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***SECULAR CHANGES IN ANTHROPOMETRIC AND PHYSICAL
CHARACTERISTICS OF SOUTH AFRICAN NATIONAL U/20 RUGBY
UNION PLAYERS (1998 – 2010)***

By

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Secular changes in anthropometric and physical characteristics of South African national U/20 rugby union players (1998-2010)

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Declaration

I, ***Wayne Lombard*** hereby declare that the work on which this dissertation is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

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List of Abbreviations and Symbols

SSISA:	Sports Science Institute of South Africa
HPC:	High Performance Centre
SARU:	South African Rugby Union
NSCA:	National Strength and Conditioning Association
ISSP:	International Society of Sports Psychology
TEM:	Technical Error of Measure
RWC:	Rugby World Cup
1RM:	1 Repetition Max
MSSRT:	Multi-Stage Shuttle Run Test
VO_{2 Max}:	Maximum Oxygen Consumption
U/19:	Age group representation of the players. Aged under 19 years.
U/20:	Age group representation of the players. Aged under 20 years.
U/21:	Age group representation of the players. Aged under 21 years.

Abstract

Introduction:

The aim of this study was to compare changes in the physical and morphological characteristics of South Africa's National U/20 rugby union players (Forwards and Backs) over a 12 year period from 1998 - 2010. This period spans an era starting just after the onset of professionalism of the game to the modern era where the influence of professionalism has filtered down to junior (U/20) levels. Any changes in morphology and physical ability of the players can be attributed to the changes in the demands of the game and reflect the characteristics that are required for a player to be successful at that level.

Methods:

Players who were U/20 at the time of representing the Junior South African National Team National over a period spanning from 1998 – 2010 were used for the study. A total of 453 players, split into two groups, Forwards ($n = 256$) and Backs ($n = 197$), underwent measurements of body mass, stature, body fat percentage, muscular endurance (pull ups), muscular strength (1RM bench press, sprint times (10m and 40m) and aerobic capacity (Multi-stage shuttle run test). All Tests were conducted once a year in either January or December of that year. Data are represented as means \pm 95 % confidence intervals. A Levene's test of homogeneity was used to determine whether the variance for each variable was equal. A two-way analysis of variance was used to determine whether there were significant differences for either main effect of 'year' or 'position' or for the interaction between 'year x position'. If the main effect of 'year' or interaction ("year x position") was significant, a Tukey *post hoc* test was used to identify specific differences. Statistical significance was accepted when $p < 0.05$.

Results:

The pooled data for the present study showed that Forwards were heavier (22%) than Backs. Over the 12 year period body mass of the Forwards average 99kg in 1998 and increased to 107kg by 2010. The Backs averaged 74kg (1998) and 89kg (2010). When looking at stature there was a significant difference between Forwards and Backs, with the Forwards being on average 4.7% taller than the backline players. There was a trend for an increase in stature over the study (1998 – 2010) for both Forwards and Backs; however, this change was not significant. Backs had a significantly lower (23%) body fat % compared Forwards. For absolute strength (1RM Bench Press) Forwards were 18% stronger than Backs. However, when the maximal effort strength scores were adjusted for body mass, Backs were stronger per kg body weight. Forwards averaged between 1.0 – 1.3 kg/kg-bw and the Backs 1.0 – 1.5 kg/kg-bw. For local muscular endurance

(Pull Ups) Forwards averaged between 7 – 14 repetitions and the Backs 11 – 21 repetitions. Backs are faster over both 10m (5% faster than Forwards) and 40m (3% faster than Forwards). Aerobic capacity showed that the Backs completed on average of between 97 – 105 shuttles compared to the Forwards 86 – 102 shuttles.

Conclusions:

The differences between Forwards and Backs are similar to those reported in the literature. However, the novel aspects of this thesis are the changes that have occurred in the measured variables over the 12 year period (1998-2010). These changes reflect the changing demands of the game over this period. From the data presented above it is plausible that due to the professional era of modern day sports or rugby specifically, players over the years have implemented strategies to gain a physical advantage by becoming bigger, faster and stronger than their opponents.

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Background and Motivation for the Study

The Discovery High Performance Centre (HPC) of the Sports Science Institute of South Africa (SSISA) has built an ongoing relationship with the South African Rugby Union (SARU) since 1995. As the relationship developed, there was an appreciation for the important role of science in the modern era of sport. Also it became clear that the physicality of rugby union went beyond just playing the game, and that the preparation and implementation of training programmes and data analysis formed an important role in ensuring the players are adequately prepared to play the game.

The HPC has provided various services to the SARU since the opening of the SSISA in 1995 including but not limited to;

- 1) Promoting the ‘science of rugby physiology’ to stakeholders.
- 2) Objectively assessing the physical fitness of players through the implementation of standardized tests performed under controlled conditions at SSISA.
- 3) Providing players with training programmes for rugby based on current scientific principles and physical performance test results.

The HPC has tested players from the National U/21 squads since 1998 and then the National U/20 squads since the change from U/21 to U/20 competitions in 2006. Seeing the need to analyze the data, it was believed that a research study should be conducted to identify possible trends in physiological and anthropometric data collected at the testing camps at the SSISA. Understanding the trends will have practical application for training and also assist with the identification of up-and-coming rugby players of the future.

Chapter One:

LITERATURE REVIEW AND SCOPE OF THESIS

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1. Introduction

1.1 The early years of rugby football

According to an urban legend the “formation” of the game of rugby football can be attributed to the story of a young boy, William Web Ellis, who in 1823, during a football game picked up the ball and ran with it while attending the Rugby School in the United Kingdom (UK). This legend led to the International Rugby Board (IRB), the world governing body and law maker for rugby union, naming the Rugby World Cup (RWC) the “*William Web Ellis Trophy*”^{1,2}. From that day in 1823 the game played by Rugby School spread to various public schools in the UK and in 1848 Cambridge University gave it a trial run³. Then in the same year, due to the growth in its popularity, the game developed its own code. Hence by 1860 onwards, two very different forms of football emerged; one which permitted handling the ball and one which did not. This continued until 1895 when rugby football split into two separate codes, namely, rugby union and rugby league. In 1871 the first Rugby Football Union was formulated by 21 amateur clubs, who drew up the original laws of the game³. Rugby league went on to become professional in 1898, whereas rugby union only became professional nearly 100 years later (1995). The game of rugby union has since gone from strength to strength, with men and women in more than 100 countries spanning across five continents playing the game. The IRB has currently 97 full member unions and 20 associate members, with the RWC attracting approximately 4.2 billion television viewers from around the world².

Therefore, in this review the possible trends shown by rugby players since the inception of the professional era will be discussed. Furthermore the review will also address various aspects such as Rugby in South Africa, the relevance of physiological profiling of age group rugby players, the physiological demands of the game and the role strength and conditioning plays in rugby. These areas are not only important to the understanding of the attributed physiological advancements of the game today, but also contribute to an understanding of the relevant importance of the ‘physical maturity’ of a player competing at a particular level.

1.2 Rugby Union from a South African Perspective

Rugby, with over 10 million followers, has become one of South Africa's favorite sports, second to soccer^{1,4}. The South African National 15 man rugby team, known as the Springboks, have been a formidable force in the rugby world, prior to and since the induction of the professional status to rugby union in 1995, going on to win the RWC on two occasions in 1995 and 2007. Furthermore, the national sevens team, known as the "Blitz Bokke", are also an international competitive force, winning the HSBC 2010/11 Sevens World Series. The national junior team has also competed well in every IRB Junior World Championship, winning the U/19 tournament in 2005 and then the U/20 tournament in 2012⁵.

1.3 Rugby Union – The Technical Side

Rugby union (referred to as rugby from here onwards) is an intermittent high intensity collision sport⁶. A match lasts for 80 minutes (two halves of 40 minutes each), and is contested between two teams, each consisting of 15 players. It has been shown that the ball is in play for approximately 30 – 35 minutes of the match (see also changing demands of rugby), with the remaining time made up of various stoppages (injury time, penalties and ball out of play). Each player has a designated position to which he/she is assigned according to the laws outlined by the IRB (figure 1). These positions are generally grouped into Forwards (1-8) and Backs (9-15). Also within the two groups the players can be further divided into Front Row (1-3), Tight Five (1 – 5), Loose forwards (6-8), Halfbacks (9 -10), Inside Backs (11 – 12) and Outside backs (13-15)⁷. However, for the purpose of this review playing positions will be referred to as Forwards or Backs.

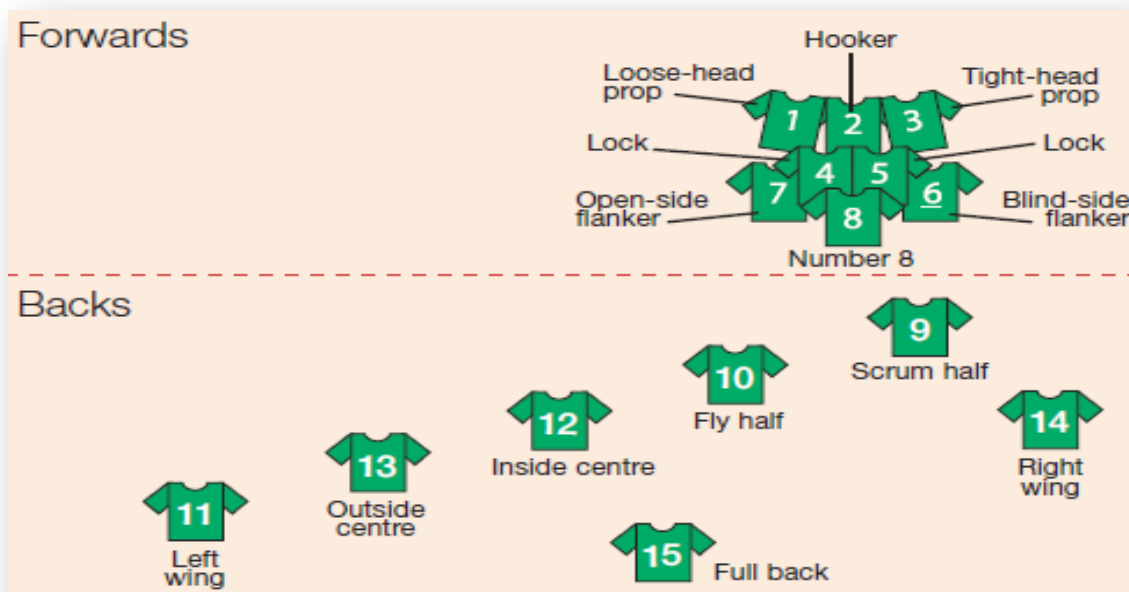


Figure 1: Rugby Union playing positions. (Image adapted from the IRB Beginners Guide to Rugby, - their copyright law allows for publication of their work for educational purposes)

1.4 The Science and Physiology of Rugby

Since the beginning of the professional era in 1995, it has been said that the fitness and anthropometric profiles of elite players have steadily improved over time⁷. It is for this reason that research in recent times has aimed at the identification of the physiological demands of the game. *Cunniffe et al*, conducted a study in 2009, using global positioning system tracking software, to help establish the physiological demands of the game⁸. Their findings provided insight into the various demands placed on different positions. They showed that during a match (all players played either in the Celtic league or Guinness Premiership; the highest club representation in Ireland, Scotland, Wales and England) players recorded a mean and peak heart rate of 172 and 200 bpm⁻¹ respectively. This equates to readings that are 78 - 90% maximum heart rate (HRmax). Furthermore, they showed that Backs spent 42% of playing time at 80-90% HRmax whereas Forwards spent approximately 27% of playing time in these heart rate zones. They were also able to show that players generally only accelerated for a maximum of 4 – 6 seconds at any given time and velocity, covering distances of anywhere between 30m – 60m⁸. One of the key findings of the study was the actual “impact load” experienced by Forwards (1274 impacts) vs. Backs (798 impacts)⁸.

Furthermore, when looking at the aerobic capacity of players, an earlier study which considered players in the English Premiership, showed that Backs have a higher peak $\dot{V}O_2$ than Forwards⁹. This was largely attributed to the varying game demands for each position as well as the increased stature and body mass of Forwards compared with their backline counterparts^{7,9}. It is clear that physiological profiling of players is an important component to determine the players readiness to withstand the demands of a high intensity game with high impact loads^{8,10}. It has been well documented that strength, power and local muscular endurance are important characteristics of modern era rugby players. For example, *Duthie et al (2003)*, showed that the mean peak force during scrummaging can range from 6210-9090N⁷. The general perception that Forwards need to possess a great amount of absolute strength and power is supported by a study showing that Forwards produce a greater peak force at lower isokinetic speeds than backs¹¹. However, Backs seem to produce greater force at lower speeds as shown in international level sprinters¹¹. With the evidence presented above, a primary goal of training should be to prepare the players for sudden bursts of energy with lower or insufficient recovery, so the players can cope with, and recover from, intermittent high intensity activities⁷. Therefore it may be assumed that in the modern era of professional rugby, players who are generally bigger, faster and stronger tend to have an advantage over smaller and less powerful opponents¹². This was further emphasized by *Norton et al (2001)* who suggested that sport is “*Darwinian, in that only the fittest, reach the highest level of participation*”¹³.

1.5 Secular Changes

Has the professional era increased the physical demands of rugby resulting in a change in physical attributes of modern day players?

It has long been debated that the modern day athletes are bigger, stronger, faster, especially at age group level, due to various factors¹³. This was shown in two studies conducted in 2000 and 2001, each looking at the evolution of athletes over a period of time. In the 2000 study, *Olds* showed that the average physique of rugby union players has steadily increased from 1905 – 1975 and then again from 1975 – 1999. However the rate of change from 1975 – 1999 was almost 3 – 4 times greater than that between 1905 – 1974 (Table 1)¹⁴. This study showed that the mean increase in body mass, stature and body mass index (BMI) per decade was 2.6 kg, 1.0 cm and 0.4 kg.m⁻² respectively¹⁴.

Table 1: A summary table of findings for the “*evolution of physique in male rugby union players in the twentieth century*”, (Olds, 2001).

	1905 – 1974			1975 - 1999		
	All Players	Forwards	Backs	All Players	Forwards	Backs
Body Mass (kg)	87.8	92.7	80.0	95.1	103.7	84.7
Stature (cm)	1.80	1.83	1.76	1.84	1.83	1.79
BMI (kg.m⁻²)	26.2	27.1	24.9	28.6	30.0	26.8

Note: Olds represented all data as means for each variable during the period between either 1905 – 1974 or 1975 – 1999.

A further study by Norton *et al* (2001) showed that the general secular changes for Australian children and adolescents (over the a period of 150 years) for stature was 1.2cm for females and 1.3cm for males¹³. The change in the adult population was estimated at 0.4cm per decade¹³. This study also showed that professional athletes across 22 sporting codes over a 100 year period, are 1) generally bigger than the average population, and 2) are increasing in body mass (kg), stature (cm) and BMI (kg.m⁻²) at a faster rate than the average population¹³.

Lastly, a study of National Hockey League players showed that only the fittest, strongest and most skilled players are recruited into the national league, once again making the case for increase physical attributes of modern day athletes¹⁵. Furthermore, in rugby the frequent changes to the laws¹⁶ result in a change in the physical demands of the game. For example, law changes have been associated with increased playing time and number of rucks, mauls and passes. This leads to an increase in the physiological demands placed on the players. They therefore need to train harder to become fitter, stronger, bigger and faster to cope with the physicality of the modern game¹⁶. This makes it increasingly difficult for athletes without these characteristics to successfully compete at the highest levels^{12,14}.

From a rugby perspective, the demands of the game have increased over time due to changes in the laws of the game, making it faster and more spectator ‘friendly’¹⁶. Since the start of the professional era in 1995 the ball is in play for 10 minutes longer (from 24:42 m:s in 1991 – 35:12 m:s in 2007) at international level¹⁶. Furthermore, another study conducted on the Bledisloe Cup (1972 – 2004), showed that the ball-in-play time increased by 20% during the period of the study¹⁷. Not only did the ball-in-play time increase, but also the number of rucks (72±18 vs. 178±27) and tackles (160±32 vs. 270±25) (1972 vs. 2004 respectively), also increased. The increase in impact stress resulted in more associated muscle damage¹⁸.

The modern professional rugby player is therefore bigger, stronger and faster than players from the pre-professional era^{13,14}. This can be associated with accommodating the demands of the game of the professional era. Also the bigger and stronger players have longer careers, are the first to be recruited into a squad, and earn a higher salary¹³. It remains to be seen whether this trend of having bigger and stronger players filters down to the youth playing the game at a high level.

1.6 To Test or not to Test? The Role of Physiological Testing in Elite Sports.

Physiological testing enables the abilities of the players to be assessed. Furthermore, physiological testing identifies which physical traits need improvement¹⁹. Testing not only sets a baseline level of physical characteristics of each player, but also tracks their progress, determines their physical potential to play a sport at a certain level, and their readiness to return to play after injury^{15,19}. Even though many physical abilities are innate or genetically predetermined, many of them can be improved through physical training, and it is through testing that these areas are identified¹⁹. Many published peer reviewed articles support the concept of physiological testing. According to *Gabbett et al 2007*, anthropometrical and physiological characteristics are related to playing ability but do not discriminate between successful and less successful players in rugby league²⁰. Another paper published in 2009, concluded that variables derived from anthropometric, physical, and biomechanical testing play an important role in high performance sports²¹. For example, physiological testing can be used to set normative standards for each testing variable for the identification of potential talent²¹. Physiological testing also provides the coach, medical staff and selectors with an overall impression of an athlete's physiological profile, providing that the testing battery was valid, reliable and meaningful²². In an International Society of Sports Psychology (ISSP) position stand on physical testing it was shown that physical skill testing can be used to assess athletic ability in individual and team sports¹⁰. This position stand summarized the benefits and limitations of testing as follows:

Benefits of testing¹⁰:

1. Testing results can be used to provide feedback to the athlete so they can monitor their progress.
2. Information enables coaches to customize training programmes, to improve on the athlete's identified weakness.
3. Normative values can be developed for different test variables. These values can be adjusted for different ages and levels of proficiency.

Limitations of Testing¹⁰:

1. Physical testing does not allow for the assessment of players' cognitive skills.
2. Most physical tests are conducted individually and in stationary conditions and may not be sports specific.
3. Physical skills testing takes place when in a rested state.

There are logical reasons for testing the physiological characteristics and morphology of elite athletes. However, the testing protocols should be well designed and specific to the demands of the sport²². Furthermore, it is important that physiological testing only forms one part of athlete management. This means that it is important that adaptations to training stress, training goals, injury management as well as psychological well-being of the athlete are all monitored throughout training^{10,22}. In addition, the author believes that physiological testing plays a crucial role in the identification of physical attributes of players and for return to play post injury analysis.

1.7 The role of strength and conditioning in elite rugby

As has been discussed previously, rugby is a sport that incorporates intermittent, short duration, high intensity exercise, maximal efforts of power and strength, muscular endurance, agility and speed. The muscles of the players must be able to withstand the forces of the repeated collisions which occur throughout a match^{6,23}. In addition to rugby players having to be in peak physical condition to cope with the demands of the game, they also have to maintain their muscle mass¹⁶. It is for these reasons that strength and conditioning plays an important role in the careers of modern day rugby players¹⁶.

The major purpose of implementing a strength and conditioning programme is to: 1) induce physiological and morphological adaptations which are associated with an improvement in the performance and 2) decrease the risk of injury^{16,24}. Furthermore, *McGuigan et al (2012)* argue strongly for the benefits of strength training to improve sports performance. In this review, the authors found that strong correlations occurred between physical capacities that are developed through the implementation of a strength and conditioning programme and sports specific skills such as speed and agility²⁵. Specifically for rugby, they reported that tackling ability is significantly correlated ($r = 0.38$) to lower body power²⁵.

To ensure that the players are optimally conditioned for rugby it is important that the strength and conditioning programmes are specifically designed, not only for rugby as a whole but also to match the demands of each position^{6,16,23}. The phases of a strength and conditioning programme

are periodized into four phases, each with distinctly different training goals and adaptations^{6,26,27}. Therefore, as shown in Table 2, a rugby season can be divided into off-season, pre-season, in-season as well as the transition period, with each phase having a significant difference in terms of physical preparation for rugby.

Table 2: Sample periodization plan for rugby. Adapted from BokSmart, underground strength training,²⁸

Training Phase	Off Season	Pre-Season	In – Season	Transition Period
Resistance Training Goals	Hypertrophy Strength Base Muscular Endurance	Strength Power	Strength Maintenance	
Conditioning Training Goals	Largely High Intensity Interval type training	Largely High Intensity (speed, agility, high intensity intervals)	General physical fitness maintenance	Rest / active recovery
Training Volume	High	Medium	Low	
Training Intensity	Low - Medium	Medium - High	High	

In summary, it is important that training is specific to the demands of rugby to induce the desired physiological adaptations which are associated with improved performance^{16,24}. Furthermore, it is important that players of all age groups adopt a well structured and designed rugby specific strength and conditioning programme to sufficiently prepare them physically for the demands associated with the game, as well as reduce the chance of acquiring musculoskeletal injuries^{6,16,26,29}.

1.8 Physiological attributes of rugby players

As mentioned previously, a well-conditioned rugby player should have a high level of strength, power, muscular endurance, agility, speed, and be able to resist fatigue arising from short duration high intensity exercise. Within this general profile of characteristics, each playing position requires specific morphological and physiological attributes^{16,30}.

The next section will discuss all the physical and anthropometric variables, such as body mass, stature, body fat %, strength, muscular endurance, general endurance and speed. Each variable will be discussed with regards to positional differences and changes over time, as the demands of the game have changed.

1.9 Anthropometrical Evaluations

1.9.1 Body Mass (kg)

1.9.1.1 Effects on Performance

There is a significant correlation between the mean body mass of teams and final rankings in the Rugby World Cup between 1987 to 2007³¹ with the heavier teams performing better than their lighter counterparts^{14,31}. Body mass of players has also increased as the game has developed. For example, at the highest level of competition, Forwards and Backs became 6.6kg and 6.7kg heavier respectively between 1987 – 2007³¹. In addition, the body mass of players aged 18 years or over, playing from state level to national level competition, has increased four times faster over the last 25 year period (1975 – 1999) compared with the rest of the century¹⁴.

1.9.1.2 Differences between Forwards and Backs

Several studies have shown that Forwards are heavier than backline players³². The heavier body mass of the Forwards serves their need to scrum, maul and win balls at the break down^{6,7}. The slightly lower body mass of the backline players is associated with greater speed, agility and explosive power^{6,32}. However, more recently, it is evident that Forwards have become more 'mobile', while maintaining their body mass. This is largely associated with an increase in lean muscle mass and a decrease in total body fat %⁷.

1.9.2 Stature

1.9.2.1 Effects on Performance

Body stature plays an important role in rugby, especially in certain positions such as lock, where jump height achieved in the line out is of utmost importance⁷. In addition, it has also been shown that overall team mean stature plays a significant role in their overall ranking in the 1999 Rugby World Cup^{31,33}. Generally, teams with taller Backs and Forwards seem to perform better than those teams that are shorter in stature³¹.

1.9.2.2 Differences between Forwards and Backs

At the elite level there is a distinct difference in stature between Forwards and Backs, with Forwards generally being taller than the Backs ^{7,32}. Within the positional groupings there is also variation in stature ^{7,32,34}. *Duthie et al (2003)* showed that the height of the players increased as the level of competition increased. They also showed that hookers and inside backs are generally the shortest players whereas the locks and outside backs are the tallest players within their respective positional groups (i.e. Forwards or Backs) ⁷.

1.9.3 Body Fat Percentage

1.9.3.1 Effects on Performance

Assessing body fat and muscle mass describes the overall tissue composition of an athlete. Elite rugby players can have a body fat percentage ranging from 8 % - 17 % ^{7,16}. The reason for measuring body composition is to determine the amount of muscle mass present as it is well known that leaner, more muscular players, are faster, stronger and more resilient to injuries ^{7,16}. It has also been shown that excess body fat may influence the speed, agility as well as vertical jump height of a rugby player ³⁵.

1.9.3.2 Differences between Forwards and Backs

Body fat percentage generally decreases with increasing levels of playing competition ⁷. Moreover, Forwards generally have a greater absolute fat mass compared to Backs. This can be attributed to the different demands of the playing positions and the role of fat mass in protection in contact sports and the influence of lean muscle mass for sprinting and explosive movements ⁷.

1.9.4 Muscular Strength – 1RM Bench Press

1.9.4.1 Effects on Performance

Muscular strength can be defined as the “*ability of a given muscle or group of muscles to generate muscular force under specific conditions*” ^{7,16,36}. Maximum strength is important in sports that involve collision between players. Therefore training to increase strength has become an important part of developing a rugby player in preparation for the demands of the sport ⁷. Muscular strength generally increases linearly as the level of competition increases. Therefore the better players are generally the strongest players, but the strongest are not necessarily the best players ³³. Muscular strength scores can also be represented as relative to body weight ³⁷. The most basic method in adjusting for body size is dividing the body mass by the weight lifted ³⁸. Another popular method

used to determine relative strength differences between two athletes, when adjusting for body weight is the Allometric Modeling method. This method uses the index “ $y \cdot x^{-b}$ ”, with “y” representing the mass lifted, “x” is the body mass and “b” is the allometrically derived exponent. The most accurate lifts that the Allometric method can be used for are the bench press ($BP \cdot BM^{0.57}$) and squat ($SQ \cdot BM^{-0.60}$)³⁸. For the purpose of this study, isometric scaling was used when adjusting for body weight.

1.9.4.2 Differences between Forwards and Backs

As mentioned previously, Forwards are exposed to higher impact forces than Backs, due to a greater frequency at which they are involved in the tackle and ruck situations as well as scrummaging^{7,16}. It is therefore important that Forwards have a greater amount of muscular strength to be able to withstand these forces without which may prevent injury^{7,16,39}. However there is conflicting evidence with regards to Forwards being stronger than Backs, as some research has shown no significant differences in 1RM bench press scores³³. For example, differences were shown between Forwards and Backs for all age groups between 16 – 19 years, with Forwards having a greater absolute 1RM bench press score. However, when adjusting for body weight, Backs are generally stronger³³. Smart et al (2012), showed that Super 14 Forwards were about 8% stronger than Backs in the bench press⁴⁰. It is generally accepted that the athlete with a greater body mass, is stronger when looking at the absolute values as described above. However, when correcting for body mass, the heavier athlete is generally at a disadvantage compared to the lighter player³⁸.

1.9.5 Muscular Endurance – Maximal Pull Ups

1.9.5.1 Effects on Performance

Muscular endurance is the ability of a muscle or a group of muscles to contract repetitively without fatiguing⁴¹. Many physiological variables may affect the local muscular endurance of the athlete. For example, muscular strength, metabolic characteristics of the muscle, blood circulation within the muscle and the ratio of type 1 muscle fibers to type 2 fibers all contribute to the ability of the muscle to resist fatigue⁴¹. The characteristic of muscle endurance allows players to perform multiple tackles, win more balls at the rucks and mauls as well as lift in the line outs⁶.

1.9.5.2 Differences between Forwards and Backs

The pull ups test is used to assess local muscular endurance^{16,41}. It is well documented that Forwards generally perform fewer repetitions when compared to their backline counterparts^{32,34,42,43}. A study of u/16 and u/18 players showed that the Backs scored about 17% higher than the Forwards³².

1.9.6 Sprinting performance - 10m & 40m Sprint Times

1.9.6.1 Effects on Performance

As mentioned previously, rugby is an intermittent high intensity sport that requires the players to perform maximal or sub maximal accelerations during a match⁷. Two types of speed are important in intermittent high intensity sports such as rugby; namely, top end speed and speed endurance^{7,16}. Top end speed is the ability of an athlete to run at maximal speed for a short duration, whereas speed endurance is the ability to repeatedly sprint at maximal or sub maximal speeds¹⁹.

1.9.6.2 Differences between Forwards and Backs

It has been documented that backline players can achieve maximum velocities similar to those of track sprinters over 15 to 35m⁷. The majority of the literature supports the notion that rugby players generally sprint between 10 – 20m at a time, however most of these short sprints are not at maximal speeds as it can take up to 30m to reach top end speed^{7,16}. At Super Rugby level, Backs entered the high speed zone of faster than 20km.h⁻¹ on 34 occasions compared to the 19 times of the Forwards⁴⁴. In addition, on average backline players sprint on 24 ± 7 occasions and Forwards who sprint on 13 ± 6 occasions during a match. Importantly 76% of these sprints involved change of direction, which is another important component for rugby players being able to break lines and to make and avoid tackles^{7,8,16,40}. On most occasions backline players have been faster over 10, 20 and 40m sprint tests compared to Forwards. The mean speed over 30m for U/21 Backs and Forwards being 4.4 and 4.6 seconds respectively^{7,16}. The majority of sprints, regardless of playing position, occur for 4 to 6 seconds and for about 1.2% of total playing time⁸.

1.9.7 Aerobic Endurance – Multi Stage Shuttle Test

1.9.7.1 *Effects on Performance*

It is important that athletes performing at a high level have a well developed endurance capacity, to allow them to cope with the demands of the sport. This fitness characteristic is often represented by the maximal oxygen consumption ($\dot{V}O_2 \text{ max}$) and a test for $\dot{V}O_2 \text{ max}$ is often included in a battery of test for high performance athletes^{9,45}. However, the measurement of $\dot{V}O_2 \text{ max}$ requires sophisticated equipment, and a graded exercise protocol that usually takes place in a controlled laboratory environment⁴⁶. This makes it impractical for teams. Therefore in 1982 *Léger et al*, devised a field based maximal shuttle run test to predict the $\dot{V}O_2 \text{ max}$ ⁴⁷. The $\dot{V}O_2 \text{ max}$ was directly proportional to the number of shuttles completed in the 20m shuttle test. Over time the relevance of $\dot{V}O_2 \text{ max}$ has diminished, particularly for a sport such as rugby and the data from the test are rather reported as the number of shuttles⁴⁶.

1.9.7.2 *Differences between Forwards and Backs*

Forwards have a $\dot{V}O_2 \text{ max}$ ranging anywhere from 44-55 $\text{ml}O_2 \cdot \text{kg} \cdot \text{min}^{-1}$ and backs 47–60 $\text{ml}O_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ⁹. The lower $\dot{V}O_2 \text{ max}$ values represented by the Forwards may be due to a greater stature, body mass, as well as an elevated body fat percentage⁹. This was further supported by a study on American football players, indicating that players with a higher body fat percentage were more likely to have a lower level of aerobic fitness⁴⁸. Furthermore *Durandt et al*, reported similar findings when comparing Forwards with Backs at u/16 and u/18 level, showing that Backs perform about 8% better than Forwards when combining both the u/16 and u/18 data⁴⁹.

1.10 Synopsis

The literature review has shown that rugby players have had tremendous physiological gains since the start of the professional era. A superior physical capacity is required by rugby players to compete at the higher levels where the physical demands of the game have increased. With this in mind, it is evident that there is a lack of studies accurately reporting the morphological and physiological changes of junior rugby players competing at the international level. These data are important for future reference to establish the minimum normative requirements of various physical components for individuals wanting to compete at this level. Moreover, limited research has been conducted showing secular trends in rugby players over ten or more years^{13,14}.

It has been argued that some of the most important components of fitness for rugby union players are aerobic capacity, muscular strength, muscular endurance, speed and muscle power output. Furthermore, a few studies have shown the relevant importance of body stature and mass for performance in rugby at the professional, age group or senior levels, with the bigger players generally being more successful.

It is also evident that there are significant differences between the characteristics of the Forwards and Backs within a team. Studies show that the Forwards are the bigger and stronger players, whereas the Backs are the faster and fitter players. However, when adjusted for body mass, the difference in strength to body mass ratio is in favor of backline players.

Research describing the morphological and physical characteristics of players is important not only from a 'talent identification' perspective, but also for strength and conditioning specialists who are required to prescribe training to meet the changing demands of the game. There are still many unanswered questions regarding the trends of the size and physical capabilities of players since the inception of the professional era, such as;

- 1) involvement of nutrition and the so called supplement boom
- 2) implementation of advanced strength and conditioning programmers
- 3) Coaching ethos

Therefore it is important that the trends are identified to ensure that players of the future are well established before competing at this level.

1.11 Research Aims & Objectives

The aim of this study was to compare changes in the physical and morphological characteristics of South Africa's National U/20 rugby union players (Forwards and Backs) over a 12 year period from 1998 - 2010. This period spans an era starting just after the onset of professionalism of the game to the modern era where the influence of professionalism has filtered down to junior (U/20) levels. Any changes in morphology and physical ability of the players can be attributed to the changes in the demands of the game and reflect the characteristics that are required for a player to be successful at that level. The magnitude of the competition at this level has increased significantly as shown by the attendance of over 35000 people at the 2012 final of the annual Junior World Championship played in South Africa between South Africa and New Zealand.

1.12 Research Methods

The study is a retrospective descriptive study. Approval for the study was granted by the research and ethics committee of the University of Cape Town (*HREC REF 001/2011*). All the players participating in the study were required to complete a standard consent form as set out by the Discovery High Performance Centre (HPC) of the Sports Science Institute of South Africa (SSISA). The evaluation also included a detailed medical history questionnaire (Appendix A). All forms were checked by the tester in charge, who was a Biokineticist, and the medical team (Sports Physician, Physiotherapist, Biokineticist) that were present with the squad. Any contraindications to testing were highlighted, and these players were excluded from that particular test if necessary. A clause included in the consent form was for permission for the SSISA to use the data for research when or if required, with the players anonymity being guaranteed.

1.13 Hypothesis

H1: It is hypothesized that secular increases in body mass, absolute strength as well as local muscular endurance will be most significant over the 12 year period.

Ho: No changes in any physiological and/or anthropometrical variables will be seen over the 12 year period.

Chapter Two:

METHODOLOGY

University of Cape Town

2. Methodology

2.1 Study population

The population sample consisted of u/20 rugby players who represented the junior South African National team between 1998 – 2010 ($n = 453$). The group was divided into two; Forwards ($n = 256$) and Backs ($n = 197$). The players had a mean age at the time of testing of 18.1 ± 0.7 years old. All players gave their permission to be tested and an informed consent form was signed (Appendix A). Players were tested in either December or January of 1998 – 2010. However it is important to note that the inaugural Junior World Championships was in 2002, and was competed at U/21 level (2002 – 2006), the U/19 level competition was introduced in 2007 and the U/20 competition replaced both these formats in 2008². However, only data for those players who were aged 20 years or younger at the time of representing the junior South African National team were analysed.

2.2 Physiological testing protocol

The test protocol consisted of an evaluation of the anthropometric (stature, body mass, body fat %) and physical characteristics (upper body absolute strength, upper body muscular endurance, sprinting speed and aerobic capacity). The test battery was described in the testing protocol manual of the HPC and therefore all protocols were administered similarly over the study. All testing sessions took place indoors at SSISA under the supervision of a Biokineticist trained in the testing protocol and procedures. Although testing occurred intermittently throughout the year, the data from either the January or December testing session were used for this study. This decision was made because the majority of data collected was at this time, during the build up towards the Junior World Championships each year. A comparison of the test results in January and December showed that the data could be used inter-changeably. This comparison is shown in detail in Appendix B.

2.3 Statistical analysis

Data were processed using Statistica version 10 (StatsSoft Inc. USA). In 2008 testing did not occur in January or December, therefore there are no data for this year. Descriptive statistics were used to analyze the data for each year and group (Forwards and Backs). Data are represented as means \pm 95 % confidence intervals. A Levene's test of homogeneity was used to determine whether the variance for each variable was equal. A two-way analysis of variance was used to determine whether there were significant differences for either main effect of 'year' or 'position' or for the interaction between 'year x position'. If the main effect of 'year' or

interaction (“year x position”) was significant, a Tukey *post hoc* test was used to identify specific differences. Statistical significance was accepted when $p < 0.05$. Graphical representation of the differences between the Forwards and Backs as well as the effects of changes over time for Backs and Forwards are displayed in chapter 3. For certain variables the numbers of players in the division of the Backs and Forwards differs from the total number of subjects due to missing data from the database. The Cohen’s effect size (ES) was calculated to quantify the magnitude of difference between groups and subgroups using the nomenclature categorization of ES according to 0.2 (small), 0.5 (medium), 0.8 (large)⁵⁰.

2.4 Validity and reliability of testing procedures

Validity and reliability of testing protocols are the two most fundamental aspects that need to be adhered to when testing elite athletes. Validity refers to the degree to which the test measures, what it is supposed to measure¹⁹. Hence, construct validity is important to ensure that the selected tests are valid and measure what has been set out to measure¹⁹.

Reliability is a measure of the degree of consistency and repeatability of a test¹⁹. According to the National Strength and Conditioning Association (NSCA) there are a few factors which may affect the reliability of a test battery, namely¹⁹.

1. **Inter-rater reliability**
2. **Intra-rater variability**
3. **Intra-subject variability**
4. **Test validity**

According to *Thomas et al* (2005), the technical error of measurement (TEM) can be attributed to four different sources⁵¹:

1. **Participants:** This may include many factors such as mood, motivation, health and familiarity with the tests.
2. **The testing:** Testing instruction and the lack of clarity of these instructions may induce errors with the procedures of the tests.
3. **Scoring:** errors are associated with scoring due to the competence, dedication and experience of the scorers.
4. **Instrumentation:** it is important that all mechanical and electronic equipment used in the testing batter are calibrated prior to testing to ensure reliability of the scores obtained.

TEM was determined using the spreadsheet “Reliability from consecutive pairs of trials”, downloaded from www.sportsci.org⁵². While it is best practice to generate the technical error of measurement (TEM) from one’s own laboratory, this was not always possible, therefore previously established values from other laboratories have sometimes been used (in this case a reference will be provided). TEM generated in this laboratory will be referenced as HPC data. TEM is the magnitude of the error expressed as the standard deviation of the estimate for a particular variable^{51,52}.

2.5 Anthropometric Evaluation

The anthropometric evaluation for each subject consisted of body stature (cm), body mass (kg) and body fat (%).

2.5.1 *Body mass:*

Each player was weighed on an electronic scale (MVW Industrial Floor scale; 200kg capacity) while barefoot and wearing only shorts and a t-shirt. Each player was instructed to stand with his weight distributed evenly on both feet and his hands at his side and to look directly ahead. Body mass was recorded in kilograms (kg) to the nearest 100th gram (0.1kg). (TEM = 0.48kg, CI 0.33 – 0.83kg; TEM as % CV = 0.6%, CI 0.4 -0.7%) (HPC data).

2.5.2 *Stature:*

The measurement was recorded with the subject barefoot with his arms hanging by his sides. His heels, buttocks, upper back and head were in contact with the stadiometer (SECA Leicester 214 stadiometer). The measurement was recorded as the height from the floor to the vertex of the head. The vertex is defined as the highest point on the skull when an imaginary line between the lower margin of the eye socket and the upper margin of the zygomatic bone is parallel to the ground. The measurement was recorded at the point of deep inhalation to the nearest millimeter. (TEM = 0.33cm, CI 0.26 – 0.44cm; TEM as % CV = 0.2%, CI 0.2 -0.3%)(HPC data).

2.5.3 *Skinfolds:*

The four skinfold sites (Triceps, Biceps, Subscapularis and Supra-iliac) were identified and clearly marked. The skinfold thickness was measured by grasping a fold of skin and the underlying subcutaneous tissue between the thumb and forefinger, 1-2cm above the site to be measured. The fold was pulled away from the underlying muscle and the jaws of the calipers were placed on either side of the site, at a depth of approximately 1cm and at a right angle to the fold. The

skinfold was held throughout the application of the caliper and the reading was recorded when the needle became steady after the full pressure of the calipers had been applied. All the measurements were on the right side of the player. The measurement was recorded to the nearest mm. Harpenden Skinfold Calipers (Medical Devices Directive 93/42/EEC for a class 1 Device with measuring function and is calibrated using masters traceable to National Standards) where used for all measurements. A Biokineticist trained in anthropometry did all measurements. Therefore it is expected that the inter-rater variability would be relatively low.

2.5.3.1 The four skinfolds measured were as follows:

2.5.3.2 Triceps skinfold:

The fold is vertical and is measured from the posterior surface of the arm midway between the top of the shoulder (Acromion process) and the elbow (Olecranon process). The players were instructed to let their arms hang loosely by their sides while the measurement was recorded. (TEM = 0.6mm, CI 0.49 – 0.76mm; TEM as % CV = 7.2%, CI 5.9 -9.2%)(HPC, data).

2.5.3.3 Biceps skinfold:

The measurement was recorded from the front of the subject, on the anterior surface of the arm midway between the top of the shoulder and the elbow. The arm was in the same position as for the triceps skinfold. (TEM = 0.30mm, CI 0.24 – 0.40mm; TEM as % CV = 9.6%, CI 0.8 - 13.1%)(HPC data).

2.5.3.4 Subscapularis skinfold:

The player was instructed to stand with his arms at his side. The fold was in an oblique plane just below the inferior angle of the scapula, descending laterally and downwards at an angle of approximately 45° to the horizontal. (TEM = 0.64mm, CI 0.51 – 0.86mm; TEM as % CV = 7.4%, CI 5.9 -10.0%)(HPC data).

2.5.3.5 Supra-iliac skinfold:

The player stood with the abdominal muscles relaxed. The measurement was taken 5cm above the iliac crest. The fold is an oblique fold descending medially and downwards at an angle of 45° to the horizontal. (TEM = 0.64mm, CI 0.51 – 0.86mm; TEM as % CV = 6.1%, CI 4.8 - 8.2%)(HPC data).

2.5.4 *Body Fat %*

Percentage body fat can be calculated from the skinfolds measurements using the *Durnin and Womersley* (1974) body density equation together with the Siri equation⁴⁵. The *Durnin and Womersley* equation is used to estimate the body density, calculated from age (years), sum of 4 skinfold sites (Biceps, Triceps, Subscapularis and Supra-Iliac)(mm) and body mass (kg)⁵³. The body density was then substituted into the Siri equation (1961) ($Body\ Fat\ \% = 495 / Body\ Density - 450$) to calculate the percentage body fat⁵⁴. (TEM = 0.34%, CI 0.27 – 0.46%; TEM as % CV = 2.7%, CI 2.2 - 3.7%)(HPC data).

2.6 Physical Tests

2.6.1 *Muscle strength (1RM bench press)*

The one repetition maximum (1RM) bench press test was used to evaluate the player's maximal upper body strength. The test was conducted according to the National Strength and Conditioning Association (NSCA) 1RM testing protocol. According to this protocol players were supine on a bench in the five point contact position, with their feet flat on the floor and their hips and shoulders in contact with the bench. The players were instructed to grip the bar with a hand spacing of 1.5 times the biacromial width. All players completed a light warm-up including dynamic movements of the upper torso as well as set of 5 - 10 repetitions at 40-50% of their estimated 1RM. The weight was then increased to 60 - 70% of predicted 1RM and three repetitions were completed. Subjects rested for five minutes before the weight was increased to the estimated 1RM. If the subject completed the repetition successfully the weight was increased by 5-10% . If the attempt was unsuccessful the weight was decreased by 2.5-5%. The next repetition was only attempted after a 4 minute rest period. The maximum weight lifted was recorded as the player's 1RM¹⁹. The tester gave verbal coercion throughout the lift. An attempt was deemed correct if the player lifted the bar in a controlled manner and lowered the bar to the centre of his chest (lightly touching the chest), followed by extending the arms into a fully extended position. The attempted lift was disqualified if the player lifted his buttocks off the bench during the movement, if he bounced the bar off his chest, or if the spotter was required to assist in the lift. The 1RM bench press test is reliable (ICC, R = 0.99; CV = 1.4%) and valid⁵⁵.

2.6.2 *Relative Bench Press*

Relative bench is calculated to allow for size variations within a group. The simplest method of adjusting for size is by using isometric scaling, where the body size is divided by the score obtained for the particular variable tested. For the purpose of this study the equation would be “*Relative bench = Body mass / 1RM Bench Press score*”^{37,38}.

2.6.3 *Muscle endurance*

Upper body muscular endurance was assessed by the pull ups tests conducted during each testing session.

2.6.3.1 *Pull-ups (maximum)*

The test was conducted with an underhand grip and the hands 10-15cm apart. The player started in the hanging position and ascended to a position with his chin above the bar. When returning to the starting position the arms needed to be in the fully extended position. Players were instructed to pull their knees up in the front during the movement to prevent arching of their backs. The maximal number of completed pull-ups was recorded. *Gabbett et al* (2008) showed a TEM for pull ups to be 6.4% and the ICC being $R=0.98$ ⁵⁶.

2.6.4 *Sprint times (10m and 40m)*

The aim of these tests was to determine the player’s top end sprint time (40m) as well as his explosiveness over 10m. Players had a rigorous warm-up supervised by a Biokineticist. The warm-up consisted of 10 minutes of sub-maximal cycling, followed by light jogging with dynamic warm-ups and movement preparation of all major leg musculature. Players were then allowed to do two trial runs on the synthetic rubber surface for 40m at 65% of the maximal effort and then again to the 10m mark at 80% of the maximal effort. Subjects were then given 5 minutes to do additional stretching of their choice. The photoelectric sensors (Brower Speed Trap II wireless sprint system) were placed at the start line and at distances 10m and 40m from the start. Players were instructed to sprint maximally from a sprinter start position, for 40m through the sensors. Each subject completed two maximal effort runs separated by a 5 minute recovery period. Times were automatically recorded at 10m and 40m sprint times respectively. *Gabbett et al*, showed test-retest reliability of the 10m and 40m sprint to be $R= 0.95$ and 0.97 respectively, with a TEM of 1.8% and 1.2% respectively⁵⁶.

2.6.5 *Aerobic Capacity (20m Multi-stage shuttle run test)*

The 20m multistage shuttle run was used to assess the endurance capacity of the players^{47,57}. A 20m distance was measured and marked out on the floor. Subjects were instructed to run between the lines, and attempt to complete each 20m distance and turn according to the pace determined by the recorded sound. The test started at a slow speed that increased each minute. If the player failed to keep up with the recorded sound for two consecutive laps, he was withdrawn from the test. The player could however voluntarily withdraw if he felt he was unable to maintain the pace set by the recorded sound. The score for this test was defined as the number of successfully completed laps of 20m.

University of Cape Town

Chapter Three:

RESULTS

University of Cape Town

3. Anthropometric Evaluation

3.1 Body Mass

The body mass of Forwards and Backs between 1998 – 2010 are represented in table 3. Mean body mass for all groups ranged from 82.9 – 100.6 kg, with Forwards (94.1 – 108.1kg) significantly ($p = 0.0001$) heavier than the backline players (73.9 – 87.9 kg). The main effect of year was significant ($p = 0.0001$). A detailed comparison of all significant findings is shown beneath in table 3. There was no significant interaction between (position x year) ($p = 0.66$).

Table 3: Body Mass (kg) for South African National u/20 rugby players. Means are reported as \pm 95% CI

	Backs	- 95% CI	+ 95% CI	n	Forwards	- 95% CI	+ 95% CI	n	All Groups	- 95% CI	+ 95% CI	n
1998	73.9	68.9	79.0	19	99.2	94.7	103.7	20	86.9	81.6	92.2	39
1999	78.0	72.6	83.5	21	96.6	91.3	101.9	22	87.5	82.9	92.2	43
2000	70.5	66.8	74.3	18	94.1	89.4	98.8	20	82.9	78.0	87.8	38
2001	75.2	70.9	79.6	13	97.5	90.8	104.3	20	88.8	83.0	94.5	33
2002	77.2	72.7	81.7	16	96.3	92.2	100.4	19	87.6	83.2	91.9	35
2003	82.2	77.0	87.4	15	99.1	94.8	103.4	19	91.7	87.3	96.0	34
2004	80.1	73.5	86.6	12	98.4	94.1	102.6	18	91.1	86.2	95.9	30
2005	83.1	78.3	88.0	14	100.2	96.1	104.2	20	93.2	89.0	97.3	34
2006	78.6	75.5	81.7	25	99.7	95.8	103.5	32	90.4	86.7	94.2	57
2007	87.8	83.4	92.2	17	104.2	100.4	108.1	22	97.1	93.2	100.9	39
2009	87.4	81.9	92.8	9	108.1	104.3	111.9	16	100.6	95.5	105.7	25
2010	87.9	83.8	92.1	16	106.9	103.0	110.8	25	99.5	95.5	103.5	41
All	79.7	78.2	81.1	195	100.1	98.7	101.4	253	91.2	89.8	92.5	448

Main Effect

Position $p = 0.0001$

Year $p = 0.0001$

Table 4: Post hoc comparison for year (body mass)

Year	p	ES	Nomenclature	Year	p	ES	Nomenclature
1998 vs. 2009	0.02	0.85	Large	2000 vs. 2009	0.0003	1.08	Large
1998 vs. 2010	0.003	0.80	Large	2000 vs. 2010	0.00002	1.18	Large
1999 vs. 2009	0.03	0.85	Large	2002 vs. 2009	0.04	0.92	Large
1999 vs. 2010	0.01	0.74	Medium	2002 vs. 2010	0.01	0.85	Large
2000 vs. 2007	0.001	0.94	Large				

ES - Effect Size: Description of the magnitude of the difference in effect size

The mean body mass (and 95 % CI) are shown for Forwards and Backs in figure 2.

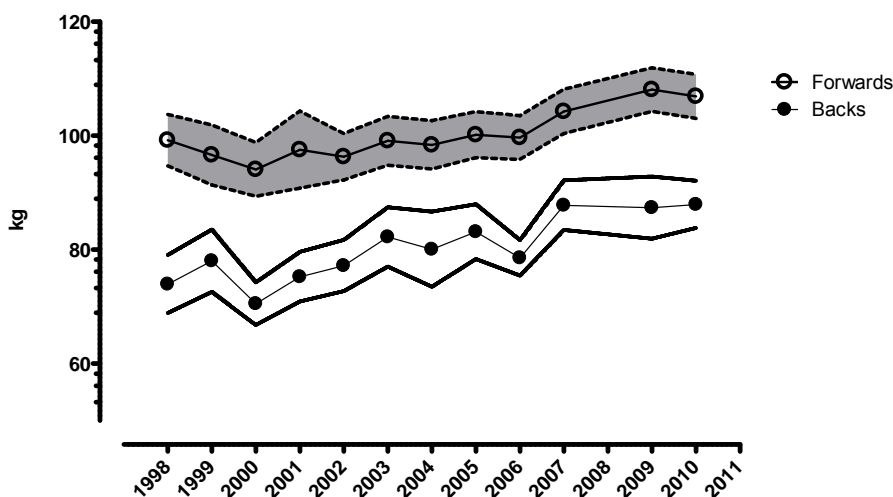


Figure 2: Mean body mass of Forwards and Backs are represented in the graph from 1998 – 2010. Significant comparisons are shown in table 4. Data are shown at mean \pm 95% CI

3.2 Stature

The stature (cm) of all players between 1998 – 2010 is represented in table 5. Mean stature for all groups ranged from 178.5 – 185.8 cm, with Forwards (180.9 – 188.0 cm) significantly ($p = 0.0001$) taller than backline (172.9 – 182.2 cm). The main effect of year was significant ($p = 0.001$)(table 5). There was no significant interaction between (position x year) ($p = 0.75$).

Table 5: Stature (cm) for South African National u/20 rugby players. Means are reported as \pm 95% CI

	Backs				Forwards				All Groups			
	Mean	- 95% CI	+ 95% CI	n	Mean	- 95% CI	+ 95% CI	n	Mean	- 95% CI	+ 95% CI	n
1998	172.9	169.8	176.0	16	184.9	181.0	188.9	18	179.3	176.1	182.5	34
1999	177.0	174.5	179.5	21	185.8	182.3	189.3	22	181.5	179.0	184.0	43
2000	173.4	170.6	176.2	18	183.5	178.8	188.1	20	178.7	175.6	181.8	38
2001	174.5	170.7	178.4	13	180.9	177.4	184.6	21	178.5	175.7	181.3	34
2002	177.8	172.2	183.4	14	187.0	183.2	190.8	18	183.0	179.5	186.5	32
2003	179.1	171.7	186.6	10	185.3	180.2	190.3	15	182.8	178.7	186.9	25
2004	176.3	172.8	179.8	12	183.9	179.4	188.4	18	180.9	177.7	184.0	30
2005	177.4	173.6	181.1	14	186.1	181.9	190.2	20	182.5	179.3	185.6	34
2006	176.0	173.6	178.4	25	186.5	183.9	188.9	32	181.9	179.7	184.1	57
2007	182.2	179.4	184.9	17	186.9	183.6	190.2	22	184.8	182.6	187.1	39
2009	181.7	177.7	185.6	9	188.0	183.5	192.7	16	185.8	182.4	189.1	25
2010	178.7	175.6	181.7	16	187.2	184.4	190.1	25	183.9	181.5	186.3	41
All	177.0	176.0	177.9	185	185.6	184.5	186.6	247	181.9	181.1	182.7	432

Main Effect

Position $p = 0.0001$

Year $p = 0.001$

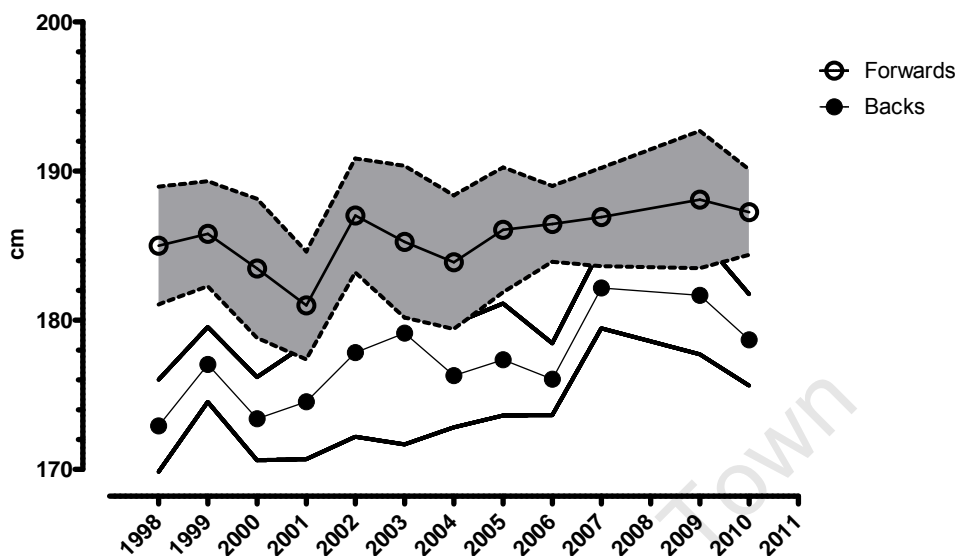


Figure 3: Mean stature of Forwards and Backs are represented in the graph from 1998 – 2010. No significant interactions were observed.

3.3 Body fat percentage

Body Fat % is represented for all players from 1998 – 2010 in table 6. Mean scores for all groups were estimated between 14.4 – 20.1%. Backline players’ mean body fat percentage was significantly ($p= 0.0001$) lower, than that of Forwards. Backs averaged between 12.2 – 18.2% whereas Forwards ranged between 16.3 – 22.1%. The main effect of year was significant ($p= 0.001$). Table 7 below details these significant findings. There was no significant interaction between (position x year) ($p = 0.75$). It is important to note that missing data would significantly influence the results of this variable and the interpretation of any trend over time.

Table 6: Body fat % for South African National u/20 rugby players. Means are reported as \pm 95% CI

	Backs	- 95% CI	+ 95% CI	n	Forwards	- 95% CI	+ 95% CI	n	All Groups	- 95% CI	+ 95% CI	n
1998	14.2	12.3	16.1	14	17.7	15.8	19.6	18	16.2	14.7	17.6	32
1999	18.2	16.6	19.8	21	22.1	19.8	24.4	19	20.1	18.6	21.5	40
2000	12.2	11.2	13.2	18	16.3	14.6	18.1	20	14.4	13.2	15.6	38
2001	15.4	12.0	18.8	12	18.7	16.4	21.0	20	17.5	15.6	19.4	32
2002	-	-	-	0	-	-	-	0	-	-	-	0
2003	-	-	-	0	-	-	-	0	-	-	-	0
2004	-	-	-	0	-	-	-	0	-	-	-	0
2005	-	-	-	0	-	-	-	0	-	-	-	0
2006	13.9	13.1	14.8	25	18.1	16.6	19.5	32	16.2	15.2	17.3	57
2007	-	-	-	0	-	-	-	0	-	-	-	0
2009	13.0	11.8	14.3	9	18.9	17.5	20.3	16	16.8	15.3	18.3	25
2010	13.9	12.9	14.9	16	16.8	15.3	18.3	25	15.7	14.6	16.7	41
All	14.4	12.8	16.0	115	18.4	16.6	20.2	150	16.7	15.3	18.1	265

Main Effect

Position p = 0.0001

Year p = 0.001

Table 7: Post hoc comparison for year (body fat %)

<i>Year</i>	<i>p</i>	<i>ES</i>	<i>Nomenclature</i>	<i>Year</i>	<i>p</i>	<i>ES</i>	<i>Nomenclature</i>
1998 vs. 1999	0.001	0.83	Large	1999 vs. 2006	0.001	1.14	Large
1999 vs. 2000	0.001	1.14	Large	1999 vs. 2010	0.001	0.98	Large

The mean body fat % (and 95 % CI) is shown for Forwards and Backs in figure 4.

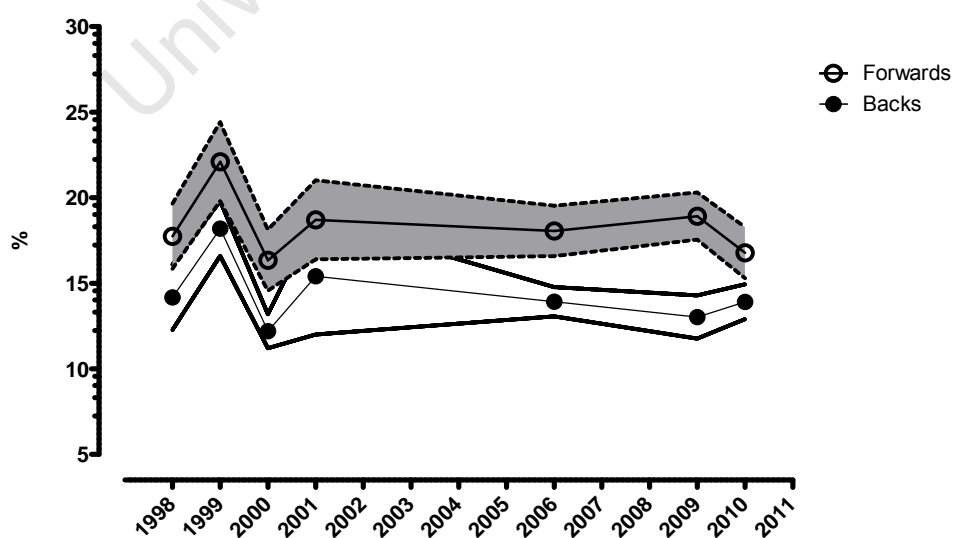


Figure 4: Mean body fat % of Forwards and Backs are represented in the graph from 1998 – 2010. Significant findings are shown in table 7.

3.4 Physical Evaluations

3.4.1 Bench Press

The bench press scores of Forwards and Backs between 1998 – 2010 are represented in table 8. The bench press score for all groups ranged from 89 -135 kg. The mean scores of the Forwards between 1998 – 2010 ranged from 90 – 138 kg, whereas the mean score of the Backs ranged from 77 – 131kg. The main effects of ‘position’ and ‘year’ were significant ($p= 0.0001$). A detailed comparison of all significant findings is shown beneath table 8. There was no significant interaction between (position x year) ($p = 0.37$).

Table 8: Absolute strength (kg) for South African National u/20 rugby players. Means are reported as \pm 95% CI

	Backs	- 95% CI	+ 95% CI	n	Forwards	- 95% CI	+ 95% CI	n	All Groups	- 95% CI	+ 95% CI	n
1998	77	70	85	19	99	93	106	20	89	83	94	39
1999	79	70	87	21	102	96	108	20	90	84	96	41
2000	80	70	89	12	90	81	98	20	86	80	92	32
2001	80	71	88	10	106	90	123	12	94	83	105	22
2002	95	89	101	15	111	104	118	19	104	98	109	34
2003	106	97	115	14	122	112	131	16	114	107	121	30
2004	100	80	120	6	116	105	127	15	111	102	121	21
2005	105	95	116	12	117	108	126	17	112	105	119	29
2006	93	87	100	24	120	113	127	31	108	102	115	55
2007	115	105	125	16	132	123	141	20	124	118	131	36
2009	118	105	130	9	137	125	149	16	130	121	139	25
2010	131	119	142	15	138	128	148	24	135	128	142	39
All	97	93	100	173	116	113	119	230	108	105	110	403

Main Effect

Position $p = 0.0001$

Year $p = 0.0001$

Table 9: Post hoc comparison for year (bench press)

Year	<i>p</i>	<i>ES</i>	<i>Nomenclature</i>	Year	<i>p</i>	<i>ES</i>	<i>Nomenclature</i>
1998 vs. 2003	0.001	1.12	Large	2000 vs. 2006	0.001	0.94	Large
1998 vs. 2004	0.01	1.01	Large	2000 vs. 2007	0.001	1.41	Large
1998 vs. 2005	0.001	1.08	Large	2000 vs. 2009	0.001	1.49	Large
1998 vs. 2006	0.001	0.83	Large	2000 vs. 2010	0.001	1.54	Large
1998 vs. 2007	0.001	1.34	Large	2001 vs. 2003	0.04	0.86	Large
1998 vs. 2009	0.001	1.45	Large	2001 vs. 2007	0.001	1.15	Large
1999 vs. 2003	0.001	1.05	Large	2001 vs. 2009	0.001	1.23	Large
1999 vs. 2004	0.03	0.93	Large	2001 vs. 2010	0.001	1.36	Large
1999 vs. 2005	0.001	1.01	Large	2002 vs. 2007	0.001	0.97	Large
1999 vs. 2006	0.001	0.68	Medium	2002 vs. 2009	0.001	1.15	Large
1999 vs. 2007	0.001	1.10	Large	2002 vs. 2010	0.001	1.25	Large
1999 vs. 2009	0.001	2.15	Large	2003 vs. 2010	0.001	0.91	Large
1999 vs. 2010	0.001	1.95	Large	2004 vs. 2010	0.01	0.99	Large
2000 vs. 2002	0.001	0.82	Large	2005 vs. 2010	0.001	0.99	Large
2000 vs. 2003	0.02	1.19	Large	2006 vs. 2007	0.04	0.70	Medium
2000 vs. 2004	0.001	1.11	Large	2006 vs. 2009	0.001	0.90	Large
2000 vs. 2005	0.02	1.19	Large	2006 vs. 2010	0.001	1.04	Large

The mean bench press score (and 95 % CI) for Forwards and Backs are shown in Figure 5.

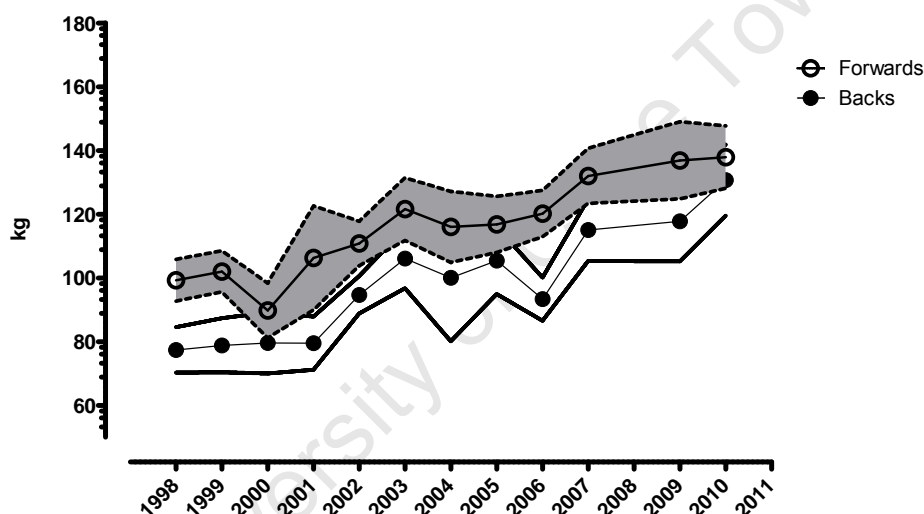


Figure 5: Mean bench press (kg) of Forwards and Backs are represented in the graph from 1998 – 2010. Significant comparisons are shown in table 9.

3.4.2 Relative Bench Press

The absolute strength score, when adjusted for body weight, are represented as relative bench press values, for Forwards and Backs between 1998 - 2010 are shown in table 10. The relative bench press score for all groups ranged from 1.0 – 1.4 kg/kg^{bw}. The mean scores of the Forwards between 1998 – 2010 ranged from 1.0 – 1.3 kg/kg^{bw}, whereas the mean score of the Backs ranged from 1.0 – 1.5 kg/kg^{bw}. The main effects of ‘position’ and ‘year’ were significant ($p= 0.001$) and ($p=0.0001$). A detailed comparison of all significant findings is shown beneath table 10. There was no significant interaction between (position x year) ($p = 0.095$).

Table 10: Relative bench (kg/kg^{bw}) press scores for South African National u/20 rugby players. Means are reported as \pm 95% CI

	Backs	- 95% CI	+ 95% CI	n	Forwards	- 95% CI	+ 95% CI	n	All Groups	- 95% CI	+ 95% CI	n
1998	1.0	1.0	1.1	19	1.0	0.9	1.1	20	1.0	1.0	1.1	39
1999	1.0	0.9	1.1	21	1.0	1.0	1.1	20	1.0	1.0	1.1	41
2000	1.1	1.0	1.2	12	1.0	0.9	1.0	20	1.0	1.0	1.1	32
2001	1.0	0.9	1.2	10	1.1	0.9	1.2	12	1.1	1.0	1.2	22
2002	1.2	1.2	1.3	15	1.2	1.1	1.2	19	1.2	1.1	1.2	34
2003	1.3	1.2	1.4	14	1.2	1.1	1.3	16	1.3	1.2	1.3	30
2004	1.2	1.0	1.4	6	1.2	1.1	1.3	14	1.2	1.1	1.3	20
2005	1.3	1.2	1.4	12	1.2	1.1	1.3	17	1.2	1.1	1.3	29
2006	1.2	1.1	1.3	24	1.2	1.1	1.3	31	1.2	1.1	1.2	55
2007	1.3	1.2	1.4	16	1.3	1.2	1.4	19	1.3	1.2	1.4	35
2009	1.3	1.2	1.5	9	1.3	1.2	1.4	16	1.3	1.2	1.4	25
2010	1.5	1.4	1.6	15	1.3	1.2	1.4	24	1.4	1.3	1.5	39
All	1.2	1.2	1.2	173	1.2	1.1	1.2	228	1.2	1.2	1.2	401

Main Effect

Position $p = 0.0001$

Year $p = 0.001$

Table 11: Post hoc comparison for year (relative bench press)

Year	p	ES	Nomenclature	Year	p	ES	Nomenclature
1998 vs. 2002	0.01	0.0	Trivial	2000 vs. 2002	0.01	0.59	Medium
1998 vs. 2003	0.001	0.5	Medium	2000 vs. 2003	0.001	0.0	Trivial
1998 vs. 2005	0.001	0.53	Medium	2000 vs. 2005	0.001	0.0	Trivial
1998 vs. 2006	0.001	0.59	Medium	2000 vs. 2006	0.01	0.0	Trivial
1998 vs. 2007	0.001	0.48	Small	2000 vs. 2007	0.01	0.0	Trivial
1998 vs. 2009	0.001	0.5	Medium	2000 vs. 2009	0.01	0.0	Trivial
1998 vs. 2010	0.001	0.58	Medium	2000 vs. 2010	0.01	0.18	Trivial
1999 vs. 2002	0.01	0.0	Trivial	2001 vs. 2003	0.02	0.0	Trivial
1999 vs. 2003	0.001	0.53	Medium	2001 vs. 2007	0.001	0.0	Trivial
1999 vs. 2005	0.001	0.56	Medium	2001 vs. 2009	0.001	0.0	Trivial
1999 vs. 2006	0.001	0.59	Medium	2001 vs. 2010	0.001	0.19	Small
1999 vs. 2007	0.001	0.5	Medium	2002 vs. 2010	0.001	0.23	Small
1999 vs. 2009	0.001	0.53	Medium	2005 vs. 2010	0.04	0.22	Small
1999 vs. 2010	0.001	0.58	Medium	2006 vs. 2010	0.001	0.23	Small

The mean relative bench press score (and 95 % CI) for Forwards and Backs are shown in Figure 6.

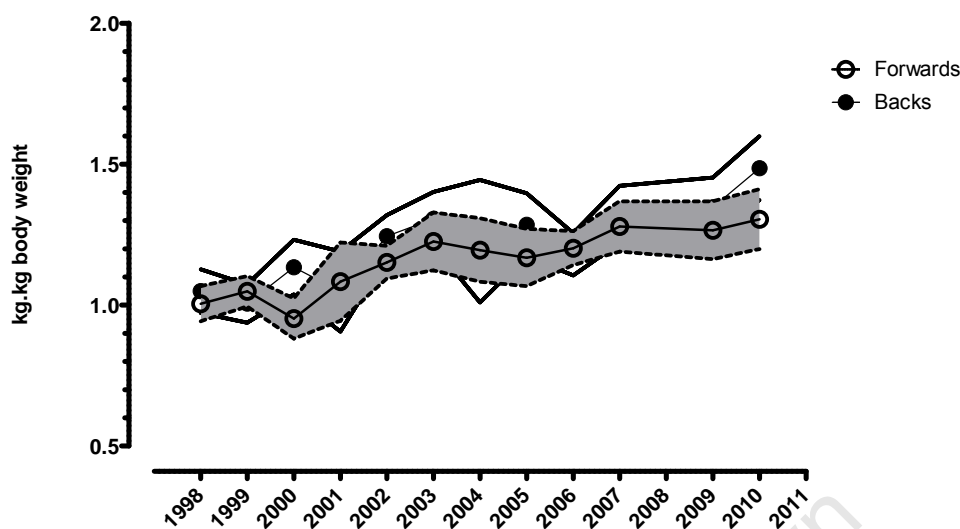


Figure 6: Mean relative bench press ($k.kg^{bw}$) of Forwards and Backs are represented in the graph from 1998 – 2010. Significant comparisons are shown in table 11.

3.4.3 Pull Ups

Pull up scores for Forwards and Backs between 1998 – 2010 are represented in table 12. The pull up score for all groups ranged from 9 – 15 reps. The mean scores of the Forwards between 1998 – 2010 ranged from 7 – 14 reps, whereas the mean score of the Backs ranged from 11 – 21 reps. The main effects of ‘position’ and ‘year’ were significant ($p= 0.0001$). A detailed comparison of all significant findings is shown beneath table 13. There was no significant interaction between (position x year) ($p = 0.12$).

Table 12: Upper body muscular endurance (pull ups) for South African National u/20 rugby players. Means are reported as \pm 95% CI

	Backs	- 95% CI	+ 95% CI	n	Forwards	- 95% CI	+ 95% CI	n	All Groups	- 95% CI	+ 95% CI	n
1998	12	10	14	18	9	7	10	19	10	9	11	37
1999	11	10	13	19	10	8	12	18	11	9	12	37
2000	12	9	14	13	8	6	9	20	9	8	11	33
2001	11	9	13	11	7	5	9	17	9	7	10	28
2002	16	14	18	15	12	10	14	18	14	12	15	33
2003	17	13	20	14	12	10	15	16	14	12	16	30
2004	16	11	21	6	12	10	15	17	13	11	15	23
2005	16	13	19	11	12	10	14	18	14	12	15	29
2006	13	11	15	24	10	8	11	27	11	10	13	51
2007	15	14	17	16	14	11	17	20	14	13	16	36
2009	15	12	18	9	10	8	12	16	12	10	14	25
2010	21	17	25	13	12	10	14	23	15	13	17	36
All	14	13	15	169	11	10	11	229	12	12	13	398

Main Effect

Position $p = 0.0001$

Year $p = 0.001$

Table 13: Post hoc comparison for year (pull ups)

<i>Year</i>	<i>p</i>	<i>ES</i>	<i>Nomenclature</i>	<i>Year</i>	<i>p</i>	<i>ES</i>	<i>Nomenclature</i>
1998 vs. 2003	0.02	0.82	Large	2000 vs. 2010	0.01	0.95	Large
1998 vs. 2007	0.01	0.81	Large	2001 vs. 2002	0.001	1.04	Large
1998 vs. 2010	0.001	0.83	Large	2001 vs. 2003	0.001	1.04	Large
1999 vs. 2007	0.05	0.74	Medium	2001 vs. 2004	0.03	0.97	Large
1999 vs. 2010	0.01	0.77	Medium	2001 vs. 2007	0.001	1.03	Large
2000 vs. 2002	0.01	0.95	Large	2001 vs. 2010	0.01	1.01	Large
2000 vs. 2003	0.001	0.97	Large	2005 vs. 2001	0.001	0.96	Large
2000 vs. 2005	0.02	0.87	Large	2006 vs. 2010	0.01	0.67	Medium
2000 vs. 2007	0.01	0.96	Large				

The mean pull ups score (and 95 % CI) for Forwards and Backs are shown in Figure 7.

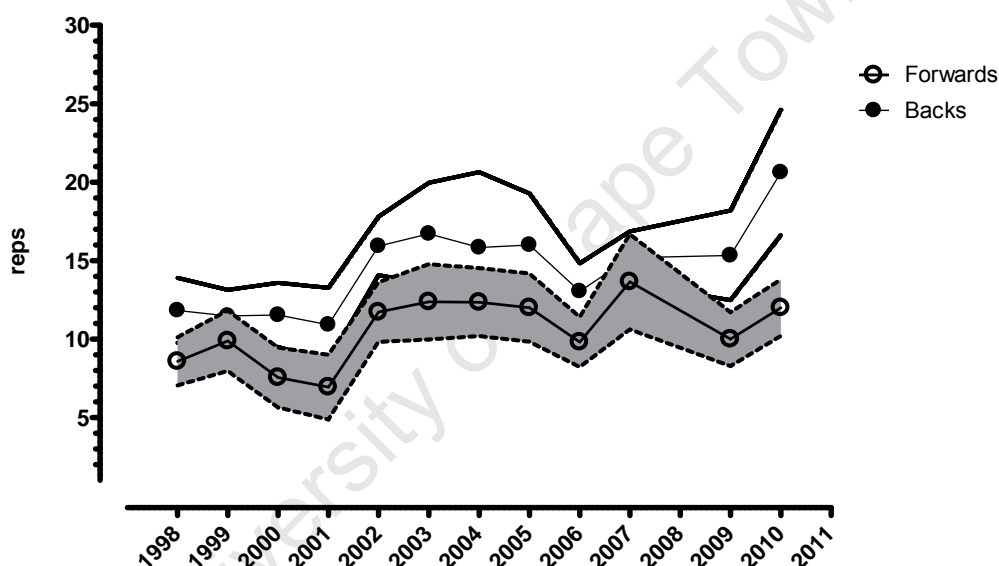


Figure 7: Upper body muscular endurance (pull ups) of Forwards and Backs are represented in the graph from 1998 – 2010. Significant comparisons are shown in table 13.

3.4.4 10 and 40m Sprint Times

The times for the sprint tests for both Forwards and Backs are represented in tables 14 and 15. The data are representative of the times (s) obtained by the players in the national U/20 players between 1998 – 2010. No data were available for 10m sprints for the year 2000. The 10m sprint time for all groups ranged from 1.73 – 1.86s, with the Backs (1.69 – 1.81s) being faster than the Forwards (1.77 – 1.88s). Sprint times over 40m showed similar trends, with Backs being significantly faster than the Forwards. The mean sprint time for all groups over 40m was 5.23 – 5.49s. The respective mean sprint times for Backs and Forwards were; 5.01 – 5.31s and 5.36 – 5.58s. The main effects of ‘position’ and ‘year’ was significant ($p = 0.0001$). A detailed comparison of all significant findings is shown beneath tables 14 and 15.

There was no significant interaction between (position x year) for 40m sprints ($p = 0.45$), however a significant interaction was shown for 10m sprint ($p=0.021$). Table 16 shows the significant findings of the interaction for 10m sprint time.

3.4.4.1 10m Sprint time

Table 14: 10m sprint (s) time for South African National u/20 rugby players. Means are reported as \pm 95% CI

	Backs	- 95% CI	+ 95% CI	n	Forwards	- 95% CI	+ 95% CI	n	All Groups	- 95% CI	+ 95% CI	n
1998	1.83	1.80	1.87	18	1.88	1.85	1.92	16	1.86	1.83	1.88	34
1999	1.79	1.75	1.83	19	1.77	1.71	1.82	16	1.78	1.75	1.81	35
2000	-	-	-	0	-	-	-	0	-	-	-	0
2001	1.81	1.73	1.89	8	1.81	1.76	1.86	19	1.81	1.77	1.85	27
2002	1.80	1.76	1.84	12	1.88	1.84	1.91	18	1.85	1.81	1.88	30
2003	1.77	1.70	1.83	5	1.85	1.81	1.88	18	1.83	1.80	1.86	23
2004	1.77	1.72	1.83	7	1.85	1.81	1.90	15	1.83	1.79	1.87	22
2005	1.77	1.73	1.81	12	1.87	1.83	1.92	14	1.83	1.79	1.86	26
2006	1.76	1.73	1.78	22	1.86	1.84	1.88	31	1.82	1.79	1.84	53
2007	1.75	1.71	1.78	15	1.82	1.79	1.85	17	1.79	1.76	1.81	32
2009	1.72	1.67	1.78	9	1.79	1.74	1.83	16	1.76	1.73	1.80	25
2010	1.69	1.64	1.74	12	1.76	1.71	1.80	21	1.73	1.70	1.77	33
All	1.77	1.76	1.78	139	1.83	1.82	1.84	201	1.81	1.80	1.82	340

Main Effect

Position $p = 0.0001$

Year $p = 0.0001$

Position x Year $p = 0.021$

Table 15: Post hoc comparison for year (10m Sprint)

Year	P	ES	Nomenclature	Year	P	ES	Nomenclature
1998 vs. 2003	0.001	1.12	Large	2001 vs. 2003	0.04	0.86	Large
1998 vs. 2004	0.01	1.01	Large	2001 vs. 2007	0.001	1.15	Large
1998 vs. 2005	0.001	1.08	Large	2001 vs. 2009	0.001	1.23	Large
1998 vs. 2006	0.001	0.83	Large	2001 vs. 2010	0.001	1.36	Large
1998 vs. 2007	0.001	1.34	Large	2002 vs. 2007	0.001	0.97	Large
1998 vs. 2009	0.001	1.45	Large	2002 vs. 2009	0.001	1.15	Large
1999 vs. 2003	0.001	1.05	Large	2002 vs. 2010	0.001	1.25	Large
1999 vs. 2004	0.03	0.93	Large	2003 vs. 2010	0.001	0.91	Large
1999 vs. 2005	0.001	1.01	Large	2004 vs. 2010	0.01	0.99	Large
1999 vs. 2006	0.001	0.68	Medium	2005 vs. 2010	0.001	0.99	Large
1999 vs. 2007	0.001	1.10	Large	2006 vs. 2007	0.04	0.70	Medium
1999 vs. 2009	0.001	2.15	Large	2006 vs. 2009	0.001	0.90	Large
1999 vs. 2010	0.001	1.95	Large	2006 vs. 2010	0.001	1.04	Large

Table 16: Post hoc comparison for year \times position (speed 10m)

<i>Year</i>	<i>p</i>	<i>ES</i>	<i>Nomenclature</i>
<i>Backs</i>			
1998 vs. 2010	0.001	1.40	<i>Large</i>
<i>Forwards</i>			
1998 vs. 1999	0.005	1.10	<i>Large</i>
1998 vs. 2010	0.001	1.10	<i>Large</i>
1999 vs. 2002	0.014	1.10	<i>Large</i>
1999 vs. 2005	0.04	1.00	<i>Large</i>
2002 vs. 2010	0.001	1.09	<i>Large</i>
2005 vs. 2010	0.01	1.10	<i>Large</i>
2006 vs. 2010	0.003	1.00	<i>Large</i>

The mean 10m sprint times (and 95 % CI) for Forwards and Backs are shown in Figure 8.

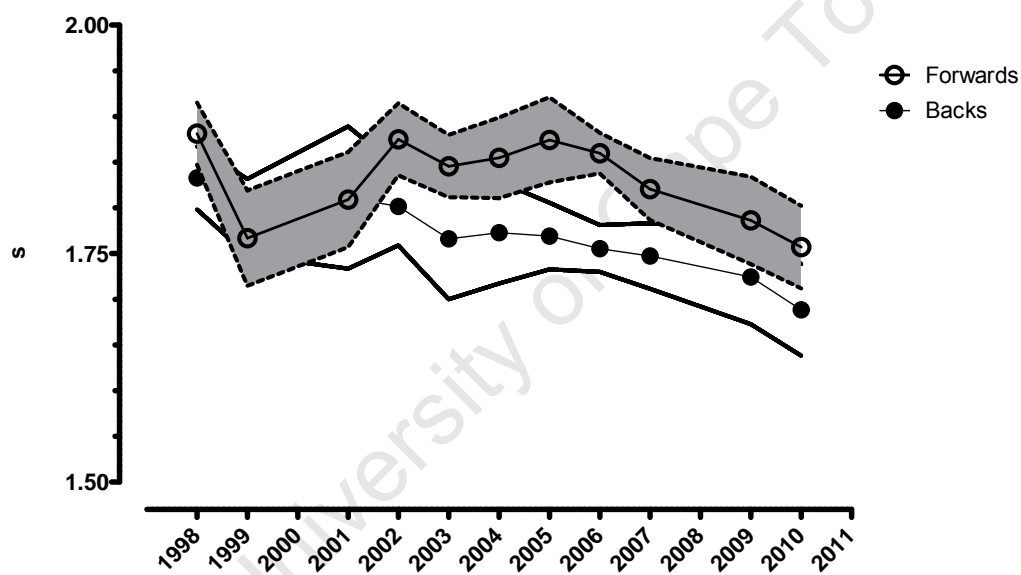


Figure 8: 10m sprint time of Forwards and Backs are represented in the graph from 1998 – 2010. Significant comparisons are shown in table 15 and 16.

3.4.4.2 40m Sprint time

Table 17: 40m sprint (s) time for South African National u/20 rugby players. Means are reported as \pm 95% CI

	Backs	- 95% CI	+ 95% CI	n	Forwards	- 95% CI	+ 95% CI	n	All Groups	- 95% CI	+ 95% CI	n
1998	5.31	5.24	5.38	18	5.58	5.49	5.68	16	5.44	5.37	5.51	34
1999	5.31	5.21	5.42	19	5.43	5.32	5.54	16	5.37	5.29	5.44	35
2000	5.06	4.95	5.16	10	5.46	5.31	5.60	15	5.30	5.17	5.42	25
2001	5.27	5.09	5.44	8	5.58	5.45	5.72	19	5.49	5.37	5.61	27
2002	5.21	5.14	5.28	12	5.50	5.38	5.62	18	5.38	5.29	5.48	30
2003	5.23	5.05	5.40	5	5.50	5.40	5.60	18	5.44	5.34	5.54	23
2004	5.17	5.00	5.35	7	5.50	5.39	5.61	15	5.39	5.29	5.50	22
2005	5.16	5.05	5.26	12	5.54	5.42	5.66	14	5.36	5.26	5.47	26
2006	5.18	5.12	5.24	22	5.53	5.45	5.61	31	5.39	5.32	5.46	53
2007	5.11	5.05	5.17	15	5.43	5.32	5.54	17	5.28	5.20	5.36	32
2009	5.16	5.02	5.29	9	5.49	5.37	5.61	16	5.37	5.26	5.48	25
2010	5.01	4.93	5.08	12	5.36	5.22	5.50	20	5.23	5.12	5.34	32
All	5.19	5.16	5.22	149	5.49	5.46	5.52	215	5.37	5.34	5.39	364

Main Effect

Position $p = 0.0001$

Year $p = 0.001$

Table 18: Post hoc comparison for year (40m Speed)

Year	p	ES	Nomenclature	Year	p	ES	Nomenclature
1998 vs. 2010	0.04	0.61	Medium	2001 vs. 2010	0.01	0.84	Large

The mean 40m sprint times (and 95 % CI) for Forwards and Backs are shown in Figure 9.

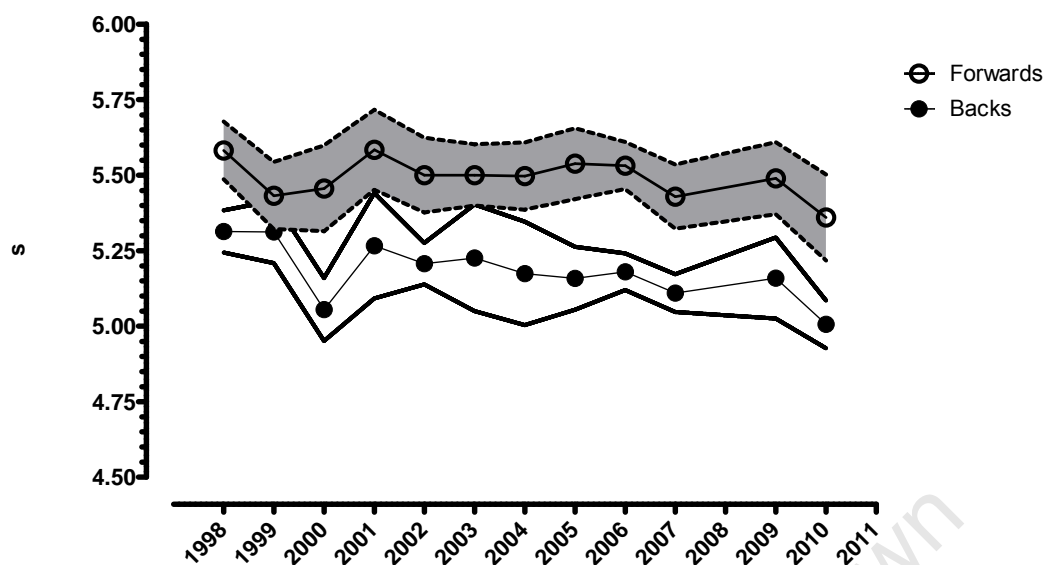


Figure 9: 40m sprint time of Forwards and Backs are represented in the graph from 1998 – 2010. Significant comparisons are shown in table 18.

3.4.5 Aerobic Capacity

Tables 17 and 18 represent the mean number of shuttles completed in the MSSRT for both Forwards and Backs between 1998 – 2010. The mean number of shuttles completed for both groups ranged between 90 – 105, and mean $\dot{V}O_2$ max ranged between 49.1 – 52.3 ml.kg.min⁻¹. Backline players on average showed a greater aerobic capacity (97 – 105 shuttles & 51.5 – 54.0 ml.kg.min⁻¹) than their counterparts (86 – 102 shuttles & 48.0 – 53.0 ml.kg.min⁻¹). No data were available for 2002 and 2010. The main effect of ‘position’ was significant ($p=0.0001$), however ‘year’ was not ($p=0.929$). Furthermore, no significant interaction was shown between ‘year x position’. (See also Appendix C for predicted $\dot{V}O_2$ max values)

3.4.5.1 Multi-Stage Shuttle Run Test (shuttles)

Table 19: Aerobic capacity (MSSRT) (Shuttles) for South African National u/20 rugby players. Means are reported as \pm 95% CI

	Backs	- 95% CI	+ 95% CI	n	Forwards	- 95% CI	+ 95% CI	n	All Groups	- 95% CI	+ 95% CI	n
1998	101	94	108	18	87	78	96	16	94	89	100	34
1999	102	93	110	16	92	81	102	16	97	90	103	32
2000	105	95	114	12	91	78	105	18	97	88	105	30
2001	105	93	118	8	83	73	92	18	90	81	98	26
2002	-	-	-	0	-	-	-	0	-	-	-	0
2003	105	87	122	4	93	85	101	16	95	88	102	20
2004	103	93	113	7	89	80	98	14	93	86	101	21
2005	104	98	110	13	90	81	99	15	97	91	103	28
2006	103	98	108	23	93	86	99	28	97	93	102	51
2007	97	90	104	12	102	92	112	15	100	94	106	27
2009	101	92	111	9	86	77	94	15	92	85	98	24
2010	-	-	-	0	-	-	-	0	-	-	-	0
All	102	100	105	122	91	88	93	172	95	93	97	294

Main Effect

Position $p = 0.0001$

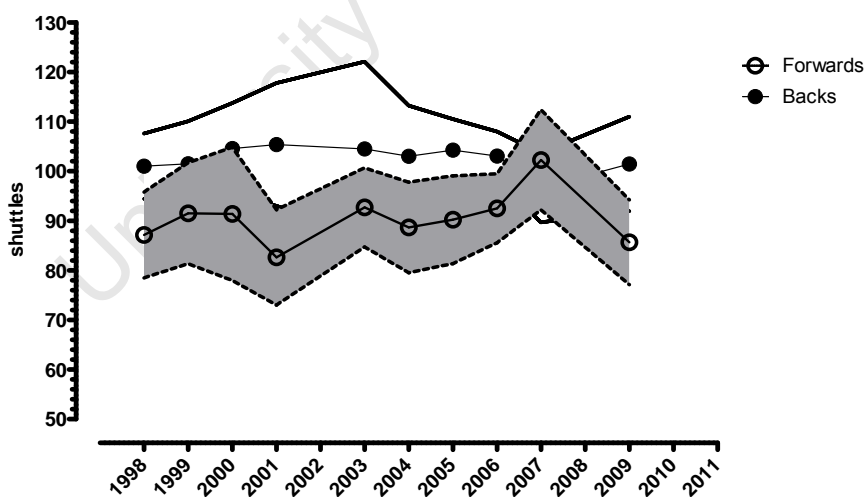


Figure 10: Aerobic capacity of Forwards and Backs are represented in the graph from 1998 – 2010.

It is evident that there were significant differences in the anthropometrical and physical fitness data for both the Forwards and Backs. In addition, as shown in the data certain variables (body mass, muscular strength, muscular endurance and sprinting performance) showed significant changes over time. This is an important finding, as it confirms that the changing demands of the game, particularly since the game became professional, are met by changes in morphological and physical characteristics of the players.

The differences between the Forwards and Backs have been summarized, by expressing the differences between each variable tested as a percentage (Figure 11).

Backs were superior in the following components of fitness:

1. **Local muscle endurance:** 24 % greater number of pull up repetitions
2. **Aerobic endurance:** 11% greater number of completed shuttles run in MSSRT
3. **40m Sprint:** 5% faster time recorded over 40m
4. **10m Sprint:** 3% faster time recorded over 10m
5. **Body Fat %:** 23% less body fat percentage

Forwards were superior in the following components of fitness:

1. **Stature:** 5% greater stature (cm)
2. **Body Mass:** 23% heavier (kg)
3. **Absolute strength:** 18 % more mass lifted in 1 repetition bench press

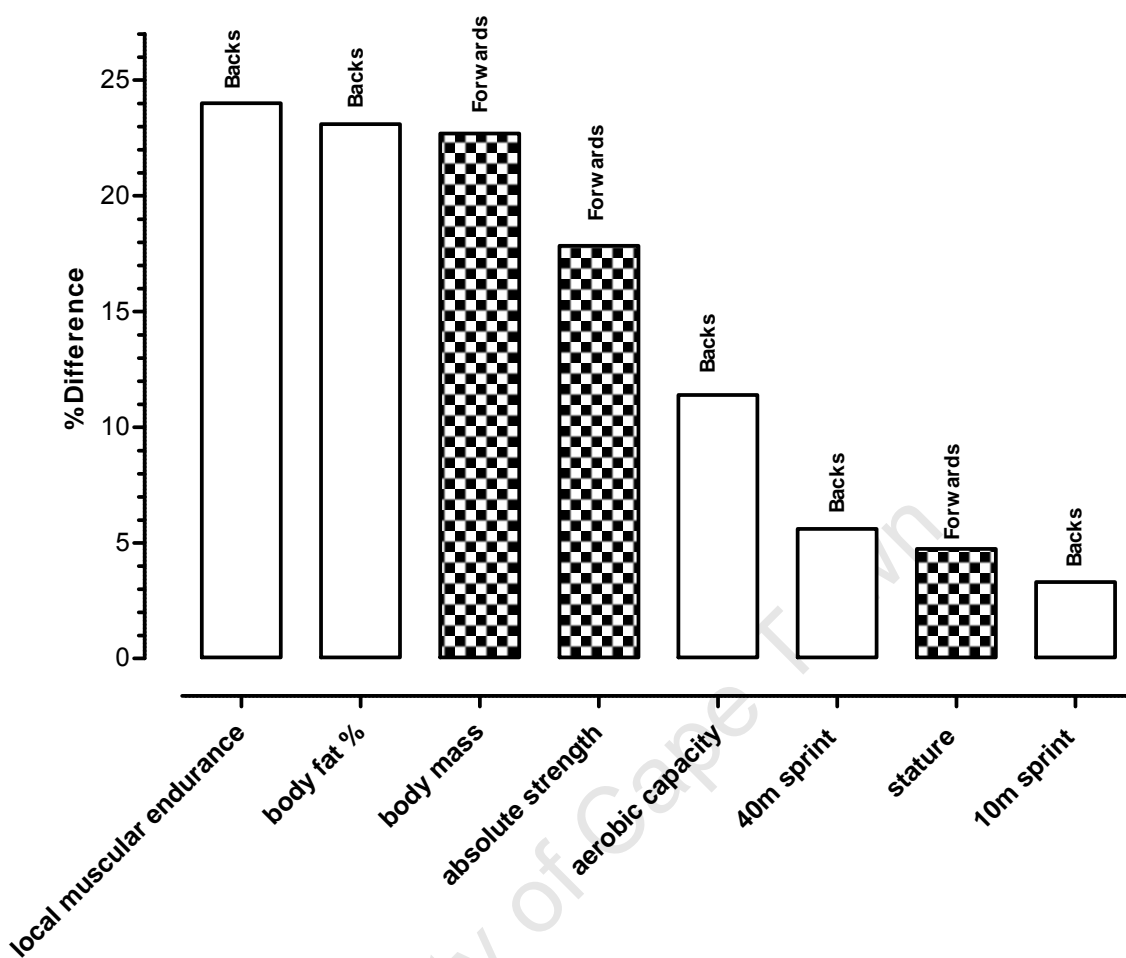


Figure 11: Percentage differences between forwards and backs for each variable tested between 1998 - 2010

Lastly, figure 12 depicts all the variables for all groups and their relevant changes over time. This shows how body mass has increased at a considerable rate when compared to height. The figure also shows how sprint times, muscular strength and endurance have all improved in relation to the increase to body mass. However, it also indicates the slight decrease in aerobic capacity. Figure 12 is consistent with the notion of the law of diminishing value, in that player who are bigger, faster and stronger today may not meet the physical requirements of athletes of the future. Therefore, modern era rugby players are required to work harder and harder than their predecessors were as the demands of the game have advanced over the past 20 years.

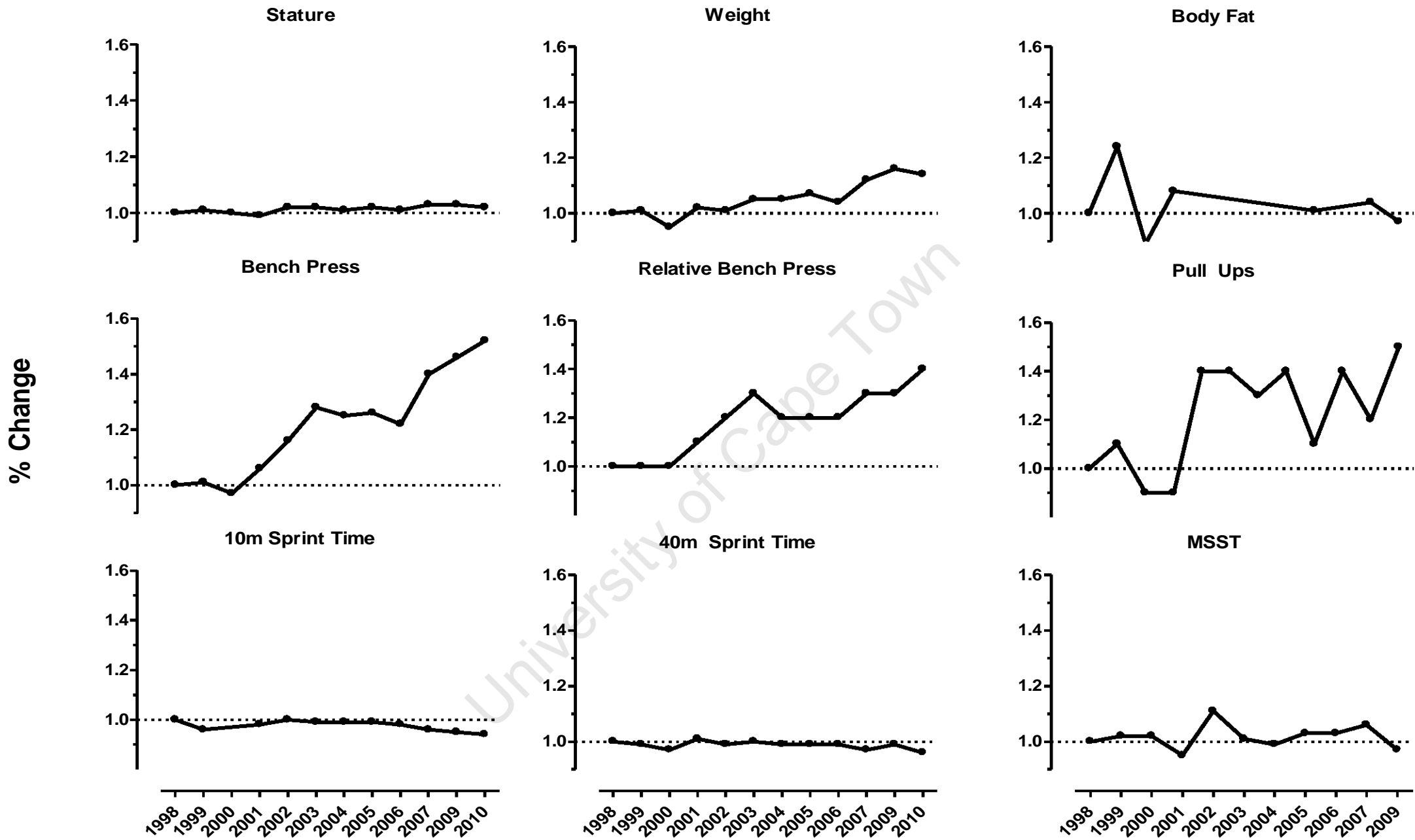


Figure 12: Changes over time represented for all groups for each variable tested. Data are represented as percentages.

Chapter Four

DISCUSSION

University of Cape Town

Modern high performance athletes are exposed to physiological testing and their characteristics are compared to normative data throughout their careers. Even though an athlete's physical abilities are largely innate or genetically predetermined⁵⁸, it is important that these traits are measured and monitored over time. This process serves to identify an athlete's potential to compete at a particular level, when they can return to play following an injury, and predicts their potential for long term success in a particular sport^{19,59}.

It is for these reasons that research into the physiological capacities of athletes within a particular sport and within a specialization associated with the sport is important. In accordance with this the anthropometrical and physical characteristics of the South African National U/20 Rugby Union players were analysed for trends over a 12 year period (1998 – 2010). The following section will discuss the trends in these variables and the differences between the Forwards and Backs. The discussion will be compartmentalized into the different characteristics and then summarized collectively.

4.1. Anthropometrical Data

4.1.1 Body Mass

Body mass of players competing in collision sports is an important anthropometrical variable associated with performance. This is supported by a recent study which showed a significant correlation between an increased body mass and performance in rugby³¹. *Sednead et al* (2012), showed that the Forwards of teams reaching the quarter, semi and finals of the RWC, were significantly heavier than the forwards of the teams who did not reach the finals³¹. The Backs for the same teams were also found to be heavier however the difference was not significant³¹. In addition secular trends indicate that over the past 37 years there has been a general increase in the overall body mass of all rugby players^{13,14,31}.

In the present study, the pooled data showed that Forwards were generally heavier (22%) than Backs. The body mass of the Forwards averaged 99kg in 1998 and increased to 107kg by 2010. The Backs averaged 74kg (1998) and 89kg (2010). The increase in body mass over this period was generally linear for both Forwards and Backs. These trends are consistent with the trends of rugby players in general¹³. It is possible that the transition into the professional era, has increased the awareness of players about good nutrition and year round conditioning training leading to the increase in body mass.

4.1.2 Stature

There was a significant difference between Forwards and Backs, with the Forwards being on average 4.7% taller than the backline players. Although there was a trend for an increase in stature over the study (1998 – 2010) for both Forwards and Backs, this change was not significant. It should be noted that the players in this study were still growing and not at their maximal adult heights. There is a slight increase in height into the early 20's⁶⁰. Certain positions are dependent on having tall players (locks). These players are required to jump in the line out to retrieve the ball and it is generally advantageous that they are the tallest players in the team³³. The fact that stature did not show significant changes over time, in contrast to body mass, can perhaps be explained because stature is 80% heritable and the remaining 20% can be attributed to various factors such as the environment, nutrition, training etc⁵⁸.

4.1.3 Body Fat %

Body fat was measured in this study because leaner more muscular players have a physiological advantage as they produce a great amount of absolute force and are generally faster⁶¹. However, it is acknowledged that body fat predicted from skinfold thickness and body density should be interpreted with caution⁷. In addition, the measurement error between tests is another factor influencing the reliability of testing over a period⁶¹. In this study, which spanned 12 years, there were multiple testers. Therefore, the variability associated with the inter-subject variability may have overridden any changes in body fat. It is with these limitations as background that the body fat measurements in this study are interpreted.

In the present study, Backs had a significantly lower (23%) body fat % compared Forwards. This difference can be considered significant despite the limitations described above. This may be one of the reasons for the Backs running faster over 10m and 40m and having a greater strength to body mass ratio than Forwards. Although there was a slight decrease in body fat % over the duration of the study, the missing data from the study may have impacted on determining any trends over time. Once again, a reduction in body fat may be attributed to the increased awareness of nutritional requirements by professional athletes as well as the increased time allocated for strength training leading to an increase in lean muscle mass.

4.2 Physical Evaluations

4.2.1 Muscular Strength (bench press & relative bench press)

Absolute strength is an important attribute for performance in rugby regardless of playing position. However, certain positions require a greater absolute strength than other positions due to the specific demands of that particular position. Muscular strength, measured in the laboratory, has a strong relationship to performance in the field in contact sports, and more specifically rugby^{15,16}. Hence, muscular strength is an important component of fitness to assess. It is important to note that for the purpose of this study no leg strength test was performed. The main reason for this is due to the complexity of the technique of the most commonly used test, which is the squat.

It is well known in the rugby world that Forwards are bigger players than the Backs. This was confirmed in this study. It is therefore not surprising that the Forwards were 18% stronger than the Backs. However, when the maximal effort strength scores were adjusted for body mass, Backs were stronger per kg body weight. Forwards averaged between 1.0 – 1.3 kg/kg^{bw} and the Backs 1.0 – 1.5 kg/kg^{bw}³⁸.

The changes in absolute strength for the duration of the study were significant with an increase in both the Forwards and the Backs. These data also show that body composition should be considered when interpreting strength data as players with a greater amount of lean muscle mass and less fat mass are at a significant advantage when the expression of strength is normalized.

4.2.2. Muscular Endurance (Pull ups)

Rugby players are expected to produce repeated muscle contractions over the entire duration of a match without showing signs of fatigue and impaired performance. This characteristic is associated with players making multiple tackles, performing optimally at rucks and mauls as well as winning more balls in the line out due to consistent lifting⁶. Players who have none or minimal fatigue have a distinct advantage over players who show symptoms of fatigue. The ability to sustain muscle contractions is measured by the pull ups test. More specifically this test is designed to assess the endurance capacity of the Biceps, Latissimus Dorsi, Anterior Deltoids, and a large portion of the upper medial back⁶². Although the results showed that the Forwards were less fatigue resistant compared to the Backs, they were also heavier which would have been a handicap for them in the test because a heavier player has more mass to lift. Over the 12 year period of the study the Forwards averaged between 7 – 14 repetitions and the Backs 11 – 21 repetitions. Importantly, the data showed that muscular endurance for each year increased with

the greatest increase occurring between 2001 – 2002. In addition, by 2010 the players had performed the most repetitions for any year tested, showing almost 50% improvement from 1998 – 2010 for all groups.

4.2.3 10m & 40m Sprint Times

Testing the sprint ability of the player over 10m and 40m is important as performance over these two distances gives an indication of the player's explosive acceleration (10m) as well as his ability to maintain this over a more sustained distance (40 m)⁷. The data in this thesis showed that Backs are faster over both 10m (5% faster than Forwards) and 40m (3% faster than Forwards). This is consistent with the studies discussed in the review of the literature (Chapter One). However, no significant change over time was noticed.

4.2.4 Aerobic Capacity

It is generally accepted that Forwards have a lower aerobic capacity than Backs⁹. This was supported by the results of this study where the Backs completed on average of between 97 – 105 shuttles compared to the Forwards (86 – 102 shuttles). The lower aerobic capacity in Forwards may be attributed to their heavier body mass, greater stature as well as increased body fat % compared to the Backs. No changes in the aerobic capacity were noticed for the period of this study, with the lowest scores being run in 2001 and 2009. As mentioned earlier in the literature (Chapter One), an increased body mass has a negative correlation with aerobic capacity. Therefore, with the increase in body mass over the course of this study, it may be concluded that this is associated with the observed decrease in aerobic capacity.

Chapter Five

PRACTICAL APPLICATION & CONCLUSIONS

University of Cape Town

The differences between Forwards and Backs have been largely supported in the literature (Chapter One). However, the novel aspects of this thesis are the changes that have occurred in the measured variables over the 12 year period (1998-2010). These changes reflect the changing demands of the game. For example, body mass increased between 20 – 30% from 1998 to 2010. Backs averaged 73kg in 1998 and then increased to 88kg in 2010. The same trend occurred for Forwards, who averaged 99kg in 1998 and increased to 107kg in 2010. This equates to an increase of 1.3kg/annum and 0.7kg/annum increases in body mass for Backs and Forwards respectively over a 12 year period. This followed a slightly lower trend to that presented by *Olds* in 2001 showing that both Forwards and Backs body mass increased over a 14 year period at a rate of 2.6kg per decade^{14,63}. These findings are consistent with those presented by *Sedeaud et al* (2012), who reported that since the start of the professional era, there has been a gradual increase in body mass of rugby union players. This is significant as, in that same study they also showed that body mass is a good predictor of performance³¹. Furthermore, the results are consistent with the findings of other studies, showing that Forwards are significantly heavier than Backs³¹. This is an important characteristic for all Forwards as it has also been shown that they spend the most time in a contact situation, and being heavier ensures they are more tolerant of these impact forces^{64,65}.

Despite data missing for body fat % analysis in 2002 - 2005 and 2007, the general trend for this component was a decrease for both Forwards and Backs. This indicates that the general increase in body mass could be attributed to an increase in lean muscle mass. This may have also accounted for some of the physiological gains over the 12 year period such as the sprint times over 10m and 40m and absolute strength improving for both groups. There were no changes in the relative muscle strength (measured by relative bench press) over the time period of the study. This suggests that the absolute strength developed in proportion to the increase in body mass in both groups. Local muscular endurance (pull ups) also improved over the 12 years suggesting improved resistance to fatigue. The Backs had a larger improvement compared to the Forwards (9 vs. 5 reps).

An explanation for the increase in body mass, presumed to be mainly lean body mass, can be attributed to the game becoming more professional over the course of the study. This resulted in the players being exposed to strength and conditioning routines earlier in their careers. In South Africa, high performance workshops have been conducted at U/16 and U/18 National youth rugby weeks from 2002. During these workshops all players, coaches and administrators were educated on the important role that strength and conditioning plays in rugby.

Furthermore each player received a strength and condition programme that was 1) *age specific* and 2) *rugby specific*. Many of these players, that attended these workshops, may have come through the ranks and benefited from the training programmes they received.

From the data presented above it is plausible that due to the professional era of modern day sports or rugby specifically, players over the years have implemented strategies to gain a physical advantage by becoming bigger, faster and stronger than their opponents. For rugby specifically, due to certain rule changes and regulations placed on the game, heavier and leaner players are more likely to be successful as they are able to handle the increase in occurrences and forces involved in the contact situation^{16,31}. In addition, with contracts becoming available to play rugby as a full time career, players believed that being at a physical advantage may increase their likelihood of playing rugby at a professional level and possibly prolonging their careers.

In conclusion, this study has great implications on future strength and conditioning prescription for all rugby players. It is clear that the game is becoming more physically demanding and that players are required to keep up with these ever changing demands. Players therefore need to ensure that they spend quality time on strength and conditioning as part of their overall preparation for rugby. Furthermore, these training programmes need to ensure that they address all the components of fitness, important to not only rugby but also each position specifically.

Chapter Six

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Chapter Seven

APPENDICES

University of Cape Town

Appendix A

Consent Form

I (print name) _____ hereby consent to participating in the physiological assessment on the following terms:

1. I have been informed about the physiological assessment procedures and understand what I will be required to do.
2. I understand that I will be partaking in physical exercise some of which is at maximal intensity. I understand that there is always a risk of injury associated with high intensity exercise.
3. I understand that I can withdraw my consent, freely and without prejudice, at any time.
4. I have told the testing personnel about any illness or physical defect I have that may contribute to the level of risk.
5. I understand that the information obtained from the test will be treated confidentially with my right to privacy assured. However the information obtained may be used for statistical analysis or scientific purpose with your right to privacy retained.
6. I release the testing personnel from any liability for any injury or illness that I may suffer while undertaking the physical assessment, or subsequently occurring in connection with the assessment, or that is to any extent contributed to by it.
7. I accept however that the testing personnel will take every precaution to ensure that no incidents will occur.

Participant signature _____ Date _____

Parent/Guardian name (if under the age of 18) _____

Parent/Guardian signature _____ Date _____

Players ID number:

Appendix B

Effect Size for all Testing data for January and December

Table 20: Data represented for each variable tested, for both groups. Effect sizes were determined to identify effects of testing over two consecutive months (December and January)

Variable	Dec	Jan	n	p	Effect size	Nomenclature
Height (cm)	185.2 ± 8.3	185.2 ± 8.4	39	0.5	-0.01	Trivial
Weight (kg)	102.0 ± 13.0	101.9 ± 13.4	38	0.7	0.01	Trivial
SUMSK*(mm)	43.6 ± 15.8	41.14 ± 14.43	38	0	0.16	Trivial
Body Fat (%)	16.5 ± 3.9	16.1 ± 3.7	38	0	0.11	Trivial
Pull Ups	13 ± 6	15 ± 6.6	34	0	-0.18	Trivial
Bench Press (kg)	136 ± 22	129 ± 19	37	0	0.34	Small
Speed 10 (s)	1.76 ± 0.10	1.74 ± 0.09	35	0.1	0.2	Small
Speed 40m (s)	5.35 ± 0.29	5.35 ± 0.27	34	0.8	0.02	Trivial
MSST [#] (shuttles)	90 ± 17	94 ± 17	18	0.1	-0.27	Small

Note. Mean Values (±SD) for Height, Weight, Sum of 4 skinfolds (SUMSK), Pull Ups, Bench Press, Speed 10m, Speed 40m, and Multi Stage Shuttle Test (MSST)

Appendix C

Multi-Stage Shuttle Run Test (Predicted V_{O_2} max)

Table 21: Aerobic capacity (MSSRT- V_{O_2} Max) for South African National u/20 rugby players. Means are reported as \pm 95% CI

	Backs	- 95% CI	+ 95% CI	n	Forwards	- 95% CI	+ 95% CI	n	All Groups	- 95% CI	+ 95% CI	n
1998	52.8	50.8	54.7	18	48.2	45.8	50.7	16	50.6	49.0	52.3	34
1999	52.6	50.1	55.2	16	49.7	46.6	52.8	16	51.2	49.2	53.1	32
2000	53.7	51.0	56.3	12	49.4	45.4	53.4	18	51.1	48.5	53.7	30
2001	54.0	50.4	57.5	8	46.9	43.9	50.0	18	49.1	46.5	51.7	26
2002	-	-	-	0	-	-	-	0	-	-	-	0
2003	53.8	48.8	58.8	4	50.3	47.8	52.7	16	51.0	48.9	53.1	20
2004	53.2	50.2	56.1	7	49.0	46.2	51.8	14	50.4	48.2	52.5	21
2005	53.6	51.9	55.4	13	49.5	46.8	52.2	15	51.4	49.7	53.2	28
2006	53.2	51.8	54.7	23	49.9	47.9	52.0	28	51.4	50.1	52.8	51
2007	51.5	49.5	53.5	12	53.0	50.0	55.9	15	52.3	50.5	54.1	27
2009	52.8	49.9	55.6	9	48.0	45.3	50.7	15	49.8	47.7	51.9	24
2010	-	-	-	0	-	-	-	0	-	-	-	0
All	53.0	52.4	53.7	122	49.4	48.6	50.3	172	50.9	50.3	51.5	294

Main Effect

Position

$p = 0.0001$

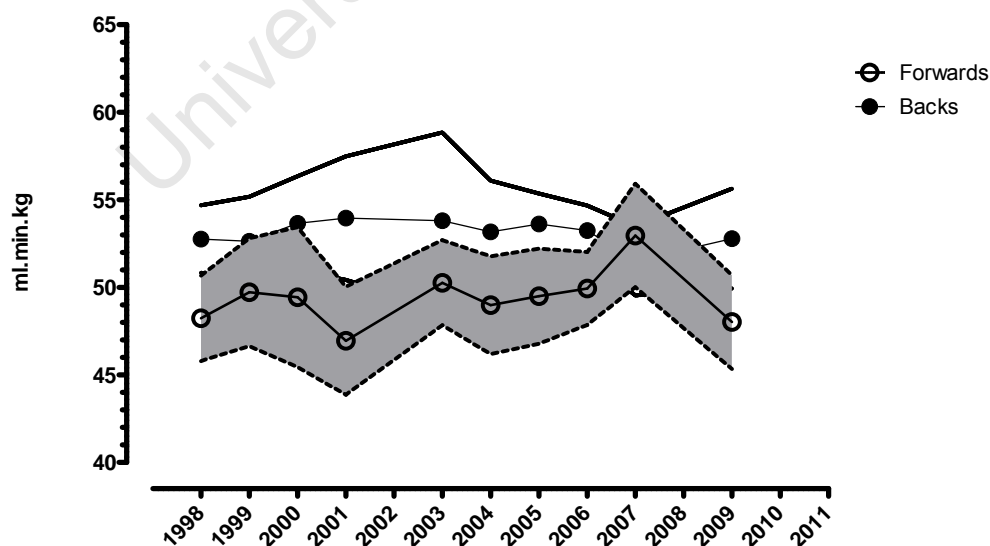


Figure 13: Predicated V_{O_2} max of Forwards and Backs are represented in the graph from 1998 – 2010. Significant comparisons are shown in table 21.

Appendix D

Pre-participation Form

INITIAL CONSULTATION

Identification Details:

Date

Surname:			
First name:			
Date of Birth:		Age:	
Address:			
Telephone no.:			

Personal Medical History

Condition	Yes	No
Surgery		
Head injury (with unconsciousness)		
Asthma		
High blood pressure		
Chest pain		
Diabetes		

Injury to joints	Past	Present	Injury to muscles	Past	Present
Neck			Neck muscles		
Shoulder			Deltoids		
Elbow			Back muscles		
Wrist			Chest Muscles		
Lower Back			Stomach muscles		
Hip			Buttock muscles		
Knee			Groin muscles		
Ankle			Hamstring		
			Quadriceps		
			Calves		

Medical Screening:

Question	Yes	No
Have you ever been diagnosed with a heart condition?		
Do you feel pain/tightness in your chest when exercising?		
Have you had chest pain when doing physical activity in the past month?		
Do you lose your balance because of dizziness? Do you ever lose consciousness?		
Do you have a joint/bone problem that could be made worse by a change in your physical activity?		
Have you ever been told that you have high blood pressure?		
Do you smoke?		
Has anyone in your family died of a heart condition before age 50?		
Are you currently doing less than 20 minutes of exercise 3x a week?		
Do you have a cholesterol problem?		
Are you diabetic?		

Playing Position:

Injury Details:
