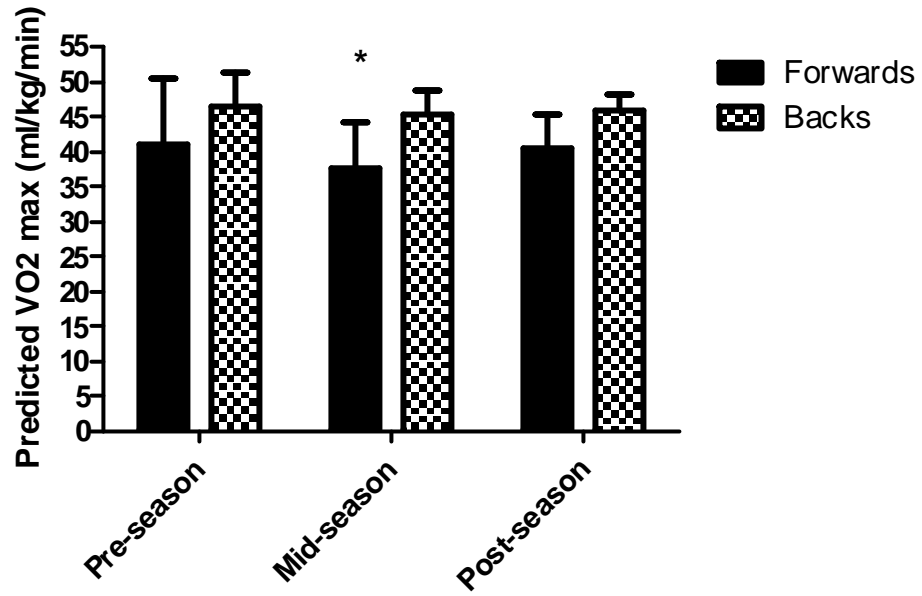
Figure 14 depicts the changes in aerobic endurance within each positional group. Backs achieved a significantly ($p < 0.01$) higher aerobic endurance score when compared to forwards at mid-season ($45.28 \pm 3.4 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ vs. $37.76 \pm 6.29 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) and end-of-season testing ($46.03 \pm 2.21 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ vs. $40.58 \pm 4.79 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$), and with the mean highest $\text{VO}_{2\text{max}}$ score at pre-season for both backs ($46.49 \pm 4.75 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) and forwards ($41.12 \pm 9.28 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$). An assessment of the forwards aerobic endurance over the course of the season, showed a marginal decrease from pre-season to mid-season then a significant improvement from mid-season to the end of season ($p < 0.01$). In contrast, no significant differences were observed within backs throughout the season.



* significant at $p < 0.01$

Figure 2: Mean number of push-ups by position over the three test sessions





* significant at $p < 0.01$

Figure 3: Mean predicted VO_2 max ($\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) by position over the three sessions test



CHAPTER 5

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter will include a discussion of the changes in physical fitness characteristics of the South African Elite women's rugby players over a competition season. A two-factor analysis of variance (ANOVA) is used to examine differences in anthropometric and physical characteristics between and within playing positions over the competition season with data derived from forwards and backs at pre-season, mid-season and post-season. Where applicable, possible explanations are provided to offer insight as to why some variables are statistically significant ($p < 0.01$), while others are not. Conclusions will be drawn in accordance with the aims and findings then recommendations are made for further research.

5.2 ANTHROPOMETRIC CHARACTERISTICS

The anthropometric measurements assessed were body mass, percentage body fat, and sum of skinfolds at the three testing sessions over the duration of the competition season.

5.2.1 Stature

The stature of the South African women's rugby union players was shorter than those reported in senior club and international female rugby union players (Kirby & Reilly, 1993; Quarie et

al., 1995; Schick et al., 2008). However, in contrast to the patterns observed by Schick et al., 2008, but consistent with the findings of several other anthropometric studies (Kirby & Reilly, 1993; Quarrie et al., 1995; Sedlock et al., 1988), there was no significant difference in stature between forwards and backs.

5.2.2 Body Mass

The results obtained from the study show that forwards are significantly ($p < 0.01$) heavier than backs. These current findings concur with previous observations on elite, amateur and adolescent male and females rugby players that demonstrated that rugby forwards possess greater body mass than backs at various playing levels (Durandt et al., 2006; Duthie et al., 2006a; Gabbett, 2007; Kirby & Reilly, 1993; Meir & Halliday, 2005; Quarrie & Hopkins, 2007; Quarrie et al., 1995; Schick et al., 2008). The difference in body mass may be accounted for by skeletal factors, since forwards have a greater limb girths and bone diameters (Kirby & Reilly, 1993; Quarrie et al., 1995).

The introduction of professionalism and law changes in rugby union led to an increased emphasis on body mass as a greater body mass confers an advantage in the contact phases due to greater momentum players are able to generate (Quarrie & Hopkins, 2007). When comparing the participants positional body mass to other relevant literature, SA elite women's forwards had similar body mass to their international counterparts (Schick et al., 2006) which is the equivalence of a U16 SA male rugby hooker (Durandt et al., 2006). However, the South African Elite Women's backs weighed less than the teams at the 2006 Women's Rugby World

Cup (Schick et al., 2006). Attention to nutrition and increased focus on weight training may assist to make changes in body mass so overcome possible disadvantages in contact phases.

When comparing body mass across the season, the backs' body mass decreased significantly ($p < 0.01$) by 1.5 kg from pre-season to mid-season and then returned to pre-season weight by post-season testing, whilst the forwards showed minimal, non-significant fluctuations in body mass over the competitive season. Body mass is likely to change during the course of a competitive season as a result of periodised training, injury breaks, habitual patterns such as diet and drinking which may lead to energy imbalances thus resulting in weight loss or gain (Burke et al., 1986). The decrease in body mass for the backs during the pre-season could be due to caloric restriction in combination with high levels of aerobic and anaerobic endurance and resistance training performed during this period coupled with training matches. In general, rugby players with lower skinfold typically have an increased body mass as a result of heavy training loads whilst players with higher skinfolds often exhibit a decrease in body mass (Reilly & Doran, 2001). Hence, researchers and conditioning coaches' need the collective measurement of body mass and skinfolds in determining the influence of body composition change in strength based sports such as rugby.

5.2.3 Sum of Skinfolds

In the current study, forwards had a substantially greater skinfold thickness than backs in pre-season and mid-season but no marked difference at post-season. This greater sum of skinfolds

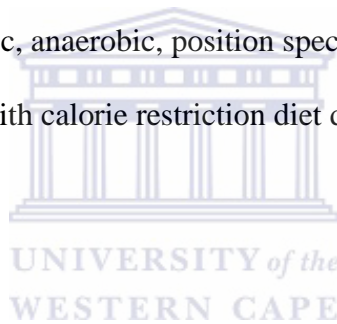
in forwards is reflected as additional body fat which may serve as a protective buffer in contact and collision situations (Duthie, 2006).

Body fat values for the backs are similar to other team sports such as field hockey, soccer and touch rugby (Duthie, Pyne & Hooper, 2003). When comparing the skinfold thickness to other female team sport players, the SA elite female rugby backs (106.66 ± 19.12 mm), have a greater sum of 7 skinfold thickness in comparison with soccer (95.9 ± 23.0 mm) (Tumility, 2000), hockey (68.2 ± 13.6 mm) (Lawrence & Polgaze, 2000) and touch rugby players (71.3 ± 11.85 mm) (O'Connor, 1997), but lower sum of skinfold values when compared with international female rugby league backs (114.8 ± 20.2 mm) (Gabbett, 2007). Reilly and Doran (2001), indicated that where extra mass consists of fat rather than lean tissue, the power-to-weight ratio is reduced, energy expenditure during movement is increased, horizontal and vertical acceleration are diminished which suggests that the South African backs could benefit from a loss of subcutaneous fat, thereby improving their power and speed which can have a positive influence on outcomes during closely contested matches.

In rugby, desirable changes in body composition (increases in lean mass and/or decrease in skinfolds) occur primarily during preparation of competition when training volume is high (Duthie et al., 2006a; Holmyard & Hazeldine, 1993; Gabbett, 2005a, 2005b; Tong & Mayes, 1995). Furthermore, skinfold thickness and or lean mass was maintained throughout the competitive phase of the season when training loads were reduced, match loads and injuries were at their highest (Gabbett, 2005a; Duthie et al., 2006a). Despite a significant decrease ($p < 0.01$) in body mass at the beginning of the season, there was no variation in the backs

skinfold thickness throughout the season. With the greater mobility of rugby players associated with body fat levels and higher lean muscle mass (Olds, 2001), sport nutrition counseling and direction supervision of training will be most beneficial to the players.

With respect to the forwards, although skinfold thickness decreased throughout the season, it was only significant when a comparison was made between pre-season and post-season testing. The decrease in skinfold thickness (from 137.40 ± 30.08 mm to 116.84 ± 20.01 mm) may be attributed to the players perhaps starting the season with higher than optimal skinfold values as a result of inactivity or low levels of physical activity during the off-season and then undergoing high levels of aerobic, anaerobic, position specific skills (scrumping and mauling) and weight training combined with calorie restriction diet during the season.

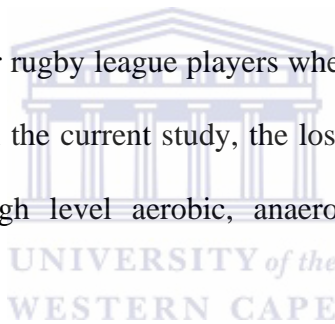


5.2.4 Percentage Body Fat

Several researchers have reported that forwards generally possess greater estimated percentage body values than backs (Duthie, et al., 2003). As expected, this research revealed that forwards carry a higher percentage of body fat than backs. Whilst additional body fat may serve as a protective buffer from injury, excess body fat acts as “dead weight” thus adversely affecting the player’s work rate and speed (Duthie et al., 2003). The percentage body fat of SA elite women rugby union backs and forwards was calculated to be 23.81 ± 3.28 % and 29.10 ± 5.6 %, respectively. These values are higher to those reported for England female rugby union backs (21.2 ± 1.7 %) and forwards (26.11 ± 4.56 %) at the same testing period (Kirby & Reilly, 1996). A likely explanation for the lower percentage body fat measurement amongst

English female rugby players is that their bodies are placed under greater physical demands during the season as they have a structured and highly competitive international and domestic season. As a result of the high physical demands and greater preparation time (off-season and pre-season) for regular competition, their muscular skeletal structures are more highly developed.

For both positional groups, percentage body fat decreased significant between pre-season and mid-season. At post-season, the percentage body fat increased significantly whilst no significant changes were reported for the forwards. These findings are in agreement with a study (Gabbett, 2005a) of senior rugby league players whereby percentage body fat decreased during the pre-season period. In the current study, the loss in body fat may also have been a result of the frequency of high level aerobic, anaerobic and muscle strength training performed during pre-season.



5.3 PHYSICAL PERFORMANCE CHARACTERISTICS

5.3.1 Flexibility

- Sit-and- Reach test

Testing the combined flexibility of erector spinae, external rotators of the hips, hamstrings and gastrocnemii muscles has been an integral part of health-related and sport specific assessments for many decades (Holt, Pelham & Burke, 1999). Many exercises designed to increase strength and aerobic capacity tend to decrease the flexibility of the erector spinae and hamstring musculature hence less than ideal flexibility in these muscles may increase the

likelihood of injury during a training session or competition (Holt, Pelham & Burke, 1999). On the other hand, it has been suggested that highly extensible muscles, which do not possess the necessary coordination and stability, may lead to joint dislocations and ligament strain (Cowan, Jones, Tomlinson, Robinson & Polly, 1988).

Changes in flexibility occur after stretching exercises and flexibility training is used in the warm-up before training or competition (Lambert, 2009). There were no statistically significant changes in flexibility over the competition season within each positional group although there was a non-significant decrease of 3.94 cm and non-significant increase of 5.45 cm during mid-season and post-season, respectively. As tightness in any of the muscle groups may contribute to the limitation of movements whilst measuring sit-and-reach flexibility (Holt et al., 1999). It is difficult to explain the practical but non-significant change in flexibility throughout the season as the players as stretching was an integral component of the recovery sessions. Further research, need to utilise protocols that will separately assess the four muscle groups involved, as this will enable the strength and conditioning coach to get a better understanding of the exercises or work load that may result in the limitation the muscles range of movement.

5.3.2 Muscular Power

The vertical jump has been used extensively as a measure of explosive leg power in contact sports as it is highly related to dynamic performance activities such acceleration and breaking tackles (Nicholas, 1997). The vertical jump height reported for participants of this study

(forwards = 38.5 ± 5.03 cm; backs = 44.8 ± 8.30 cm), is higher than elite Australian female rugby league forwards (35.1 ± 8.0 cm) and backs (35.7 ± 5.9 cm) (Gabbett, 2007) and equivalent to senior New Zealand female rugby players (forwards = 39.6 ± 5.60 cm; backs = 44.8 ± 8.30 cm) (Quarrie et al., 1995) which suggests that the players have satisfactory explosive leg power to compete internationally.

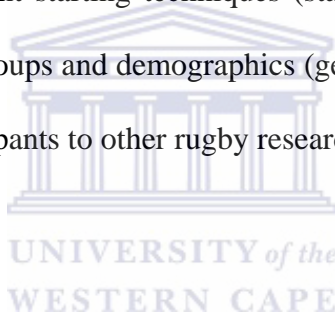
In the current study, although there were no significant differences between positional groups in the vertical jumping height results, the current data indicated that the backs obtained higher mean vertical jump displacement values than the forwards. This is similar to a previous study on elite Australian female rugby league players (Gabbett, 2007) whereby no significant positional differences were found for the vertical jump test using the Vertec height measuring device. This pattern of results differs from the findings of a previous research studies (Maud, 1983; Rigg & Reilly, 1988) whereby backs generally produce a superior vertical jump performance compared with forwards when assessed using the chalk board or wall measuring tape. Hence, such comparisons may not be valid and reliable as the vertical jump assessment did not use standardised methods over this period (e.g. chalk board versus Vertec) (Duthie et al., 2003).

Based on this study, there were no changes in vertical jump performance over the course of the season for both forwards and backs. It has been suggested that to enhance vertical jumping ability, one needs to implement a well-designed training program that includes short plyometric sessions as part of the strength and conditioning program (Hoff, Kemi & Helgaud, 2005). The relatively modest change in jumping height within the participants of this study

can be possibly attributed to a greater focus on gym based lower body resistance and lack of plyometric training.

5.3.3 Speed

Speed is integral to successful performance in various contact football codes such as Australian rules, rugby league and rugby union (Baker & Nance, 1999; Deutsch, et al., 2002; Sayers, 2000) as it is potentially decisive in determining the outcome of a game (Duthie et al., 2006). However, due to different starting techniques (standing or kneeling), sprint distance (10, 30, 40, 60 m), positional groups and demographics (gender and age), it proved difficult to compare the speed of the participants to other rugby research studies.



- 10 m sprint

In the present study, the acceleration capabilities of forwards and backs were assessed over a 10m distance. The current 10m sprint results revealed that backs were faster than forwards during the three testing sessions although a significant difference was only found in preseason. These results are contrary to previous research (Duthie et al., 2003) that backs have a superior sprinting ability than forwards. With good running speed over short distances fundamental to success (Duthie et al., 2006), the strength and conditioning staff should develop sprint training programs with greater emphasis on acceleration from a standing start.

Sprint times over 10m, for both forwards and backs were significantly slower in mid-season than in pre-season and significantly faster at the end of the season than in mid-season. These findings are contrary to previous research on senior (Gabbett, 2005a) and junior (Gabbett, 2005b) rugby league players, whereby the times remained relatively unchanged throughout the season. The improvement in speed during the second half of the season can be attributed to an increased amount of time devoted towards developing acceleration qualities for all positions from various starting positions.

- 40 m sprint

At all three testing sessions, backs were faster than forwards over 40m. The faster maximum sprint times are to be expected as backs have greater space in which to run thus achieving higher speeds than do forwards during a game, who are closer to the opposition (Duthie et al., 2006). Over the competition season, similar results were observed for both positional groups as in the 10m sprint.

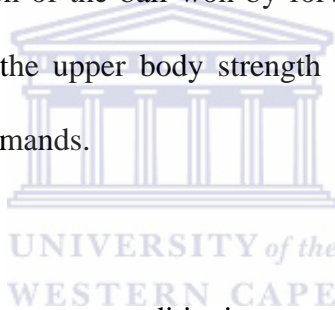
5.3.4 Muscle Strength

Upper body strength is important to sporting codes such as rugby union, rugby league and Australian football, which all involve contact and collision during play (Hrysomallis, 2010). As rugby union involves the upper body in both pushing and pulling activities, it is important that these movements are replicated when assessing players. The bench press and pull-ups

provide a good measure of the upper body strength, both in terms of absolute and relative strength.

- Absolute strength

Forwards generally have high levels of upper body strength when compared with the backs, as they are required to perform optimally in scrumming, rucking and mauling. Data from the present study revealed no significant difference in 1RM bench press between forwards and backs at any stage of the competitive season. These findings are unexpected as backs traditionally distribute possession of the ball won by forwards, which requires high level of strength. Thus, it appears that the upper body strength of these forwards is not optimally developed for their positional demands.



The goal for a pre-season and in-season conditioning program is to maximise muscular fitness before the competition season and maintaining the pre-season gains, respectively (Hrysomallis, 2010). In this research, the 1RM bench press surprisingly remained constant for both backs and forwards throughout the season despite the players being prescribed a specific periodised strength and conditioning program. Although this study did not research the training program per se, the unchanged strength results could possibly be due to a lack of direct supervision of a strength coach on daily basis during gym training. This notion is supported by Coutts, Murphy and Dascombe (2004) that direct supervision of resistance training in athlete's results in increased strength gains compared with unsupervised training.

Strength and conditioning coaches may provide support to the athlete in the form of technique analysis, motivation, goal setting and psychological reinforcement during training.

- Ratio Scaled Strength

It is common practice to normalise strength performance by dividing the absolute strength outcome variable by body mass, to account for differences in body size in rugby (Atkins, 2004; Crewther et al., 2009). Research has shown that when expressing strength using absolute values, forwards are significantly stronger than backs (Duthie et al., 2003). However, when accounting for differences in body mass using ratio scaling the performance favours the lighter backs (Atkins, 2004; Crewther et al., 2009). During pre-season and off-season testing, the absolute expression of strength was greater for the significantly heavier forwards, but after ratio scaling these performance measures favoured the significantly lighter backs throughout the season, with a significant difference being noted at mid-season (backs = 0.91 ± 0.14 ; forwards = 0.71 ± 0.18).

- Pull-ups

The pull-up is often called a test of arm and shoulder strength and is used to assess the muscle strength of the elbow flexors and shoulder extensors (Jenkins & Reaburn, 2000). Pull-up performance is largely influenced by body size, as individuals with larger body mass are expected to complete fewer pull-ups (Vanderburg & Edmonds, 1997). Contrary to these findings, this research noted no significant difference between forwards and backs for pull-up scores. However, with the exclusion of large residuals (same participant at pre-season and

mid-season, which performed 12 and 13 pull ups, respectively), backs completed greater number pull-ups compared with forwards as a result of a significantly small body size.

The number of pull-ups completed by the backs from pre-season (2.74 ± 2.66) to mid-season (4.2 ± 3.08) increased then remained constant from mid-season to post-season (4.73 ± 3.52). In addition, the forwards shoulder and arm strength remained constant throughout the season (pre-season = 1.43 ± 3.2 ; mid-season = 1.69 ± 3.66 , post-season = 0.58 ± 0.99). As in the 1 RM bench press, there were no significant improvements in pull-up strength for both positional groups throughout the season. With upper body strength being important for success in rugby (Hrysomallis, 2010; Meir et al., 2001), the lack of improvement in muscular strength in the preparatory phase, is of concern, as it may limit the participants ability to successfully challenge and overcome their opponents during contact phases (Meir et al., 2001).

5.3.5 Muscle Endurance

- Push-ups

Rugby players, especially forwards are required to repeatedly wrestle for ball possession hence rugby researchers have predominately used the 1 minute push-up to assess a player's ability to sustain continuous muscle activity. In the current study, the backs completed a greater number of push-ups at all three testing sessions but with a significant difference only being observed at pre-season testing. Given that forwards in this study have a significantly

greater percentage body fat than backs, it is to be expected that they would perform fewer push-ups as excess body fat has been shown to hinder one's ability to continuously perform muscle movements (Gabbett et al., 2008).

For both positional groups, there was a significant ($p < 0.01$) incremental increase in upper body muscle endurance over the three testing sessions with peak scores being achieved at post-season for both backs (36.27 ± 11.43) and forwards (26.33 ± 10.22). These results are to be expected, as a muscle endurance base is needed to allow repeated work efforts during matches throughout the season.

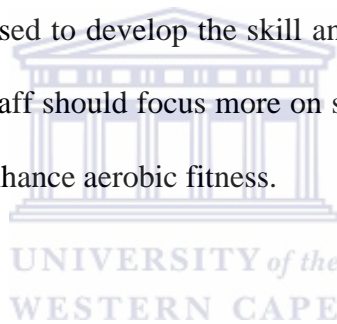
5.3.6 Aerobic Endurance



- Multi-Stage shuttle run

Although researches have clearly established the anaerobic nature of rugby union, it is also clear that a well-developed cardio-respiratory fitness level is the cornerstone of success in any physically dynamic sport such as rugby (Williams, Reid & Coutts, 1973). In the present investigation, backs exhibited a higher predicted maximum oxygen uptake than forwards. This is supported by previous researchers who have reported that backs typically possess greater levels of endurance fitness than forwards (Quarrie et al., 1995, 1996; Gabbett, 2007). The greater body mass and percentage body fat of the forwards is likely to be the reason for the lower aerobic fitness. The different forward and aerobic fitness profiles, lends support to the concept of position specific aerobic exercise program (Scott et al., 2003).

A reasonably high aerobic fitness level is important for the ability to sustain high intensity, intermittent exercise bouts so as to aid the recovery between repeated periods of ball retention and repeated recycling off the ball (Evans, 1973). The estimated maximum oxygen uptake of the backs ($46.49 \pm 4.75 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) and forwards ($41.12 \pm 9.28 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) of this study were lower than those of the Senior New Zealand Union forwards and backs (44.75 and $54.48 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ respectively) (Quarrie et al., 1995). The lower aerobic fitness values of the elite South African women players has the potential to limit their ability to recover quickly between high intensity efforts during a match thus having an adverse effect on skill execution level in game defining moments such as scoring or preventing the opposition from scoring. With skills-based games been used to develop the skill and fitness of rugby players (Gabbett et al., 2008), the conditioning staff should focus more on skill-based conditioning games over traditional interval training to enhance aerobic fitness.



For most elite rugby research studies, an increased aerobic fitness was reported at pre-season (Holmyard & Hazeldine, 1993; Gabbett, 2005a; Tong & Mayes, 1995) with a decrease being observed towards the end of the season (Gabbett, 2005a). The significant improvements in fitness in the early stages of the season have been attributed to the high training loads experience during this period (Gabbett, 2005a), while reductions in aerobic fitness as the season progressed may be due to lower training loads and higher match loads and injury rates during this period (Gabbett, et al., 2008). In contrast to these studies, there were no changes in aerobic fitness over the entire season for backs, whilst improvements in aerobic endurance for forwards were witnessed from mid-season onwards. Based on these findings, it seems that the

highest training loads were conducted in-season rather than during the general preparatory phase of the season.

5.4 SUMMARY

Thirty two elite female rugby players who were members of the South African Rugby Union High Performance Squad for the 2010 Women's Rugby World Cup were assessed on three separate occasions (pre-season, mid-season and post-season) during the 2009 competition season. The players were sub-divided into two positional categories consisting of 17 forwards and 15 backs. On all testing occasions, the fitness testing protocol was specifically completed in the following order: stature, body mass, skinfolds, sit and reach, vertical jump, speed, bench press, pull-ups, push-ups and multi-stage shuttle run. The aim of this study was to assess the physical fitness of elite women's rugby union players over a competition season.

For this study, it was hypothesised that there would be significant positional difference in stature, body composition, explosive leg power, speed, upper body muscular strength, muscular and aerobic endurance. This hypothesis was supported in that body composition varied according to position as the forwards had a greater body mass, higher sum of skinfolds and larger body fat percentage than the backs. In terms of explosive leg power, maximum speed (0-40m), muscular and aerobic endurance, backs obtained superior performance values. The current data reinforces the pronounced difference in physical fitness of the forwards and backs as forwards spend greater time in physical contact with the opposition while the backs spend more time running, allowing them to cover greater distances. Players within

these two broad positional groups have different tasks during specific phases of the game therefore further research is required to evaluate the differences between the positional categories of the female rugby players within forwards and backs.

There was not significant difference in 1 RM bench press and pull-up strength between the two positional groups. These results are unexpected given that rugby performance requires high levels of muscular strength particular in scrums, rucks and mauls, hence forwards should possess greater strength than backs. The lack of strength amongst forwards may suggest that the strength and conditioning coach should prescribe a strength program with an additional number of specific upper body sessions and greater stimulus (intensity and frequency) throughout the season for forwards. A study to determine the contribution of different strength training stimulus to strength performance during a competitive season may provide an in-depth understanding of the strength variations needed for enhanced strength amongst female rugby players.

It was hypothesised that there would be a significant improvement in the physical fitness characteristics between pre-season and mid-season. During the first half of the season, improved body composition (loss in body mass and body fat percentage) and increased upper body strength (pull-ups) were reported for backs. In addition, forwards data reflected a constant skinfold thickness, body mass and pull-ups during the same period.

The current finding of non-significant differences in explosive leg power, aerobic and muscular endurance, bench press strength and flexibility during the preparatory phase is counter to the theory that endurance, strength and power may be easily developed during off-season and pre-season training periods. Due to a lack of empirical research, the variety of physical fitness characteristics and exact training stimulus required by women rugby union players is unclear. Coaches traditionally use a combination of speed, agility, muscular power and aerobic conditioning to improve the player physical fitness.

During pre-season training, sprint times are either expected to improve (Holmyard & Hazeldine, 1993) or maintained (Gabbett, 2006). It is also noteworthy that sprint times for both positional groups significantly decreased between pre-season and mid-season. With speed being a decisive factor in winning games, the strength and conditioning coach needs to implement sprint training programmes that comprises a combination of plyometrics, sprint loading (e.g. weighted sledge towing) and resistance training as it has shown to increase running velocity.

The results support the researchers' hypothesis in that body mass, sum of skinfolds, flexibility, explosive leg strength, upper body muscular strength (bench press and pull-ups) and endurance remained constant between mid-season and post-season. In addition, there were no changes in percentage body fat and aerobic endurance within forwards and backs, respectively. This may indicate that they had reached their maximal physical fitness by mid-season. While an increase in training volume may lead to improvement or maintenance in

physical fitness, it may also be accompanied by an increase in the number and incidences of injuries sustained by players (Gabbett, 2004).

It is not entirely clear why sprint performance significantly improved for both positional groups whereas an increase in percentage body fat and aerobic endurance was observed for backs and forwards, respectively. Further research on the effects of concurrent training on the maintenance or improvement of power in female rugby players would increase our understanding of the changes in physical fitness during a lengthy competition season.

5.5 CONCLUSIONS



It was hypothesised that there would be a significant difference between the forwards and backs physical fitness. The current study reinforces scientific evidence that there is a distinction between the forwards and backs with respect to anthropometric and physical performance characteristics. The forward players had a greater body mass, higher sum of skinfolds and larger body fat percentage whereas backs demonstrated superior leg power and speed. With forward and backs spending greater time in physical contact and sprinting, respectively, during a game, this gives support to the concept of position-specific strength and conditioning programs.

The results of the present study suggest that there may have been a limited improvement in physical fitness between pre-season and mid-season within forwards and backs as it was

hypothesised there would be a significant improvement physical fitness. Of the measured physical fitness characteristics, there was significant improvement in anthropometric characteristics and no significant changes in 1 RM bench press, pull-ups, vertical jump height, push-ups and predicted aerobic power. However, a significant decrease in sprint times over the same period. Based on these findings, when developing training programs for elite women's rugby union players, strength and conditioning staff should consider incorporating skills based conditioning games with an additional resistance training session.

It was hypothesised that the improved physical fitness levels during the pre-season would be maintained as the season progresses. The data supports the researcher's finding in that the physical fitness characteristics remained constant. However, the sprint significantly increased for both positional groups. The importance of the coaches ensuring that player's fitness levels are maintained whilst on-field performance is not compromised are reinforced by these results.

5.6 RECOMMENDATIONS FOR FURTHER RESEARCH

Based on the experience gained and findings from the present study, further research to determine physical fitness requirements between forwards (front row, locks and loose forwards) and between backs (inside and outside backs) at female U/16, U/20 and senior level would assist in the development of normative data in order to facilitate talent selection and development.

The current study has described the changes in physical fitness of elite women's rugby union players during a season. With a greater number of international games being played, a study quantifying the training and match loads and injury rates for comparison with the physical fitness changes during a season could assist coaches the designing of physical fitness training programs and or modifying the current testing protocol.



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APPENDIX A

PARTICIPATION INFORMATION QUESTIONNAIRE



UNIVERSITY of the
WESTERN CAPE

Faculty of Community and Health Sciences

Department of Sport, Recreation, and Exercise Science

PARTICIPANT INFORMATION PACKAGE

Project description

This testing is being conducted as part of my postgraduate studies at University of the Western Cape (UWC) and preparation for the 2010 Women's Rugby World Cup. The purpose of this research is to establish the fitness profile of an elite women's rugby union player in South Africa. A second aim is to determine the changes in anthropometric characteristics, muscle power, speed and strength over a competitive season. This research is being conducted with full support and cooperation of the South African Rugby Union, however your decision to participate in the study is entirely voluntary.

Participant involvement

If you choose to participate in the study, you will be involved in continuous testing session throughout the World Cup campaign involving fitness testing of your individual body composition (Body Mass, Stature and 7 sum of skinfold), speed, muscle power, upper strength and endurance and aerobic endurance. The duration of the testing session will be approximately 3 hours for the entire squad.

Expected Outcomes

I expect to complete a Masters thesis for examination. In addition, publish the finding of various aspects of this research in a number of journals and publications, only after the 2010 Women's Rugby

World Cup. You will not be identifiable as an individual in any of the publication arising from the research.

Benefits of the Participants

Your involvement in this project may increase your improve your fitness profile thus potentially improving your performance. You will have access to your anthropometric and physical measurements and this will contribute to current understanding of physical fitness characteristics required for an elite women's rugby player in South Africa.

Risk and Discomfort

Every effort will be made to minimise discomfort and risk associated with all testing procedures.

Confidentiality

All information obtained from the testing will be treated confidentially and only the research team and South African Rugby Union will have access to the data collected. Your name will not be used and will no way be identifiable in any publication that arises from this research.

Voluntary Participation

Your decision to participate in the study is entirely voluntary, and you can withdraw anytime without comment or penalty. Your decision to participate will in no way influence you present and/or future involvement with the South African Women's National Rugby Team.

Enquiries

For any enquires or further information regarding this research study please contact

Researcher: Nceba Hene

University of the Western Cape

Private Bag X17, Belville 7535

Cell: 083 5787 410

Email: ncebahene@hotmail.com

APPENDIX B

CONSENT FORM



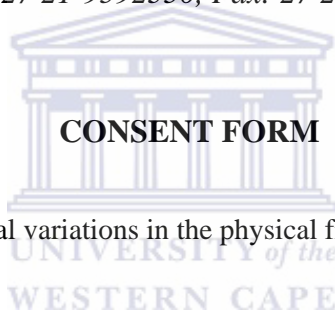
UNIVERSITY of the
WESTERN CAPE

Faculty of Community and Health Sciences

Department of Sport, Recreation, and Exercise Science

Private Bag X17, Bellville 7535, South Africa

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CONSENT FORM

Title of Research Project: Seasonal variations in the physical fitness of elite women’s rugby union players

I (Print full name and surname) hereby consent to voluntarily participate in the activities of the research. The study has been described to me in language that I understand and my questions about the study have been answered. I understand that my identity will not be disclosed and that I may withdraw from the study without giving a reason at any time and this will not negatively affect me in any way.

Signed at on this day of 20.....

Participants Signature Witness

Should you have any questions regarding this study or wish to report any problems you have experienced related to the study, please contact the supervisor and the head of department:

Head of Department: Dr S Bassett
University of the Western Cape
Private Bag X17, Belville 7535

Telephone: (021)959-2273
Fax: (021)959- 3688
E-mail: sbassett@uwc.ac.za

APPENDIX C

PHYSICAL FITNESS DATA CAPTURING SHEET

1. ANTHROPOMETRY

NAME:			
SPORT:		POSITION:	
GENDER:		DOB:	AGE:
STATURE (cm):		WEIGHT (kg):	

SKINFOLDS (mm)	
Tricep	
Biceps	
Subscapular	
Suprailiac	
Calf	
mid thigh	
Abdominal	

2. EXPLOSIVE POWER: Vertical Jump

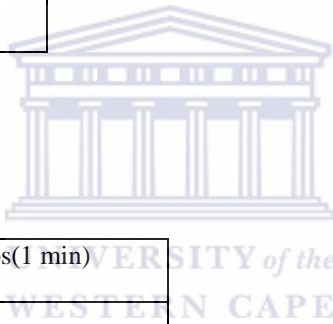
Reaching height(cm)	Jumping height 1(cm)	Jumping height 2(cm)	Diff(cm)

3. SPEED AND ACCELARATION

	10 m (sec)	40m sec
Attempt 1		
Attempt 2		

4. MUSCLE STRENGHT

	kg	kg/kg BW
1 -RM Bench Press		



5. MUSCLE ENDURANCE

Pull ups	Push ups(1 min)

6. AEROBIC ASSESSMENT : Multi stage shuttle run

Shuttle		Stage		Level

APPENDIX D

PHYSICAL FITNESS DATA

	Forwards				Backs			
	Testing Session	N	Mean	SD	N	Mean	SD	P
Stature (cm)	Pre-season	17	164.90	6.68	15	160.10	6.39	0.0432
	Mid-season	15	165.30	6.03	15	161.80	7.39	0.0314
	Post-season	14	166.00	6.80	12	161.20	7.58	0.0289
Body Mass (kg)	Pre-season	17	78.94	13.01	15	62.97	5.96	<0.0001 *
	Mid-season	15	79.51	14.19	15	61.50	6.59	<0.0001 *
	Post-season	14	78.39	11.51	12	62.95	6.09	<0.0001 *
Sum of skinfolds (mm)	Pre-season	17	137.40	30.08	15	106.66	19.12	0.0003 *
	Mid-season	15	134.32	50.31	15	90.78	21.43	0.0008 *
	Post-season	14	116.84	20.01	12	102.61	23.21	0.0616
Percentage body fat (%)	Pre-season	17	30.81	4.56	15	26.11	3.81	0.0008 *
	Mid-season	15	29.10	5.60	15	23.81	3.28	0.0116
	Post-season	14	29.24	2.93	12	27.33	2.76	0.1367
Sit-and-Reach (cm)	Pre-season	17	41.07	5.30	15	39.91	7.50	0.6423
	Mid-season	15	37.15	5.49	15	38.39	6.07	0.7543
	Post-season	14	42.60	5.60	12	39.01	7.39	0.3881

	Forwards				Backs			
	Testing Session	N	Mean	SD	N	Mean	SD	P
Vertical Jump (cm)	Pre-season	17	37.50	5.36	15	44.35	5.06	0.007*
	Mid-season	15	38.40	5.03	15	44.60	5.23	0.003 *
	Post-season	12	39.25	5.69	8	47.25	2.92	0.0001 *
10m Speed (sec)	Pre-season	17	2.08	0.08	15	1.90	0.07	0.0002 *
	Mid-season	15	2.18	0.10	14	2.06	0.14	0.0229
	Post-season	12	1.99	0.09	8	1.89	0.04	0.0078 *
40m speed (sec)	Pre-season	17	6.51	0.31	15	5.96	0.19	<0.0001 *
	Mid-season	15	6.63	0.16	15	6.13	0.78	<0.0001 *
	Post-season	12	6.41	0.29	8	5.90	0.07	<0.0001 *
1 RM Bench Press (kg)	Pre-season	17	63.57	15.86	15	55.79	9.17	0.3599
	Mid-season	14	55.00	12.40	15	57.33	7.04	0.9094
	Post-season	12	58.75	12.64	11	54.55	6.88	0.0460
Ratio Scaled Strength (kg/kg)	Pre-season	17	0.82	0.17	15	0.90	0.17	0.0418
	Mid-season	14	0.71	0.18	15	0.91	0.14	0.0021 *
	Post-season	12	0.76	0.13	11	0.88	0.14	0.1594
Pull-ups	Pre-season	17	1.43	3.20	15	2.74	2.66	0.0566
	Mid-season	13	1.69	3.66	13	4.20	3.08	0.0126
	Post-season	12	0.58	0.99	12	4.73	3.52	0.0121

Push-ups	Testing Session	Forwards			Backs			P
		N	Mean	SD	N	Mean	SD	
	Pre-season	17	16.46	8.71	15	24.83	9.47	0.0020*
	Mid-season	13	25.31	11.68	15	35.27	12.28	0.0160
	Post-season	12	26.33	10.22	11	36.27	11.43	0.0425

Estimated aerobic power (ml.kg ⁻¹ min ⁻¹)	Testing Session	Forwards			Backs			P
		N	Mean	SD	N	Mean	SD	
	Pre-season	17	41.12	9.28	15	46.49	4.75	0.0276
	Mid-season	14	37.76	6.29	14	45.28	3.40	<0.0001*
	Post-season	11	40.58	4.79	8	46.03	2.21	0.0014 *

