

**BODY COMPOSITION AND PHYSICAL PERFORMANCE  
CHARACTERISTICS OF ELITE SENIOR AND U19 SOUTH AFRICAN  
RUGBY UNION PLAYERS.**

**Submitted for the degree of Masters (Med) Exercise Science**

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## **DEDICATION**

**To Mum and Dad**

**Thank you for your love, and your emotional and financial support that has enabled me to lead a happy, loving, and very comfortable life throughout my years of study.**

**To Professor Eugene Locke**

**Thank you for your encouragement and support during my years of postgraduate study, and for your wonderful qualities of friendship, kindness and wisdom. The genuine concern that you have for others despite your own agonising disability will always be an inspiration to me. You'll be with me in spirit forever.**

University of Cape Town

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To the anonymous **external examiners** for their time, effort and expertise in reviewing this thesis.

University of Cape Town

## DECLARATION

I, *Nicola Jane Scales*, do hereby declare that the experiments presented in this thesis were conceived and executed by myself and apart from the normal guidance from my supervisors, I received no assistance.

Neither the substance nor any part thereof has been submitted in the past, or is to be submitted for a degree at this or any other University.

This thesis is presented in fulfillment of the requirements for the degree of MSc. (Med) Exercise Science.

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## ABSTRACT

Rugby union is a dynamic sport with the physical demands of the game being influenced by many factors including the dominant style of play and rule changes. Optimal preparation of players for the 'modern' or current game requires (i) that research provide objective information with respect to the anthropometric and physical performance characteristics of elite players, and (ii) that methods of enhancing these attributes are scientifically investigated and monitored so as to provide players with effective conditioning programmes.

The first and second sections of the study describe and compare the body composition and physical performance attributes of elite rugby union players during the mid pre-season, according to position of play. Two positional categorizations were used (1) forwards vs backs, and (2) props & locks vs loose-forwards & hookers vs backs. An additional aim was to compare the players assessed in this study to data available on other players of similar age and proficiency of play.

The subjects in the first section of the study were members of the SA U19 rugby squad ( $n = 44$ , 22 forwards and 22 backs). The forwards (age  $17.9 \pm 0.4$  years, mean  $\pm$  SD ) were significantly taller ( $186.2 \pm 8.1$  cm vs  $175.0 \pm 6.0$  cm,  $P < 0.01$ ) and heavier ( $97.9 \pm 10.2$  kg vs  $74.6 \pm 10.2$  kg,  $P < 0.01$ ), and had greater muscle mass ( $54 \pm 6$  kg vs  $42 \pm 5$  kg,  $P < 0.01$ ) and body fat ( $101 \pm 43$  mm vs  $63 \pm 18$  mm,  $P < 0.01$ ) than the backs (age  $17.7 \pm 0.4$  years). The forwards had greater skeletal muscle strength (leg press:  $343 \pm 61$  kg vs  $285 \pm 61$  kg,  $P < 0.01$ ; bench press:  $100 \pm 19$  kg vs  $81 \pm 19$  kg,  $P < 0.01$ ) and momentum over 10 m ( $547 \pm 54$  kg.m.s<sup>-1</sup> vs  $423 \pm 55$  kg.m.s<sup>-1</sup>,  $P < 0.01$ ) and 40 m ( $723 \pm 61$  kg.m.s<sup>-1</sup> vs  $576 \pm 70$  kg.m.s<sup>-1</sup>,  $P < 0.01$ ) than the backs. Despite the forwards body mass disadvantage (being 23.3 kg heavier than the backs) with respect to mobility, the forwards did not differ significantly from the backs in aerobic capacity ( $103 \pm 16$  shuttles vs  $113 \pm 13$  shuttles), repeat sprint ability ( $723 \pm 25$  m vs  $739 \pm 25$  m), speed over 10 m

( $1.79 \pm 0.12$  s vs  $1.78 \pm 0.08$  s) and 40 m ( $5.42 \pm 0.38$  s vs  $5.23 \pm 0.16$  s) or agility ( $11.11 \pm 0.64$  s vs  $11.12 \pm 0.53$  s).

The comparative analysis suggested that body mass is a critical distinguishing factor between elite schools players and those progressing to provincial or national teams. In addition, the SA U19 players had similar physical performance characteristics to elite junior players (under 21 years of age) from other 'world' dominant rugby nations.

The subjects in the second section of the study were members of SA senior A provincial squads ( $n = 58$ , 35 forwards and 23 backs). The forwards were significantly older ( $27.0 \pm 3.5$  years vs  $24.6 \pm 3.1$  years), and taller ( $190.1 \pm 8.2$  cm vs  $178.9 \pm 6.3$  cm,  $P < 0.01$ ) and heavier ( $109.7 \pm 10.5$  kg vs  $86.0 \pm 8.8$  kg,  $P < 0.01$ ) than the backs. They also had greater muscle mass ( $61 \pm 7$  kg vs  $59 \pm 4$  kg,  $P < 0.01$ ) and body fat ( $100 \pm 30$  mm vs  $67 \pm 17$  mm,  $P < 0.01$ ). The backs performed significantly better on the tests of aerobic capacity ( $115 \pm 16$  shuttles vs  $99 \pm 15$  shuttles,  $P < 0.01$ ), repeat sprint ability ( $739 \pm 11$  m vs  $684 \pm 38$  m,  $P < 0.01$ ), speed over 10 m ( $1.78 \pm 0.08$  s vs  $1.86 \pm 0.08$  s,  $P < 0.01$ ), and agility ( $10.89 \pm 0.35$  s vs  $11.72 \pm 0.86$  s,  $P < 0.01$ ), vertical jump ( $61 \pm 7$  cm vs  $54 \pm 7$  cm,  $P < 0.01$ ) and skeletal muscle endurance. The forwards generated greater momentum over 10 m ( $594 \pm 51$  kg.m.s<sup>-1</sup> vs  $486 \pm 50$  kg.m.s<sup>-1</sup>,  $P < 0.01$ ) and 40 m ( $781 \pm 59$  kg.m.s<sup>-1</sup> vs  $664 \pm 71$  kg.m.s<sup>-1</sup>,  $P < 0.01$ ) than the forwards and had greater 1RM bench press strength ( $116 \pm 18$  kg vs  $101 \pm 17$  kg,  $P < 0.01$ ).

Differences in both speed and aerobic endurance, as indicators of mobility, were assessed between the three positional categories (Props & Locks vs Loose-forwards & Hookers vs Backs) in the current study and compared to the differences found in a study performed on SA senior A provincial players in 1995. It was found that the differences between the positional categories were greater in 1995 compared to 1998, indicating a trend toward de-differentiation of speed and aerobic endurance between positions. The senior players of this study were heavier than most other provincial players and national players to which they could be compared, and as found with the SA U19 players this was most marked

amongst the forwards. The SA provincial players of this study performed poorly on the vertical jump test relative to other senior rugby players at both club and national level.

The third section of the study compared the body composition and physical performance attributes of the elite SA U19 and senior A provincial players described above. The senior backs were significantly more mobile than the forwards, as they had greater aerobic capacity, repeat sprint ability, speed, and agility than the forwards. This contrasted with the finding that SA U19 forwards and backs did not differ significantly on any of these variables. Therefore, compared to the senior players there was homogeneity of performance attributes amongst the U19 players.

When comparisons were made between senior and U19 players within the same positional category, loose-forwards & hookers were not significantly different with respect to any of the measures of anthropometry or physical performance. The greatest differences between the U19 and senior players occurred in the backs, with the senior backs having significantly greater upper ( $101 \pm 17$  kg vs  $81 \pm 19$  kg,  $P < 0.01$ ) and lower ( $384 \pm 74$  kg vs  $285 \pm 61$  kg,  $P < 0.01$ ) body strength, skeletal muscle endurance (push ups and sit ups), and momentum over 10 m ( $486 \pm 50$  kg.m.s<sup>-1</sup> vs  $423 \pm 55$  kg.m.s<sup>-1</sup>,  $P < 0.01$ ), 20 m, 30 m and 40m ( $664 \pm 71$  kg.m.s<sup>-1</sup> vs  $576 \pm 70$  kg.m.s<sup>-1</sup>,  $P < 0.01$ ) compared to the U19 backs.

Significant interactions ( $P < 0.05$ ) for age (U19 vs senior) and positional category (Props & Locks vs Loose-forwards & Hookers vs Backs) were found for repeat sprint ability, speed over 20 m and 30 m and agility. Compared to the U19 players differences between the loose-forwards & hookers and backs for these physical performance attributes were significantly greater amongst the senior players. These physical performance attributes were almost identical between U19 loose-forwards & hookers and backs.

The fourth section of the study described the anthropometric and physical performance characteristics of elite South African U19 provincial players (n=34) at

the middle of the off-season and assessed the changes in these variables after the administration of an unsupervised, 7 week off and early pre-season training programme.

There were no changes with respect to body mass and body fat after the training period, but significant increases occurred in the aerobic capacity (8%) and skeletal muscle strength (1RM bench and leg press increased 8 % and 13 % respectively). Skeletal muscle endurance (pull ups, push ups and sit ups) increased by 30 %, 13 % and 22 % respectively. Flexibility increased by 33 %, repeat sprint ability by 5 %, speed and momentum over 10 m by 3 %, and agility by 3 % over the 7 weeks of the study ( $P < 0.05$  pre vs post training).

In conclusion this series of studies has:

- 1) added to the understanding of the physical demands of rugby union,
- 2) shown which anthropometric and physical performance characteristics change with increasing age and level of proficiency,
- 3) increased the scientific approach to physical conditioning for the game of rugby union.

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## **1. INTRODUCTION**

### **1.1. Physical fitness, rugby union and exercise science - a historical perspective**

'Physical fitness' and 'fitness' in the context of this study encompass a set of physical attributes that influence specific sports performance. Inherent in each sport is a unique combination of athletic stresses and metabolic demands and these determine the relative importance of each physical attribute with respect to contributing to optimal performance in a particular sport. The physical attributes that relate to performance on the rugby field include the general athletic fitness components of aerobic capacity, skeletal muscle strength, skeletal muscle endurance, flexibility, and body composition; and the sports-specific fitness components of speed, skeletal muscle power, repeat sprint ability, agility, balance and co-ordination (Kibler and Chandler, 1994). By participation in specific modes of training these physical performance attributes can be enhanced by the body's process of adaptation to imposed stresses. Ultimately however, a genetically pre-determined 'ceiling' provides a limit to which improvements in each physical performance attribute can be facilitated by training.

Until the 1980's physical fitness training was not conceptualized as a method that could improve performance on the rugby field, and rugby players were able to progress to the ranks of international status on the basis of natural size, genetic athletic talent and skill. However in the early 1980s the idea that rugby players could perhaps benefit from increased levels of physical fitness was popularized by a New Zealand physical education teacher, Jim Blair. He pioneered a physical fitness programme that was both specific to the game of rugby union, specific to position of play and that incorporated regular fitness testing of players to gauge the effectiveness of training programmes (Noakes and Du Plessis, 1996). At about the same time as Blair was receiving recognition for his successful involvement with provincial New Zealand teams, the English Rugby Football Union began a national fitness programme under the direction of Tom McNab, a former national athletics coach. In 1989, under coach Bob Dwyer, Australia also introduced a programme of individualised player preparation which included extensive fitness and strength training, nutritional and psychological counseling, and analysis of

individual playing patterns and weaknesses. All three of these countries acknowledged the role of physical fitness programmes in contributing to their individual successes in the 1987 (victory for New Zealand), 1991 (victory for Australia, England runners up) and 1995 (New Zealand runners up, England semi-finalists) World Cup Rugby events.

Although South African rugby players fell behind the dominant rugby - playing countries in the years of isolation (1984 to 1992) with respect to physical preparation of international class rugby union players, they quickly made up for lost time. The appreciation of fitness in South African rugby followed Richard Turnbull's successful involvement with the Natal rugby team in 1990 and 1992, and the Transvaal rugby team's success in 1993. Their success was attributed to them following a structured pre-season physical fitness programme similar to that of the Natal team (Noakes and Du Plessis, 1996). By 1995 South African provincial coaches, players, and administrators, began to give greater support to the use of fitness trainers and acknowledged the importance of year-round training. The role of physical fitness preparation as a contributing factor to World Cup victories was highlighted once again when South Africa won the Web Ellis trophy in 1995. The South African coach, Kitch Christie, placed emphasis on the physical preparation of his 1995 World Cup squad. Although he was criticised for not basing his training methods on accepted scientific principles of training; he proved once again that purposeful, goal directed, and innovative physical preparation was a significant feature of successful international rugby union teams.

The decade of 1985 - 1995 may be viewed as one in which physical fitness made its mark in rugby union and it no longer has to prove its worth as a component of optimal preparation for the game. However 'fitness in rugby' is still in its infancy. Optimal preparation of players for the physical demands of rugby union, particularly, with respect to (i) the chronic year-round training demands; (ii) the acute physical demands of the modern style of play; and (iii) the demands of the long competitive season, requires an innovative approach and application of scientific principles of training. However, there is presently a lack of

comprehensive research of the anthropometric requirements and physiological demands of the game (Nicholas, 1997). Only two published studies have provided anthropometric and physiological data on South African players (Jardine et al., 1988; Smit et al. as quoted in Quarrie et al., 1995). Only one of these studies was performed on elite players and both studies were conducted prior to the era of professionalism, the modern style of rugby, and prior to the re-entry of South Africa into international competition.

Rugby is a dynamic game with the physical demands on the players being influenced by factors such as the dominant style of play and rule changes. Therefore, researchers need to provide objective information about the demands of the 'modern' or current game and the assessment of, and methods of improving the anthropometric and physiological characteristics of its players (Nicholas, 1997). Although the unpublished studies performed on South African players by Turnbull et al. (1996) and Clark (1998) are pioneer investigations addressing these issues, further research of this nature needs to continue.

## **1.2. Motivation for the study**

An appreciation for the important role of physical fitness optimising on-the-field performance is the basis of the relationship that has developed between the South African Rugby Football Union (SARFU) and various Provincial Rugby Unions, and the High Performance Laboratory (HPL) of the Sports Science Institute of South Africa (SSISA).

Since 1995 SARFU has contracted the services of the HPL for a number of purposes:

- I. To promote the 'science of rugby fitness' to the players, coaches, fitness trainers and medical support staff in the form of lectures, practical workshops, seminars and handouts.
- II. To objectively assess the physical fitness of players on standardised tests performed under controlled conditions at SSISA, and to compare players' test results to those of national norms.
- III. To provide players with training programmes for rugby based on current scientific principles and physical performance test results.

During 1996 and 1997 the HPL was afforded the opportunity of assessing and providing training programmes to members of four elite 'development' squads. Based on the testing and training programmes SARFU asked the following questions:

- I. How did individual players within the squad compare to one another and how did they perform relative to provincial and national players assessed in the HPL and in other countries?
- II. At what level should these players be performing on the fitness tests considering their playing position, the level at which they were being considered to play, and age?
- III. What were the individual player's weaknesses and strengths?
- IV. Was the concept of bringing elite players to the HPL from all over South Africa for three days of intensive testing and programme prescription worth the financial outlay - had players improved in the various fitness components required for rugby, following the prescribed training period?
- V. To what extent could players expect to improve on the fitness components over an 8-10 week training period?
- VI. What injuries did players have, did they need further medical investigation and how should rehabilitation progress?

Initially not all these questions could be answered objectively. Limitations included:

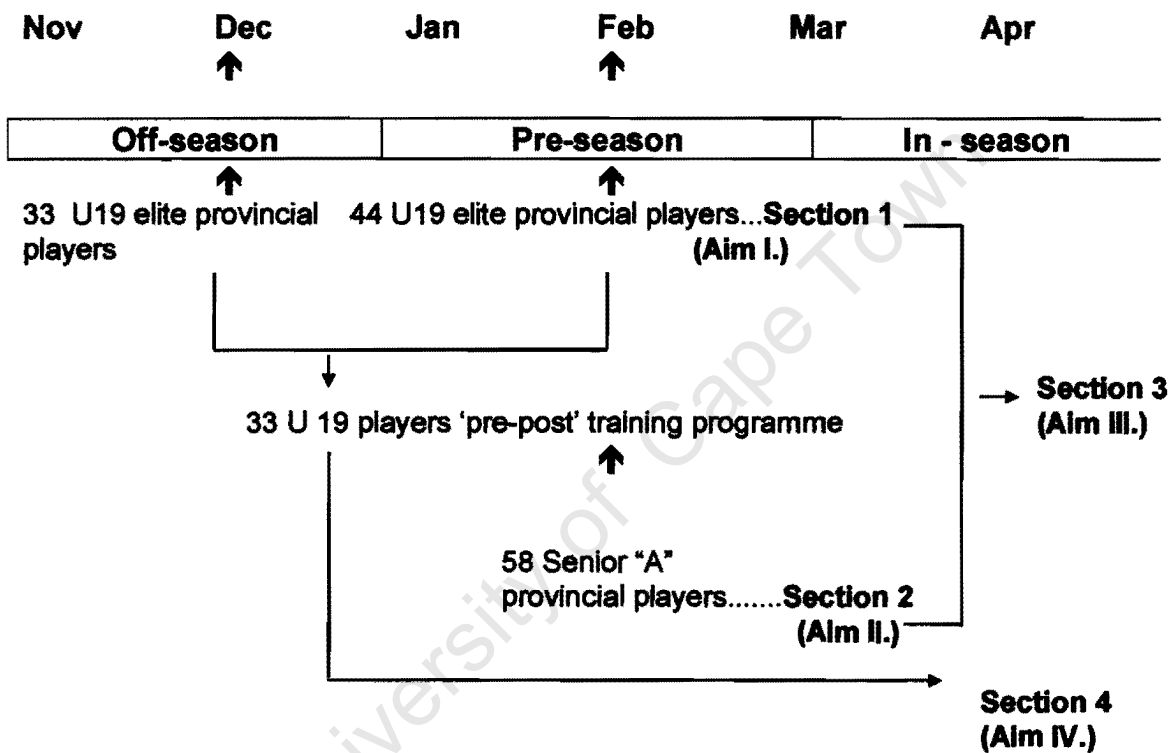
- I. Too few members in most squads for effective statistical analysis of the effectiveness of the training intervention
- II. Insufficient numbers of players in each positional category and lack of a comprehensive database to make completely objective recommendations as to what level players should be performing (although "ball park" recommendations were made)
- III. Studies performed in other countries used different test batteries to those prescribed for use in the HPL and although some test comparisons could be made, these were limited by subtle protocol differences (for example the surface upon which the multistage shuttle run and 10 and 30 m sprint were performed).

In October 1997 SARFU contracted the HPL to assess a group of 44 elite U19 players from which the U19 team to attend the 1998 U19 Rugby Union World Cup in France would be selected. SARFU requested that they be assessed during November 1997, be provided with an off-season and early pre-season physical fitness training programme, and then be reassessed in the mid pre-season (February), one week prior to their trials which were to take place in Cape Town. It was decided that because of the large number of players involved and the guarantee of all players being present at both fitness testing sessions that this project afforded the opportunity to objectively evaluate the effectiveness of a prescribed, yet unsupervised off-season and early pre-season programme on the recognised components of rugby fitness.

In an attempt to better standardize testing throughout South Africa the HPL has been contracted by SARFU to give seminars in each province on the testing of rugby players and to provide normative data for each test. Two senior 'A' provincial squads (Western Province and Boland) underwent the same full battery of physical fitness tests under the same controlled conditions and at the same phase of season (mid pre-season) as the elite U19 team. It was decided therefore that these data should be statistically analysed to provide South African players,

coaches and fitness trainers with specific fitness recommendations for different positions for the mid pre-season for both junior and senior players.

Based on the need to provide descriptive data for elite South African junior and senior rugby players and the ability to assess the efficacy of an unsupervised training programme to members of various elite and development South African Rugby Squads, the study was structured, as schematically presented below.



### 1.3. Aims of the study

The study was designed to achieve the following aims;

- I. To describe the anthropometric and physical performance characteristics of players grouped by playing position (forwards and backs, and further differentiation into props & locks, hookers & loose-forwards, and backs) within the U19 South African squad at mid pre-season, and identify any differences which may exist between these grouped playing positions.
- II. To describe the anthropometric and physical performance characteristics of players grouped by playing position (forwards and backs, and further differentiation into props & locks, hookers & loose-forwards, and backs) within

## **2. LITERATURE REVIEW**

### **2.1. Physiological demands of rugby union**

For the rugby union fitness trainer a knowledge of the physical demands that the game imposes on its players is critical in order to:

- I. Prescribe physical conditioning programmes that are specific to the game,
- II. Select and, or design physiological tests that stress the players in as similar a manner to which they are stressed during a game,
- III. Designing a test battery that assesses the components of fitness required to participate at high level play, and
- IV. Giving players feedback on physical performance assessments relative to the physical demands that the player will encounter during a game.

Notational analysis, and analysis of metabolic responses (free fatty acid and blood lactate concentrations) and physiological responses (heart rate monitoring) of players during a rugby game are three methods which have been used in studies to estimate the physical demands placed on rugby union players during a game.

#### **2.1.1. Notational analysis**

In rugby union notational analysis provides the coach with important technical and tactical information. For the trainer responsible for the physical fitness of players it provides information regarding the physical demands of the game, as it has the ability to define, quantify and characterise movements and actions typically performed and / or encountered by players during a game.

In the early 1970's notational analysis was quite subjective, rudimentary and limited in its scope. For example Evans (1973), broadly defined the physiological demands of the game as muscular strength, power, and endurance; cardiorespiratory endurance; flexibility and anaerobic capacity on the basis of his subjective observations of the actions performed by the forwards and backs. Reid and Williams (1974), on the basis that players ran 3 - 6 miles during a match, claimed that "runnability" or cardiovascular endurance (and consequently the

measurement of maximal oxygen consumption) was the most important physiological component that could distinguish proficiency of players.

With the introduction of video cameras and computers the information generated by notational analysis has become more objective, detailed and precise.

#### 2.1.1.1. Defining characteristics of distance covered during a rugby union game.

Distance covered by players during a game ranges from 4000 m - 6000 m (Reid and Williams, 1974; Morton, 1978; Noakes and Du Plessis, 1996 and Deutsch et al., 1998) and as shown in Tables 2.1. and 2.2., is influenced by both position of play (Noakes and Du Plessis, 1996; Deutsch et al., 1998), and standard or level of play (Noakes and Du Plessis, 1996) with greater distances being covered by international players compared to club level players.

**Table 2.1: Total distance covered by elite Australian U19 rugby union players.**

	IB	OB	P & L	BRF
Total distance (m)	5530	5750	4400 <sup>a</sup>	4080 <sup>a</sup>
Walking (m)	1740	1660	1000 <sup>a</sup>	992 <sup>a</sup>
Jogging (m)	2600	2110	3050	2940
Utility movements (m)	418	442	118 <sup>a</sup>	154 <sup>a</sup>
Sprinting (m)	208	297 <sup>b</sup>	72 <sup>a</sup>	94 <sup>a</sup>

Abbreviations: IB, inside backs; OB, outside backs; P & L, props and locks; BRF, back row forwards; <sup>a</sup>, significantly different from IB and OB; <sup>b</sup>, significantly different from OB. (Modified from Deutsch et al., 1998)

The findings of Deutsch et al. (1998) and those quoted in Noakes and Du Plessis (1996) show that backs cover significantly more distance than the forwards. This is in contrast to the findings of Hazeldine and McNab (1991) (as cited in Pendleton, 1996) who calculated that backs cover about 4000 m and forwards approximately 20 - 30 % further, totaling an average of 5000 - 6000 m.

Using manual notation systems it has been estimated that a rugby center (caliber of player not mentioned) can expect to cover 5800 m during a game, 1630 m of which would be covered jogging, 2160 m walking and 2000 m sprinting (Morton, 1978).

**Table 2.2. Total distance covered (meters) by rugby union players in the different positions at different levels of the game.**

Position	Running intensity	Club players	International players
Prop forward	Total distance	3635	6100
	Full speed	205	1614
	¾ of maximum speed	3430	4486
Scrum-half	Total distance	4569	6398
	Full speed	1523	1828
	¾ of maximum speed	3046	4570
Inside center	Total distance	5756	-
	Full speed	1991	-
	¾ of maximum speed	3765	-
Fullback	Total distance	3657	-
	Full speed	1219	-
	¾ of maximum speed	2438	-

(Modified from Noakes and Du Plessis, 1996). Data for flankers and eighth men are probably similar to those for scrum-halves (Noakes and Du Plessis, 1996).

Deutsch et al. (1998) found that during match play recovery for forwards was more passive in nature compared to the backs as they spent significantly more time standing still than backs (45 % vs 39 %). Compared to the elite senior players studied by Docherty et al. (1988) the Australian U19 Colts spent relatively less time walking (backs and forwards covering 1760 m and 995 m respectively), and they covered greater distances jogging (backs and forwards covering 2470 m and 2990 m respectively) than estimated by Morton (1978), suggesting the Colts exhibit a more continuous style of play than elite senior players (Deutsch et al., 1998).

Morton's (1978) estimation that approximately 2000 m is covered in sprint mode is similar to the 1600 - 1900 m shown in Table 2.2. (Noakes and Du Plessis, 1996), but is significantly further than the 94 - 208 m shown in Table 2.1. covered in sprint mode by elite U19 Australian players (Deutsch et al., 1998). It is likely differences in definitions of "sprinting" are responsible for such large discrepancies, or that international players are required to sprint considerably more than those playing at an U19 Colts level. Deutsch et al. (1998) found that elite U19 Australian outside backs (OB) and inside backs (IB) sprinted significantly further during a game than forwards, and IB sprinted significantly further than the OB. However, he found no difference between positional categories for mean single sprint distance (props and locks, 19.8 m; back row forwards, 14.5 m; IB, 18.8 m; and OB, 23.6 m). Based on the estimations of Blair, New Zealand rugby union fitness trainer, the

single mean sprint distances covered by the elite U19 Colts are shorter than those covered by senior international players. Noakes and Du Plessis (1996) quote Blair as estimating that fullbacks, wings, and centers frequently produce sprint efforts of 30 m, whereas the fly-halves more commonly produce sprint efforts of 15 m. Age differences, measurement techniques and, or style of play may account for these differences. Blair also estimated that backline players were generally challenged within 10 m of starting to sprint .

Docherty et al. (1988) did not measure distance covered in each mode of activity, but estimated the percentage of time spent performing different intensities of activities by props and centers. He reported that only 6 % of the time involved intense running (running and sprinting) compared to 47 % low intensity activities (walking and jogging), 38 % standing, and 9 % non running intense activity (tackling and competing for the ball).

Average running pace, as an indicator of intensity of play, was investigated by McLean (1992). From analysis of the 5 games in the 1989 - 90 Five Nations Championships he reported that the average running pace of players central to the action ranged from 5 - 8 m.s<sup>-1</sup>.

#### 2.1.1.2. Defining the characteristics of the intermittent nature of rugby union.

Rugby union is a game of intermittent nature. Total time with the ball in play ranges from a minimum of about 20 minutes (25 % of game duration) to a maximum of about 33 minutes (41 % of game duration) as shown in Table 2.3. and the number of activity cycles have been reported to range from 98 to 184 (IRFB Conference 1998; Morton, 1978; Maud and Schultz, 1984; Menchinelli et al., 1992; McLean, 1992; Noakes and Du Plessis, 1996; Clark, 1998).

The physiological demands of the intermittent nature of rugby union cannot be fully appreciated by only estimating distances covered, classifying the intensity at which the distance is covered, and counting activity cycles as reflected in Tables 2.3 and 2.4. Although these data clearly show the game is intermittent in nature they fail to define the nature of activity and intensity of exercise performed within an activity

cycle. In addition the data do not describe the length and intensity of rest or low intensity work periods.

**Table 2.3. Total time the ball is spent in play.**

Reference	Duration
Morton (1978)*	27 minutes
McLean (1991) <sup>#</sup>	29 minutes
IRFB conference <sup>+</sup>	Minimum: 21 min 50 s; Maximum: 31 min 56 s 3 of the 32 RWC games exceeded 30 min ball in play time.

Abbreviations: \* Results presented are a summary of findings (published 1974-75) based on the analyses of > 55 matches (regional - international level) performed by Coupon, Lynch and Gray; <sup>#</sup>, Based on analysis of five games in the 1989-90 Five Nations Championships; <sup>+</sup>, Data obtained from matches played in the 1995 Rugby World Cup; RWC, Rugby World Cup; min, minutes; s, seconds

**Table 2.4. Number and duration of activity cycles in rugby union.**

Morton (1978)*	No. per game: 135
Maud and Schultz (1984)	Average activity cycle of 12 s, interspersed with 26 s rest
Treadwell (1991) as cited in Clarke (1998) **	Ball in play for an average of 30 % of total game time (24 minutes) and most of the playing time activity cycles (67 %) never exceeded 14 s in duration. 25 % of all playing time activity cycles lasted less than 4 s, 21 % lasted 5-9 s, 21 % lasted 9 - 14 s.
McLean (1992) <sup>#</sup>	Average activity cycle 19 s
Noakes and DuPlessis (1996) <sup>§</sup>	During a match there are 125 - 160 activity cycles lasting the following periods: 32 % less than 5 s, 24 % less than 10 s, 29 % less than 20 s, 10 % less than 30 s, 1 % less than 50 s, 1 % more than 50 s
IRFB conference (1998) <sup>+</sup>	France vs Tonga = 98 playing time activity cycles, of which 63 % were less than 15 seconds in duration, and the average length was 14 s. Australia vs Canada = 114 playing time activity cycles, of which 45 % were less than 15 s, and the average length was 17 s.

Abbreviations: \*, Results presented are a summary of findings (published 1974-75) based on the analyses of > 55 matches (regional - international level) performed by Coupon, Lynch and Gray; \*\*, Based on computerized notation analysis of 4 Welsh matches in the 1991 Five Nations Championships and on 17 matches which included international matches and matches between club and international teams; <sup>#</sup>, Based on analysis of five games in the 1989-90 Five Nations Championships; <sup>§</sup>, Data obtained from two test matches played by England against South Africa in 1994; <sup>+</sup>, Data obtained from matches played in the 1995 Rugby World Cup; s, seconds

McLean (1992) addressed this shortcoming as he determined the density of physical work by assessing the patterns of work : rest ratios (W : RRs) during the 1989-90 Five Nations Championships. He categorized activities into low and high intensity activities. Low intensity activities included standing, walking, and jogging, whereas high intensity activities included running with an elongated stride, sprinting, and non-run intense activity (rucking, mauling, scrumming). Analysis of the pattern of W : RR's revealed the mean duration of activity cycles to be 19 seconds with the most frequent W : RR's to be in the ranges of 1 : 1.0 - 1.9 (26 %)

and 1 : 1.9 - 1.0 (20 %). The distributions in W : RRs were similar for the five games analysed and he showed that all bouts of high intensity exercise during a game were followed by low intensity recovery periods, and that 67 % of the bouts of high intensity work were followed by longer low intensity recovery periods (Fig. 2.1).

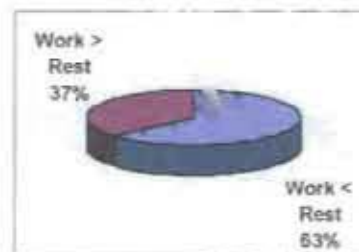


Fig.2.1. Proportion of work : rest ratios averaged over five internationals in 1989-90 (McLean 1992).

Deutsch et al. (1998) calculated the W : RR of elite U19 players and found the mean W:RR for props and locks, backrow forwards, IB and OB to be 1: 1.8, 1: 1.2, 1:3.6, and 1:2.2 respectively. The forwards therefore maintained a higher W : RR than backs and this reflected their higher intensity work rates. The mean W : RR (all positions combined) of 1 : 1.9 falls within the upper part of the range quoted by McClean (1992) of 1 : 1.1 - 1 : 1.9 for international players.

### 2.1.1.3. Defining the characteristics of set pieces in Rugby Union.

The defining characteristics of set pieces including scrums, lineouts and rucks and mauls are presented in Tables 2.5 - 2.8. The number of scrums during a game range from 14 (IRFB conference, 1998) to 45 (Morton, 1978; McLean, 1992) and during the 1995 World Cup 10 % of match time was spent scrumming (IRFB conference, 1998). Table 2.6 shows that the number of rucks and mauls during a game is increasing and currently the frequency averages 100 during international games.

Table 2.5. Summary of notational data on the characteristics of scrumming.

Reference	No. per game (Range)	No. per game (Average)	Duration of each scrum (s)	Average duration of game spent scrumming (min:s)
Morton (1978)*	35 - 45		5 - 20 (range)	7:30
McLean (1991) <sup>#</sup>	24 - 45	32		
Noakes and Du Plessis (1996) <sup>§</sup>		16		

Abbreviations: \* Results presented are a summary of findings (published 1974-75) based on the analyses of > 55 matches (regional - international level); performed by Coupon, Lynch and Gray; <sup>#</sup>, Based on analysis of five games in the 1989-90 Five Nations Championships; <sup>§</sup>, Data obtained from two test matches played by England against South Africa in 1994; min, minutes; s, seconds

**Table 2.6. Summary of notational data on the characteristics of rucks and mauls.**

Reference	No. per game (Range)	No. per game (Average)	Average duration of rucks and mauls (s)
Morton (1978)*		70	± 10
McLean (1991) <sup>#</sup>	62 - 88	73	
Noakes and Du Plessis (1996) <sup>‡</sup>		100	

Abbreviations: no., number; s, seconds; \*, Results presented are a summary of findings based on the analyses of > 55 matches (regional - international level) performed by Coupon, Lynch and Gray (1974 - 1975); <sup>#</sup>, Based on analysis of five games in the 1989-90 Five Nations Championships; <sup>‡</sup>, Data obtained from two test matches played by England against South Africa in 1994; s, seconds

Deutsch et al. (1998) found that during a match elite U19 props and locks, and back row forwards averaged 72 and 78 instances of rucking and mauling, respectively whilst the inside and outside backs only engaged in 12 and 8 rucks or mauls. With the forwards averaging 32 - 35 scrums per match, Deutsch et al. (1998) calculated that the forwards spent an average of 13.9 % of total match time in intense static activity (rucking, mauling, and scrummaging) whilst backs averaged only 1.3 % of total time in such activities. Deutsch et al. (1998) suggests that it is the relatively high involvement of forwards in intense static activity that is the main contributor to the high intensities of work indicated by the higher blood lactate concentrations and heart rates of the U19 forwards compared to the U19 backs.

Table 2.7 shows that in recent years the number of lineouts per game have decreased with there being an average of 23 - 50 during the 1995 World Cup games utilising 16 % of match time. Table 2.8 shows the duration of various kicks performed during a game.

In summary, with the assistance of computer notation and time motion analysis techniques the research quoted above has been able to accurately quantify the intermittent nature of rugby union. There is general agreement that the game of rugby union consists of short duration (on average 14 seconds) high intensity periods interspersed with low intensity periods of recovery. These recovery periods are generally longer than the work period with the most frequent W : RRs being 1 : 1 - 1.9. However, although data from notational analysis have contributed to quantifying the physical demands of rugby union, the metabolic demands of the

sport remain inconclusive as many factors exert an influence on the pattern of activity during play. These factors include environmental conditions, fitness status, level of play, officiating styles and tactics (Quarrie et al., 1995). To date notational analysis has not adequately provided comprehensive quantitative information detailing the physical demands relative to specific positions of play.

**Table 2.7. Summary of notational data on the characteristics of lineouts.**

Reference	No. per game (Range)	No. per game (Average)	Duration of each lineout (s)
Morton (1978)*	50 - 80		± 15
McLean (1991) <sup>§</sup>	38 - 46	41	
Noakes and Du Plessis (1996) <sup>§</sup>		37	
IRFB conference (1998) <sup>†</sup>	23 - 50		± 23

Abbreviations: \* Results presented are a summary of findings based on the analyses of > 55 matches (regional - international level) performed by Coupon, Lynch and Gray (1974 - 1975); <sup>§</sup>, Based on analysis of five games in the 1989-90 Five Nations Championships; <sup>§</sup>, Data obtained from two test matches played by England against South Africa in 1994; <sup>†</sup>, Data obtained from matches played in the 1995 Rugby World Cup; no., number; s, seconds

**Table 2.8. Summary of notational data on the characteristics of kickstarts, freekicks, penalty kicks, and conversions.**

Type	Average duration of each kick (s)	No. per game
Kickstart <sup>†</sup>	23.36	4 - 23
Freekick <sup>†</sup>	13.29	
Penalty kick at goal <sup>†</sup>	66.00	
Penalty kick <sup>†</sup>	23.00	
Conversions <sup>†</sup>	71.04	

Abbreviations: s, seconds; no., number; <sup>†</sup>, Data obtained from matches played in the 1995 Rugby World Cup (IRFB conference, 1998)

## 2.1.2. Metabolic measurements

### 2.1.2.1. Free fatty acid and blood lactate concentrations

Van Rensburg (1984) (as cited in Jardine et al., 1988) found that plasma free fatty acid concentrations increase three fold above resting concentration during a rugby match and blood lactate concentrations do not increase over 4 mmol.l<sup>-1</sup>, however these data should be viewed with scepticism as the blood lactate concentration will be significantly influenced by the exact time of blood collection. This finding gives the impression that aerobic metabolism predominates during a rugby match, but other studies have found greater increases in players' blood lactate concentrations during match play. McLean (1992) measured blood lactate concentrations in 6 players (4 forwards and 2 backs) during a game between two Scottish First

Division clubs. The highest figure recorded for each individual was between 5.8 - 9.8 mmol.l<sup>-1</sup>. Supporting the findings of McLean (1992) is the study of Menchinelli et al. (1992) who reported that during match play, blood lactate concentrations ranged from 6 - 12 mmol.l<sup>-1</sup>, and that of Deutsch et al. (1998) who found that blood lactate frequently approached 6 - 9 mmol.l<sup>-1</sup> for elite U19 players in positional groups of props and locks, back row forwards and inside backs. These values exceed both the average of 4 mmol.l<sup>-1</sup>, up to where aerobic metabolism is thought to be the major source of energy; and the range of 3.05 - 5.5 mmol.l<sup>-1</sup> measured during steady state running (McLean, 1992).

Thus, the results of McLean (1992), Menchinelli et al. (1992) and Deutsch et al. (1998) reflect that rugby is a game played at a high intensity, and the oxygen independent glycolytic pathway has an important role to play in the production of energy during match play. Morton (1978) unlike some of his contemporaries (Reid and William, 1974) stressed the importance of oxygen independent metabolism as the dominant power system during a match (Table 2.9).

**Table 2.9. Percentage of contribution of aerobic and anaerobic energy sources for various rugby playing positions during a match.**

Position	The ATP-CP (Phosphagen) system (%)	The oxygen independent glycolytic system (%)	The aerobic glycolytic system (%)
Tight five forwards	10	35	55
Back row forwards and scrum-half	20	35	45
Flyhalf and centers	45	20	35
Wings and fullbacks	70	15	15

(Modified from Morton, 1978)

#### 2.1.2.2. Muscle glycogen concentrations

Jardine et al. (1988) measured muscle glycogen concentrations before (93 mmol.kg<sup>-1</sup>.ww) and after (53 mmol.kg<sup>-1</sup>.ww) a rugby match, and concluded that muscle glycogen depletion was not a factor which limited performance in a single rugby match. Based on the data from this study these authors suggested that there is no basis for recommending carbohydrate loading before a rugby match. However, if players were to be involved in a series of matches over a few days, or if players were undertaking daily intense training sessions, then a high

carbohydrate diet would be recommended to optimise muscle glycogen resynthesis and enhance recovery (Jardine et al., 1988).

### **2.1.3. Heart rate monitoring**

Morton (1978), estimated a backline player to have a heart rate ranging from 135 - 180 beats per minute (bpm) and an average heart rate of 161 bpm during match play. However, these estimations should be viewed with scepticism as no information is provided as to the technique used on which to base these estimates. More recent work by Deutsch et al. (1998) provides an accurate and comprehensive analysis of heart rates during match play. They measured the amount of time spent in four heart rate zones in elite U19 Australian colt players: > 95 %, 85 - 95 %, 75 - 84 %, < 75 %, and found the following:

- I. Props and locks (58 %) and back row forwards (56 %) spent significantly more time in the high exertion zone of 85 - 95 % of heart rate maximum (HRM) than the inside backs (41 %) and the outside backs (34 %).
- II. The inside backs (37 %) and outside backs (39 %) spent significantly more time in the moderate exertion zone of 75 - 84 % of HRM than props and locks (23 %) and back row forwards (20 %).
- III. Outside backs spent significantly more time in the low exertion zone of < 75 % than the props and locks (6 %) and back row forwards (6 %).

This heart rate monitoring study is unique in that it gives an indication of the physiological strain placed on players in different positions and indicates the importance of high intensity aerobic training, particularly for the forwards.

## **2.2. Positional role**

To date the information provided by notational analysis and metabolic measurements, with the exception of the study by Deutsch et al. (1998) have not typically been position specific. Subjective analysis of the positional role has been used to evaluate the physical fitness requirements of players according to their positions (Noakes and Du Plessis, 1996; Bell et al., 1993, Evans, 1973).

Hazeldine and McNab (1991) as quoted by Noakes and Du Plessis (1996) provide a summary (Table 2.10.) of the fitness requirements of four basic playing groups or units. Such descriptions provide a general overview of the positional fitness requirements but are limited in the quantitative information they provide.

**Table: 2.10. Physical performance attributes required of rugby players according to their position.**

Position	Type of fitness			
	Aerobic capacity	Strength and power	Speed	Flexibility
<b>Props and locks</b>	<ul style="list-style-type: none"> <li>Support running after line-outs and scrums.</li> <li>Support in tackling</li> </ul>	<ul style="list-style-type: none"> <li>Leg power for driving forward in scrums, loose scrum / mauls, line-out jumping, running with the ball</li> <li>Lower back and shoulder strength for</li> <li>Upper body strength for binding in the scrums, line-outs, loose scrum / mauls</li> </ul>	<ul style="list-style-type: none"> <li>Acceleration away from scrums, line-outs, loose scrum / mauls</li> </ul>	<ul style="list-style-type: none"> <li>All-round flexibility, emphasising hips and shoulders</li> </ul>
<b>Back row forwards and hooker</b>	<ul style="list-style-type: none"> <li>Back row players run the furthest of all players on the field (&gt; 5000 m per game)</li> <li>Attacking play</li> <li>Cover defence</li> </ul>	<ul style="list-style-type: none"> <li>Leg power for driving forward in scrums, loose scrum / maul</li> <li>Upper body strength for binding in the scrum, line-outs, and ruck and maul</li> <li>Upper body strength for wrestling and ripping the ball away in tackles and mauls</li> </ul>	<ul style="list-style-type: none"> <li>Reaction and leg speed for the hooker</li> <li>Acceleration to reach the point of breakdown and to support the ball carrier</li> <li>Speed for running with the ball</li> </ul>	<ul style="list-style-type: none"> <li>All-round flexibility, emphasising shoulders, spine and hips in hookers</li> </ul>
<b>Scrum-half, fly-half and centers</b>	<ul style="list-style-type: none"> <li>Running into position to receive the ball</li> <li>Support running</li> <li>Running with the ball</li> <li>Cover defence</li> </ul>	<ul style="list-style-type: none"> <li>Leg strength to drive into the tackler and to "stay on one's feet"</li> <li>Whole body strength to absorb contact</li> </ul>	<ul style="list-style-type: none"> <li>Acceleration off the mark from scrums, line-outs, ruck and mauls</li> <li>Acceleration to make a break</li> </ul>	<ul style="list-style-type: none"> <li>Good all-round flexibility</li> </ul>
<b>Backs</b>	<ul style="list-style-type: none"> <li>Most running consists of sprinting with changes of pace</li> <li>Support running</li> <li>Cover defence</li> </ul>	<ul style="list-style-type: none"> <li>Leg strength to drive into the tackler and to "stay on ones feet"</li> <li>Whole body strength to absorb contact</li> <li>Whole body strength to make tackles</li> </ul>	<ul style="list-style-type: none"> <li>Acceleration off the mark</li> <li>Pure running speed and the ability to change pace and direction</li> <li>Speed to chase kicks</li> <li>Speed for cover defence</li> </ul>	<ul style="list-style-type: none"> <li>Good all-round flexibility, emphasising the hips</li> </ul>

Adapted from Hazeldine and McNab (1991) as cited in Noakes and Du Plessis (1996)

### **2.3. Assessment of anthropometric and physical performance characteristics**

Although there is currently general consensus as to which fitness components need to be assessed in rugby union, a wide variety of performance tests have been used. Unfortunately the broad range used often makes it difficult to compare the performance of rugby players between studies (Quarrie et al., 1996). The diversity of test protocols is reflected in Table 2.11. The selection of test protocols included in a test battery are subject to practical limitations including financial constraints, the availability of facilities and equipment, the number of players to be tested, the number of trained staff available to assist with testing, as well as the needs of the fitness trainer and or coach. McLean (1993) suggests that to facilitate the use of fitness assessments in rugby union teams, testing should be:

1. Inexpensive
2. Easy to set up
3. Short in duration
4. Able to test many players simultaneously
5. Focused on specific components of the game
6. Reliable and valid
7. Sensitive to change

This section reviews the testing protocols that have been used to assess the recognised fitness components of rugby union with a specific focus on those used by the High Performance Laboratory for the purpose of these studies. It presents morphological and physiological data available for the tests reviewed, with the latter being presented in tables and general findings or trends being discussed in the text.

**Table 2.11. Protocols used for the evaluation of the recognised components of fitness for rugby union.**

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<b>Aerobic capacity</b> Cycle ergometer: Submaximal Astrand / Rhyning nomogram used to predict maximal oxygen consumption from submaximal heart rate (Reid and Williams, 1974; Maud and Shultz, 1984), Peak power output test (Clark, 1998). Treadmill: Bruce protocol (Maud, 1983), progressive treadmill test (Jardine et al., 1988). Field tests: Multistage shuttle run according to Ramsbottom et al. (1988) protocol (Holmyard and Hazeldine, 1993; Carlson et al., 1994; Tong and Mayes, 1995; Nicholas and Baker, 1995; Mayes and Thompson, 1995; and Quarrie et al., 1995 and 1996); 600 yrd running (Evans, 1973); 4 minute shuttle run (Carlson et al., 1994); Coopers 12 minute run (Reid and Williams, 1974); 3000 m run (Tumbull, 1996; Australian Institute of Sport (AIS) - as quoted in Noakes and Du Plessis, 1996).
<b>Repeat Sprint ability</b> 5 x 20 yards (Evans, 1973); 8 x 35 m sprints with 30 seconds recovery (Tumbull, 1996); 40 m shuttle run test according to Baker et al. (1993) (Mayes and Thompson, 1995; Nicholas and Baker, 1995); 6 x 70m intermittent shuttle run protocol (Quarrie et al., 1995 and 1996).
<b>Muscle Strength</b> Handgrip dynamometer (Maud and Shultz, 1984; Tong and Mayes, 1995); Back lift (Evans, 1973); Bench press and leg press using Universal gym apparatus (Maud, 1983); Bench press (Howe, 1981; AIS as quoted in Noakes and Du Plessis, 1996); power clean - free weights (AIS as quoted in Noakes and Du Plessis, 1996); squat - free weights (AIS as quoted in Noakes and Du Plessis, 1996 and Clark, 1998); Leg Press - free weights (Howe, 1981).
<b>Muscle endurance</b> Pull ups: Maximum number (Evans, 1973 and Tumbull, 1996). Push ups: Clap push ups for 45 seconds (Carlson et al., 1994), Maximum number at a cadence of 50 repetitions per minute (Quarrie et al., 1995, 1996). Sit ups: Maximum number in 1 minute (Tumbull, 1996 and Maud, 1983), in 45 seconds (Carlson et al., 1994). Squat thrust: Maximum number in 45 seconds (Carlson et al., 1994). Repeated jump in place: Maximum number in 45 seconds (Carlson et al., 1994).
<b>Anaerobic power and capacity</b> Wingate (anaerobic power): 5 seconds (Bell et al., 1993); peak watts (Clark, 1998). Wingate (anaerobic capacity): 40 seconds (Maud and Schultz, 1984); 30 seconds (Bell, 1979; Clark, 1998).
<b>Speed</b> 30 m (Holmyard and Hazeldine, 1993), 30 m with standing and rolling start (Quarrie et al.; 1995 and 1996); 40 yard and 110 yard (Carlson et al., 1994); 10 m and 35 m (Tumbull, 1996); 35 m (AIS as quoted in Noakes and Du Plessis, 1996).
<b>Flexibility</b> Sit and reach (Tong and Mayes, 1995; Tumbull, 1996; Clark, 1998).

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### **2.3.1. Body size, body composition and somatotype**

The relationship between body size, body composition, somatotype and physical fitness is of considerable importance in rugby union. Procedures which have been used to evaluate these characteristics have included;

- I. Hydrodensitometry for the estimation of body density and consequently the determination of percentage body fat.
- II. Anthropometry for a) Skinfold measurement to estimate relative and absolute fat mass, and consequently lean body mass. b) determination of somatotype, c) determination of muscle mass.
- III. Body mass
- IV. Height

Bell (1979) and Bell et al. (1993) have used hydrodensitometry to measure body density and thereby estimate percentage (%) body fat. Although hydrodensitometry is a more direct and accurate method of body density assessment (SEE 0.4 - 0.8 % body fat) (Norton et al., 1994) than skinfold measurements there are practical limitations of its use as a tool of body composition assessment of rugby players. Very few institutions have this facility, it is time consuming, requires much tester expertise and extensive subject cooperation (Norton et al., 1994). It therefore fails to achieve criteria 1 - 4 identified by McLean (1995) as necessary to facilitate the fitness assessment of rugby union teams (page 20).

Due to the above mentioned practical limitations of hydrodensitometry, Norton et al. (1994) encourages the use of anthropometric measurements including skinfold thickness, limb girths, and bone breadths when assessment of large groups of people are required. Norton et al. (1994) advocates the summing of 4 - 8 skinfold thickness measurements as the most accurate means of evaluating body fat in games players, in preference to estimating % body fat from body density predicted via skinfold measurements.

Test - retest reliabilities for sum of skinfolds measurement errors determined by interclass correlation coefficients have been reported to be greater than 0.99; and technical error of measurement to be equal to 0.4 mm for repeated measures when skinfold measurements have been performed on sportspersons. When two or more testers measure the same site TEM has been reported as 1.0 - 2.0 mm, but less when testing athletic populations (Norton et al., 1994). The procedure of summing skinfolds eliminates two errors, that of transforming skinfold thickness (in mm) to a body density estimate which has a standard error of estimate (SEE) of about 2.3 % body fat, and secondly transforming body density to % body fat which has a SEE of 2.6 - 3.8 % body fat (Norton et al., 1994).

As shown in Table 2.12. most studies estimate absolute and relative lean body mass (LBM) after having predicted relative fat mass. Although the calculation of sum of skinfolds (without further use of an equation to derive relative fat mass) does not allow for the determination of LBM, muscle mass can be estimated from the equation of Martin et al. (1990). This equation uses the measurements of height and three limb girths corrected for skinfold thickness (forearm, mid-thigh and calf) and estimates skeletal muscle mass with an SEE = 1.53 kg and  $r^2 = 0.97$ .

The body size, body composition and somatotype of rugby union players are well documented in the literature and are summarized in Table 2.12. The different formulae used to derive body density and relative fat mass by the various investigators makes comparison between the studies difficult. However, collectively the studies do identify trends and characteristics and show that body size, body composition and somatotype of rugby union players are influenced by age, grade of play, position of play and phase of season.

Due to the different roles and performance requirements of forwards and backline players, most studies have investigated the anthropometric profiles of these two groups separately. Differences found between these two playing units and within these units (when further positional differentiation is made) show that there are

optimal characteristics for body size, body composition and physique for the various playing positions.

Compared to backline players matched for age group or level of play forwards are significantly taller (Maud and Shultz, 1984; Holmyard and Hazeldine, 1993; Nicholas and Baker, 1995; Mayes and Thomson, 1995; Carlson et al., 1994) and heavier (Bell, 1979; Maud and Shultz, 1984; Holmyard and Hazeldine, 1993; Carlson et al., 1994; Nicholas and Baker, 1995; Mayes and Thompson, 1995; Turnbull, 1996). Forwards have a greater amount of body fat (absolute and relative to their body mass) ( Bell, 1973; Bell, 1979; Maud and Shultz, 1984; Carlson et al., 1994; Nicholas and Baker, 1995; Mayes and Thompson, 1995; Turnbull, 1996 ) and lean body mass (Bell, 1979; Maud and Shultz, 1984; Nicholas and Baker, 1995) compared to backline players. However, Jardine et al. (1988) found no difference in height and % body fat between forwards and backs playing in a University team.

Table 2.13. shows that forwards playing in the 1990's are more endomorphic and less ectomorphic than backline players (Quarrie et al., 1995; Carlson et al., 1994). Carlson et al. (1994) found the American national level forwards to be more mesomorphic than their backline counterparts, whereas Quarrie et al. (1995) found that amongst New Zealand club level players forwards did not differ significantly from backline players with respect to mesomorphy. The latter finding supports the prediction of Noakes and Du Plessis (1996) regarding the de-differentiation of specific body types for specific playing positions as the role of backline players becomes more similar to that of the loose-forwards.

Bell (1979), Bell et al. (1993), Quarrie et al. (1996) and Turnbull (1996) assessed differences within the categories of forwards and backs. Bell (1979) found no differences in body mass, percentage body fat, relative and absolute lean body mass within the 5 forward playing positions. The only significant difference was between hookers and eighth men with the latter having 11 kg greater lean muscle mass.

Table 2.12. Body size and body composition of rugby union players.

Playing level and position	Age (yrs)	Ht (cm)	BM (kg)	SS (mm)	BF (%)	LBM (kg)	Reference	Comment
<b>USA Elite</b>								
Forwards	26.8	186.8	99.1	SS 9= 117	13.5	85.7	Carlson et al. (1994)	- Training squad includes national, junior and development players. - Forwards were significantly taller and heavier than backs. - Forwards had a significantly greater SS skinfolds than backs BD - Jackson and Pollock (1978) BF - Siri (1961)
Backs	25.8	178.9	80.8	SS 9= 81	9.2	73.4		
<b>USA National</b>								
Forwards		187.3	94.4	SS 3 = 34	10.5	84.4	Maud and Schultz (1984)	- Forwards were significantly taller, heavier, had higher sum of skinfolds and had greater lean body mass. BD - Jackson and Pollock (1978) BF - Siri (1961)
Backs		175.9	78.2	SS 3 = 28	7.8	72.1		
<b>USA Club</b>								
Forwards	30.7	180.7	87.7		12.4	76.7	Maud (1983)	- Tested end-of-season - No significant anthropometric differences between forwards and backs. BD - Jackson and Pollock (1978) BF - Brozak (1963)
Backs	26	178.4	80.5		11.7	71.0		
<b>South Africa Club</b>								
Forwards	23.1	187.5	98		15.2	82.9	Jardine et al. (1988)	- Forwards were significantly heavier than backs, and had significantly greater absolute muscle mass. BF - Dumin and Womersley (1974)
Backs	22.4	180.5	79.4		13.5	69.8		
<b>Wales 2nd -class</b>								
Prop		180.9	90.9		16.9	83.2	Bell (1980)	- Tested end of pre-season - Significant difference in height and weight between forward positions BD- hydrostatic weighing BF - Siri equation (1956)
Hooker		173.5	77.6		17.2	82.3		
Lock		187.9	98.8		15.6	84.4		
No. 8		189.1	86.9		11.6	89.0		
Flanker		180.2	86.3		12.1	87.9		
<b>German Club</b>								
Forwards		188.3	99.7				Kuhn (1993)	- Tested in-season
Backs		180.3	77.9					
<b>England 2nd class</b>								
Forwards	21.0		83.4		19.5	67.3	Bell (1979)	- Forwards significantly heavier, with greater fat mass (relative and absolute) and relative LBM. - no significant difference in absolute LBM BD - hydrostatic weighing BF - Siri (1956)
Backs			73.8		12.2	64.7		

Table 2.12 cont. Body size and body composition of rugby union players

Playing level and position	Age (yrs)	Ht (cm)	BM (kg)	SS (mm)	BF (%)	LBM (kg)	Reference	Comment																																																																																																																																																																																																																																																																																									
<b>Italian 'A' League</b>																																																																																																																																																																																																																																																																																																	
Forwards		184.3	96.4				Casagrande and Viviani (1993)	- Forwards significantly heavier and had greater relative fat mass.																																																																																																																																																																																																																																																																																									
Backs		180.4	81.3						<b>Wales</b>									<b>1st Class</b>									Forwards	23.7	186.2	73		11.1	86.5	Nicholas and Baker (1995)	- No difference between grades on any variables other than age.	Backs		177.6	79.3		8.0	73	<b>2nd class</b>									Forwards	21.4	185.7	91.0		11.9	80.2		- Forwards significantly taller and heavier, had a greater % body fat, and greater lean body mass than backs.	Backs		178.5	78.2		8.6	71.4	<b>Wales Senior</b>									Forwards			103.4	SS 4 = 40			Mayes and Thompson (1995)	- Tested end of pre-season - No significant differences between senior and U21 players on any variables. - In both groups forwards were heavier and had higher values for skinfold thickness.	Backs			83.9	SS 4 = 29			<b>Elite U21</b>									Forwards			97.0	SS 4 = 44			Backs			78.4	SS 4 = 30				<b>England National</b>									Forwards	29.2	184	100.3		13.3	87.0	Holmyard and Hazeldine (1993)	- Values reported were recorded the at mid-season test session. - Forwards were significantly older, taller, heavier, and had higher percentage body fat values than backs.	Backs	26.9	175	83.0		11.4	75.3	<b>Wales Senior squad</b>									Forwards	25.6	187	105.1	SS 4 = 50			Tong and Mayes (1995)	-Tested during the off-season	Backs	24.6	176	82.6	SS 4 = 36			Forwards		188	105.6	SS 4 = 46				- Tested end-of-pre-season - Forwards and backs decreased their sum of skinfold values during the pre-season training period.	Backs		177	81.5	SS 4 = 33			<b>New Zealand</b>									<b>Senior A club</b>									Forwards	22.7	186.0	98.5				Quarrie et al. (1995)	- Tested pre-season	Backs	21.9	177.8	81.8				<b>Senior B Club</b>									Forwards	25.5	181.2	88.1					- Senior A players significantly heavier and taller than senior B.	Backs	22.5	176.5	77.3				<b>U21 Club</b>									Forwards	18.9	183.3	89.4					- Senior A players significantly heavier than U21 players	Backs	18.9	177.5	75.5				<b>U19 /18</b>									Forwards	16.7	180.2	82.6						Backs	17.1	175.4	72.0	
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**Table 2.12 cont. Body size and body composition of rugby union players**

<b>Playing level and position</b>	<b>Age (yrs)</b>	<b>Ht (cm)</b>	<b>BM (kg)</b>	<b>SS (mm)</b>	<b>BF (%)</b>	<b>LBM (kg)</b>	<b>Reference</b>	<b>Comment</b>
<b>New Zealand Senior A Club</b>								
Props		182.2	102.8				Quarre et al. (1996)	- Sample sizes 10 - 13 players in each category - Back five forwards significantly taller than the front row forwards, but no significant difference in weight - Midfield and outside backs were taller and had significantly greater body mass than the inside backs.
Hookers		178.8	89.7					
Locks		191.8	101.9					
LF		186.3	96.3					
IB		172.7	75.0					
MB		179.7	85.9					
OB		179.4	83.4					

Abbreviations: yrs, years; cm, Ht, height; centimeters, BF, body fat; %, percentage; SS, sum of skinfolds with the number adjacent to the SS indicating the number of skinfolds that were summed to derive the total; mm, millimeters; BM, body mass; kg, kilograms; P, props; L, locks; LF, loose-forwards; H, hookers; IB, inside backs; MB, midfield backs; OB, outside backs. BD, body density; and BF, body fat indicate the reference for the equations or formulae used to derive body density and body fat estimates.

Quarre et al. (1996) reported that amongst New Zealand senior A club players the back five forwards were significantly taller than the front row forwards, and locks were significantly taller than loose-forwards. They found no significant differences in the body mass of front row and back row forwards, but the front row forwards were more mesomorphic and less ectomorphic than the back five forwards. Amongst the backline players the only significant differences were in body size with the midfield and outside backs being both heavier and taller than the inside backs.

Bell et al. (1993) divided members of the Welsh national squad into three groups - props & locks, and loose-forwards & hookers, and backs. The three groups did not differ with respect to height or % body fat (props & locks 16%, loose-forwards & hookers 12 %, and backs 13 %) or relative fat free mass, but both groups of forwards were significantly heavier than the backs and had greater absolute fat free mass. Turnbull (1996) divided South African senior A provincial players into the same three categories as Bell et al. (1993) and found that the props & locks and the loose-forwards & hookers were heavier and had greater subcutaneous fat levels than the backs. This pattern of differences existed at the end of the off-season, at the end of the pre-season (Table 2.14) and in the middle of the season.

**Table 2.13. Somatotypes of Rugby union players.**

<b>Playing level and position</b>	<b>Somatotype End - Mes - Ect</b>	<b>Reference</b>	<b>Comment</b>
<b>Wales 1st class college players (*)</b>		Bell (1979)	
Forwards	4.5 - 5.0 - 2.5		
Backs	4.0 - 5.0 - 2.5		
<b>Wales 2nd class college players (**)</b>			
Forwards	4.5 - 4.5 - 2.5		
Backs	4.0 - 4.5 - 3.0		
<b>England 1st and 2nd club team players (**)</b>			
Forwards and Backs combined	3.5 - 5.5 - 2.0	Reilly and Hardiker (1981)	- No significant difference in somatotype between forward and backs
<b>Italian 'A' league players (***)</b>			
Forwards	3.5 - 6.1 - 1.0	Casagrande and Viviani (1993)	- Backs less endo-mesomorphic (and more ectomorphs)
Backs	2.6 - 4.9 - 2.0		
<b>USA Elite players (***)</b>			
Forwards	3.1 - 6.6 - 1.2	Carlson et al. (1994)	- Backs were significantly lower on endomorphy and mesomorphy, and higher on ectomorphy.
Backs	2.4 - 5.9 - 1.8		
<b>New Zealand players (***)</b>			
<b>Senior A club players</b>		Quarrie et al. (1995)	- Tested pre-season
Forwards	3.7 - 6.5 - 1.1		Forwards significantly more endomorphic and less ectomorphic than backs.
Backs	2.5 - 6.2 - 1.4		
<b>Senior B Club players</b>			
Forwards	3.2 - 6.0 - 1.4		- Positions did not differ significantly in terms of mesomorphy.
Backs	2.9 - 5.3 - 1.8		
<b>U21 Club players</b>			
Forwards	3.6 - 5.9 - 1.5		- Senior A players significantly taller, heavier and more mesomorphic than Senior B.
Backs	2.4 - 5.4 - 2.2		
<b>U19 / 18 players</b>			
Forwards	3.4 - 5.6 - 2.0		- Senior A players significantly heavier, more mesomorphic and less ectomorphic than U21 players
Backs	2.2 - 5.5 - 2.3		
<b>New Zealand players (***)</b>			
<b>Senior A club players</b>		Quarrie et al. (1996)	- Front row forwards significantly more mesomorphic and less ectomorphic than back five forwards.
Props	4.5 - 7.5 - 0.5		
Hookers	3.6 - 7.1 - 0.9		
Locks	3.7 - 5.9 - 1.6		
Loose-forwards	3.7 - 6.2 - 1.3		
Inside backs	2.3 - 6.2 - 1.5		
Midfield backs	3.1 - 6.7 - 1.3		
Outside backs	2.4 - 6.0 - 1.6		

End - Mes - Ect, endomorphy - mesomorphy - ectomorphy; \*, Parnell method as cited in Bell (1979); \*\*, method as cited in Heath B and Carter J (1967); \*\*\*, method as cited in Carter J and Heath J (1990).

**Table 2.14. Comparison of body mass and body fat between three positional categories.**

Variable	Ref.	Positional category			P		
		P & L	LF & H	B	P & L vs LF & H	P & L vs B	LF & H vs B
<b>South Africa Provincial A</b>	Tumbull (1996)						
Body mass (kg)		110.1	104.6	85.1		**	**
°Body fat (%)		16.8	14.5	10.7		**	**
<b>England National</b>	Bell et al. (1993)						
Body mass		102.5	100.9	85.0		*	*
•Body fat (%)		15.5	12.3	13.1			

Abbreviations: Ref., reference; \*, P < 0.05; \*\*, P < 0.01; kg, kilograms; %, percentage; °, derived from Heath & Carter equation cited in Carter (1982); •, Body density - hydrostatic weighing and body fat derived from the equation of Siri (1956)

In some studies body size and body composition were not influenced by age (Mayes and Thomson, 1995) or proficiency of play (Nicholas and Baker, 1995). In contrast Quarrie et al. (1995) found significant differences in the anthropometric characteristics of New Zealand players differing in age (senior vs under 21 vs under 19 /18) and level of play (senior A vs senior B). Senior A players were found to be taller, heavier, more mesomorphic and have larger neck circumferences than senior B players; and to be heavier, more mesomorphic, less ectomorphic and possess larger neck circumferences than under 21 players. Under 21 players were significantly heavier and had larger neck circumferences than Under 19 / 18 players. Endomorphy was the only variable not to differ significantly across age or proficiency of play.

Seasonal variations in body size and body composition have been investigated by Holmyard and Hazeldine (1993), Tong and Mayes (1995), and Tumbull (1996). Tong and Mayes found that in Welsh national players body mass and height did not change between the off and in-season, but both forwards and backs had significantly less body fat at the beginning of the season when compared to the beginning of the pre-season. Holmyard and Hazeldine (1993) found that % body fat decreased in both the pre-season and first half of the playing season, and that backs had significantly less body fat than the forwards except during the off-season. Tumbull (1996) reported body mass and % body fat decreased from end

of the off-season to the end of the pre-season, and from the end of the pre-season to the middle of the competitive season (Table 2.15.).

**Table 2.15. Comparison of body mass and percentage body fat within three training cycles for a squad of players (Turnbull, 1996)**

Variable	End of off-season vs end of pre-season	End of off-season vs mid-season	End of pre-season vs mid-season
Body mass (kg)	98.1 vs 99.0 **	98.1 vs 95.9**	99.0 vs 95.9**
Body fat (%)	14.2 vs 13.5**	14.2 vs 12.3**	13.5 vs 12.3**

Abbreviations: \*\*, P < 0.01; kg, kilograms; %, percentage

In summary, the majority of studies show that rugby union players have unique anthropometric characteristics and somatotypes which depend on the positional role, age or proficiency of play, and phase of the season. The most prominent variation between playing positions is that forwards tend to be heavier and taller than backs. A larger body mass is beneficial to the forwards in the set scrums, rucks and mauls with respect to inertia and momentum, provided there is no adverse effect on speed (Maud and Schultz, 1984). Although rugby union is a contact game where a large body mass is desirable it is critical that players trying to increase their body mass do so via increasing lean body mass at the expense of total body fat, and thereby maintain an optimal power to weight ratio. It is a large lean body mass that increases the properties of inertia and momentum which is an advantage at impact or during contact. Noakes and Du Plessis (1996) predict that if the playing pattern adopted by New Zealand and to a lesser extent South Africa (playing the ball wide) during the World Cup 1995 becomes the dominant style of play, de-differentiation of specific body types in the different playing positions will occur. With this style requiring the backs to ruck and maul and forwards to run it can be predicted that backline players will be characterised by body types similar to loose-forwards.

### **2.3.2. Aerobic capacity**

Traditionally a high priority has been placed on the assessment and training of the aerobic fitness of rugby union players, and almost all fitness test batteries designed to assess rugby union players have included a measure of aerobic capacity (Reid and Williams, 1974; Maud, 1983; Maud and Shultz, 1984; Jardine

et al., 1988; Hazeldine and McNab, 1991; Holmyard and Hazeldine, 1993; Tong and Mayes, 1995; Nicholas and Baker, 1995; Mayes and Thomson, 1995; Quarrie et al., 1995 and 1996; Turnbull et al., 1995; Turnbull, 1996; and Clark, 1998).

During the 1970's and 1980's the aerobic capacity of rugby union players was typically evaluated on either a treadmill or cycle ergometer (Maud, 1983; Maud and Shultz, 1984; Jardine et al., 1988; and Nicholas, 1997) and maximal oxygen consumption was measured either directly or indirectly predicted (Table 2.16.).

Tests that determine maximal oxygen consumption ( $\dot{V}O_2$  max) directly require sophisticated equipment, laboratory time, trained personnel, and furthermore, the test performance modes are not specific to rugby. They are also expensive, time consuming and therefore impractical for use with large groups of players. They therefore fail to fulfill requirements 1 - 5 advocated by McLean (1993) (page 20).

Simple field tests such as the Coopers 12 minute run (Reid and Williams, 1974) and a 3 km run (Turnbull, 1996; Australian Institute of Sport as quoted in Noakes and Du Plessis, 1996) have also been used to evaluate aerobic fitness and estimate  $\dot{V}O_2$  max. These tests are easy to administer to large groups and inexpensive. However, the disadvantages are that these field test require subjects to be well motivated, they are not progressive in intensity, they require pace judgement, and most importantly are not specific to the intermittent nature of rugby union.

Currently the most popular and preferred method of aerobic assessment of rugby union players is the multistage shuttle run test as described by Ramsbottom et al. (1988). This test predicts maximal oxygen consumption ( $r = 0.92$ ) from the level and shuttle or the shuttle attained on a 20 m shuttle run test with an estimated standard deviation about the regression line of  $3.5 \text{ mlO}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ . Test-retest reliability coefficients have been reported as  $r = 0.95$  (Leger et al., 1988). The advantages of this test are that it is more rugby specific requiring players to repeatedly accelerate, decelerate, and turn, it is progressive in nature, and a pre-recorded tape dictates the pace at which players are required to run. Tables 2.17 and 2.18. show the performances of rugby players on the multistage shuttle run.

**Table 2.16. Maximal oxygen consumption of rugby union players determined by stationery cycling or treadmill running.**

Level of play	Position	n.	Mode	VO <sub>2</sub> max (lO <sub>2</sub> .min <sup>-1</sup> )	VO <sub>2</sub> max (mlO <sub>2</sub> .kg <sup>-1</sup> .min <sup>-1</sup> )	Reference	Comment
USA Club	Forwards	8	TM	4.73	54.1	Maud (1983)	- No significant differences between groups.
	Backs	7		4.77	59.5		
USA National	Forwards	8	CE	4.26	45.1	Maud and Shultz (1984)	- Test performed the day after an international game. - Analyses did not include differences between backs and forwards.
	Backs	8		3.67	46.7		
			CE		47.6* 51.7*		
South Africa Club players	Forwards	15	TM	5.14	55.8	Jardine et al. (1988)	- Absolute VO <sub>2</sub> max significantly greater in the forwards. - Relative VO <sub>2</sub> max significantly greater in the backs.
	Backs	14		4.41	52.0		
England Club		20	CE		46.3	Bell et al. (1980)	

Abbreviations: \*, Values predicted from heart rates during a submaximal test using the Astrand Rhythmic nomogram; CE = cycle ergometer; TM = treadmill; n., number of subjects; Mode, exercise mode; VO<sub>2</sub> max, maximal oxygen uptake; lO<sub>2</sub>.min<sup>-1</sup>, liters per minute; mlO<sub>2</sub>.kg<sup>-1</sup>.min<sup>-1</sup>; milliliters of oxygen per kilogram of body mass per minute

Although the multistage shuttle run is a more sports specific measure of aerobic fitness in rugby players than the cycle, treadmill and running tests discussed, McLean (1993) questions the sensitivity of the test to detect changes in the fitness of elite players following training. He reported that the Scotland squad did not improve in their performances on this test after a successful conditioning programme, but did improve on a test of 'repeat sprint' nature, the 85 % maximum shuttle run. This therefore suggests that amongst elite players the latter type of test should be used in preference to the multistage shuttle run (Ramsbottom et al., 1988) when wanting to effectively assess a training programme.

**Table 2.17. Multistage shuttle run performances of rugby union players (protocol of Ramsbottom et al. 1988).**

Level of play	Position	n.	Shuttle no.	Level and shuttle	Predicted VO <sub>2</sub> max (mlO <sub>2</sub> .kg <sup>-1</sup> .min <sup>-1</sup> )	Reference	Comments
<b>Wales</b> Senior squad	Forwards	21	106	12, 2	54.3	Tong and Mayes (1995)	End of pre-season testing.
	Backs	18	124	13, 8	59.1		
<b>Wales</b> 2nd class	Forwards	15	102	11, 10	53.3	Nicholas and Baker (1995)	Significant differences between forwards and backs.
	Backs	15	118	13, 2	57.7		
1st class players	Forwards	15	98	11, 6	51.8		No significant differences between 2nd class and 1st class players.
	Backs	15	114	12, 10	56.3		
<b>Wales</b> Elite senior	Forwards	13	110	12, 8	56.0	Mayes and Thomson (1995)	End of pre-season testing.
	Backs	10	122	13, 6	58.8		
Elite U21	Forwards	19	108	12, 4	55.0		No significant differences between forwards and backs.
	Backs	25	118	13, 2	57.5		
<b>New Zealand</b> Senior A club	Forwards	50	109	12, 5	54.8	Quarrie et al. (1995)	Testing performed during the pre-season.
	Backs	43	127	13, 10	59.8		
Senior B club	Forwards	19	114	12, 10	56.5		Significant differences between forwards and backs.
	Backs	19	115	12, 11	56.5		
U21 club	Forwards	32	105	12, 2	54.3		Significant differences between grades of play.
	Backs	29	118	13, 2	57.6		
U19 /18	Forwards	29	100	11, 8	52.5		Significant differences between grades of play.
	Backs	24	105	12, 0	53.7		
<b>England</b> National	Forwards	9	120	13, 4	58.0	Holmyard and Hazeldine (1993)	Mid-season testing values, but there was no improvement from end of pre-season to mid season.
	Backs	9	126	13, 10	59.6		
							No significant differences between backs and forwards at pre or mid-season.

Abbreviations: no., number; VO<sub>2</sub> max , maximal oxygen uptake; mlO<sub>2</sub>.kg<sup>-1</sup>.min<sup>-1</sup>, milliliters of oxygen per kilogram of body mass per minute; n., number of subjects

**Table 2.18. Multistage shuttle run performances of different positional categories within a rugby union squad.**

	Position	n.	Shuttle number	Level and shuttle	VO <sub>2</sub> max (mlO <sub>2</sub> .kg <sup>-1</sup> .min <sup>-1</sup> )	Comments
New Zealand	Props	13	96	11, 4	48.0	Testing performed during the pre-season
Senior A club	Hookers	6	124	13, 8	59.3	
	Locks	15	111	12, 7	55.4	
	Loose-forwards	15	111	12, 7	55.4	
	Inside backs	11	138	14, 9	62.7	
	Midfield backs	14	127	13, 11	59.8	
	Outside backs	18	120	13, 4	58.2	

Abbreviations: VO<sub>2</sub> max , maximal oxygen uptake; mlO<sub>2</sub>.kg<sup>-1</sup>.min<sup>-1</sup>, milliliters of oxygen per kilogram of body mass per minute; n., number of subjects

### 2.3.3. Repeat sprint ability

During the 1990's a better understanding of the role aerobic capacity in rugby union has developed, and although it is still considered relevant for successful performance it is no longer perceived as a major priority for fitness development or testing (McLean, 1995). Exercise scientists and fitness trainers now place priority on a fitness component that has been coined 'repeat sprint ability' (RSA) by Dawson et al. (1993). The authors suggest that 'match fitness' for team games which involve high intensity intermittent exercise be assessed in terms of the ability to regularly reproduce maximal sprint efforts. Accordingly, RSA tests should be designed in structure to challenge the energy systems in a manner which closely replicates the intermittent nature of rugby union.

Dawson et al. (1993) investigated the energetics of high intensity intermittent exercise characteristic of many team sports including rugby union. They concluded that all three power systems playing an important role. Oxygen independent energy systems were most closely associated with the total work achieved during RSA tests, whereas the aerobic energy system was more closely associated with the recovery / fatigue score (% decrement in ability to reproduce high intensity efforts when interspersed with a brief rest period).

The role of aerobic capacity in rugby union is therefore to facilitate recovery between the large number of short duration, high intensity bouts of exercise that players are required to perform during a game. The greater the recovery rate

during the typically less than 40 second rest or low intensity interval, the better the player is able to sustain his work capacity during intensive anaerobic efforts of strength, power or speed.

Although during the 1980's researchers recognized that rugby union was characterised by high intensity, intermittent exercise requiring both aerobic and anaerobic fitness, no tests that simultaneously challenged the aerobic and anaerobic power systems were included in test batteries. However, there is now general consensus that RSA is a vital fitness component for rugby union and this is reflected in the inclusion of RSA test protocols in recent studies investigating the physical performance characteristics of players (Holmyard and Hazeldine 1993, Nicholas and Baker, 1995; Mayes and Thompson, 1995; and Quarrie et al., 1995 and 1996).

But, the development of rugby specific repeat sprint tests is in its infancy. McLean (1995) has designed a test called the '85% maximum shuttle run test' based on notational information about the distance (average 80 m) and intensity ( $5-8 \text{ ms}^{-1}$ ) of sprints or fast running characteristically performed by players during a match, and the work to rest ratios (1 : 1.0 - 1.9) typical of rugby union. The RSA ability of the Scotland squad improved significantly on this test before and after a pre training tour and in contrast to a lack of improvement on the multistage shuttle run. This finding highlights the importance of repeat sprint tests as a measure of 'match fitness'. This test fulfills the test criteria 1 - 7 detailed on page 20 McLean (1993). The RSA test has not as yet been measured against a gold standard anaerobic test. Furthermore, the reliability of the test needs to be determined as it is a field test and may be influenced by weather and ground conditions.

The 40 m maximal intensity shuttle run (Baker et al., 1993) has a test-retest correlation of  $r = 0.86$  for the fastest 40 m shuttle run times,  $r = 0.95$  for maximum heart rate, and  $r = 0.98$  for peak blood lactate concentrations. This test has been used in a number of test batteries for rugby players (Hazeldine and McNab, 1991; Nicholas and Baker, 1995; Mayes and Thompson, 1995) and is described in detail in Hazeldine and McNab (1991). In summary the test requires that players cover a

40 m distance eight times with a 20 seconds recovery period in between sprint bouts. The average time recorded by rugby players per 40 m sprint is 8 - 10 seconds giving a work to rest ratio of about 1 : 2.0 - 2.5. Results recorded for this test include the fastest sprint, the total time taken for the eight sprints, and the fatigue index. The fatigue index is calculated as the difference between the mean of the fastest two and the slowest two sprints expressed as a percentage of the fastest two sprints (Baker et al., 1993). Nicholas and Baker (1995) reported that Welsh rugby players classified as first class (no details provided as to whether these players were provincial or club level) backs had significantly lower fatigue indices than first class forwards, whilst amongst Welsh rugby players of a lesser proficiency level there was no difference in performances between backs and forwards. Mayes and Thompson (1995) found that the fatigue index was not different between senior backs and forwards, but that the backs had a quicker total sprint time. U21 backline players had significantly higher fatigue indices and covered a greater sprint distances than their forward playing counterparts. The greater distance covered by the backs may be attributable to their superior speed (sprint ability) compared to the forwards. The similarity of the fatigue index between the senior backs and forwards suggests that they possessed similar levels of repeat sprint ability. The significantly higher fatigue index of the U21 backline players suggests the U21 backs were not as fit with regard to their ability to repeat brief maximal sprint efforts (RSA) as their forward counterparts. Mayes and Thompson (1995) concluded that there are no differences in repeat sprint ability performance, as assessed by the protocol of Baker et al. (1993), between senior and U21 elite rugby players, although there were positional differences within each age group.

Clark (1995) recommended that the High Performance Laboratory of the Sports Science Institute of South Africa use the Welsh Rugby Union shuttle run test as a measure of repeat sprint ability fitness of rugby players. This test is specific for the physical demands of rugby as performance in this test is dependent on a combination of fitness components: aerobic capacity, anaerobic capacity, speed, speed-endurance, local muscle endurance of the legs and lower back, and agility (Pendleton, 1996). The test requires subjects perform 6 x 30 s periods of high

intensity sprint performance, interspersed with 35 s of recovery (W:RR of 1 : 1.2). The protocol is detailed in the methodology section.

Pendleton (1997) investigated the reliability and validity of the Welsh Rugby Union shuttle run test (WRUsrt). He reported that the difference in the mean distance covered (m) for 3 trials ranged from 0.7 - 2 % for each sprint, and the mean standard error of the mean (SEM) value of the 6 sprints was 2 m. However, the content relevance of this test as a measure of rugby specific fitness is questionable in that it omits important behaviours such as skills; and it inappropriately weights certain behaviours such as the work to rest ratio, the distance covered per sprint, the length of each sprint, and the number of turns which reduces the pace at which each sprint activity is performed. However, the test does include repetition of periods of high intensity activity between periods of rest or low intensity exercise; frequent bursts of acceleration; and frequent change of sprint direction when at pace; all of which are important rugby specific behaviours. Pendleton (1997) suggests that the power system used at the beginning of the test is predominantly anaerobic, becoming increasingly more aerobic as the test progresses. The furthest distance covered on any sprint reflects anaerobic ability while total distance covered during the test is a reflection of aerobic fitness (Pendleton, 1997).

Although repeat sprint tests such as the 85 % of maximum shuttle run (McLean, 1993) may have greater content validity, the WRUsrt certainly has logical or face validity in that it assesses the ability to reproduce high intensity sprint efforts interspersed with a brief recovery period (Pendleton, 1997).

#### **2.3.4. Skeletal muscle strength**

Skeletal muscle strength is the maximal amount of force a muscle or muscle group can generate in a specified movement pattern at a specified velocity of movement. In an exercise such as bench press, a one repetition maximum (1 RM) is a measure of strength at a relatively slow speed of movement (Fleck and Kraemer, 1997).

The specific strength requirements within the game of rugby union vary, and include strength endurance (wrestling for the ball during a maul), explosive strength (jumping in the lineout), static strength (forwards in static and semi-static scrumming) and maximal strength and power (Hazeldine and McNab, 1991). While some strength gains may result from general strength training, gains for specific types of strength require specific types of training and targeting of specific muscle groups. This means the strength training requirements may vary considerably depending on the playing positions (Hazeldine and McNab, 1991). Muscular endurance is discussed in section 2.3.6 and explosive strength in section 2.3.7.

For optimal gains in muscle power a solid base of general muscle strength is important. (Ebben and Watts, 1998). Basic strength also contributes to other recognised fitness components for rugby - speed (Watson, 1985), and agility (Jensen and Hirst, 1980). These three fitness components, explosive strength, speed and agility, are sports specific fitness components and their development is dependent on a foundation of basic muscle strength which is considered a general component of fitness.

Rugby fitness programmes aim to develop muscle strength and hypertrophy in the off and early pre-season following which, more training time is devoted to developing the sports specific components mentioned above. Therefore, test batteries administered before and after this period of training should include some measures of both upper and lower body strength. Table 2.11 shows the variety of tests that have been used to assess the muscle strength of rugby players. Most studies have emphasized evaluating explosive muscle power rather than maximal muscle strength. Only a few studies (Maud, 1983; Howe, 1981; Clark, 1998) have assessed maximal muscle strength of the upper and lower body using the one repetition maximum (1 RM) method. The most popular test for upper body strength assessment is the bench press and for the lower body, the squat and leg press. Protocols and equipment used for these evaluations have, however differed, making comparisons between studies difficult.

The bench press is reported to have a reliability coefficient of  $r = 0.93$  (Johnson and Nelson, 1979). Clark (1998) found high school rugby players able to lift an average of 65 kg which equated to  $0.9 \text{ kg.kg BM}^{-1}$ . Following a preseason programme 1 RM increased significantly in absolute terms to 74.5 kg (14.5 %). However, due to the simultaneous increase in body mass over the training period, muscle strength relative to body mass did not change. These results can be compared to the performances of rugby scholarship holders (18-20 years old) at the Australian Institute of Sport (AIS). Tight forwards lifted on average 115 kg, loose-forwards 105 kg, and backs 95 kg (Noakes and Du Plessis, 1996).

The South African high school players assessed by Clark (1998) squatted on average 124 kg or  $1.6 \text{ kg.kg BM}^{-1}$ , and after a training programme the boys in the unsupervised training group improved by 17.5 % and those in the supervised training group by 7.6%. When expressed relative to body mass the improvements, as for the bench press, were not significant. Amongst the AIS scholarship holders tight-forwards squatted 120 kg, loose-forwards 115 kg, backs 110 kg. The AIS programme also includes a power clean in their battery of strength assessment protocols for rugby (Noakes and Du Plessis, 1996).

Maud (1983) compared the upper and lower body strength of American club level forwards and backs. Forwards lifted a significantly heavier weight (90.4 kg) than backs (79.9 kg) for the bench press 1 RM. The backs lifted a greater weight for the leg press than the forwards (288 vs 269 kg) but this difference was not significant. Tong and Wood (1995) assessed the strength differences within collegiate playing forwards and found that although for 9 of the 11 tests front-row forwards performed better than both the second-row and back-row forwards these differences were not significant. Grip strength did not differ between backs and forwards (Maud and Shultz, 1984), but improved following a preseason training programme (Tong and Mayes, 1995).

The maximal isotonic muscular strength of rugby union players has not been well researched, but this may be due to constraints including time available for testing, experience of the players and safety. Kraemer and Fry (1995) provide

thorough guidelines for administering 1 RM tests and for the purposes of assessing the efficacy of strength training in the off and pre-season. 1 RM tests are important as players must have developed sufficient strength before progressing to dynamic strength training and plyometrics (Ebben and Watts, 1998).

### **2.3.5. Skeletal muscle endurance**

Skeletal muscle endurance (the capacity for repeated sub-maximal contractions of a muscle or muscle group) is essential in rugby union especially in the arm, shoulder and abdominal regions (Hazeldine and McNab, 1991). Wrestling for the ball during a maul, making a series of sprints or driving forward in the scrum are all examples of activities requiring skeletal muscle endurance (Nicholas, 1997).

The most common methods used in the assessment of local muscle endurance are maximum number of press ups, pull ups, and sit ups performed in a set time or maximum number performed at a set pace. Differences in test protocols make comparison between studies very difficult.

Assessment of maximum number of pull ups has been reported to have a test-retest reliability coefficient of  $r = 0.99$  (Johnson and Nelson, 1979). Although pull ups have not been extensively used as a measure of muscular endurance in rugby union, they have been included in fitness test batteries by three South African provincial squads (Turnbull, 1996). Turnbull (1996) reported the maximum number of pull ups players could complete improved significantly from the end of the off-season to the end of the pre-season, but did not improve further during the first half of the competitive season. In all phases of the season, backs performed significantly better than the props and locks, and the loose-forwards and hookers. There were no significant differences between the performances of the props and locks, and loose-forwards and hookers. Turnbull (1996) also assessed abdominal and hip flexor endurance and found players sit up performance improved significantly between the off to the end of pre-season and from the end of pre-season to mid season.

First class front row players perform significantly better than their second class counterparts in push ups, and first class backs and halfbacks performed better than their second class counterparts in both push ups and sit ups (Nicholas, 1997). Carlson et al. (1994) found that there was a tendency for backs to perform better than forwards with respect to sit ups, push ups and squat thrusts. In contrast, Quarrie et al. (1995) found backs to perform significantly better than forwards for push ups. Players in different positions within the units of backs and forwards did not differ significantly in their performance during a push up test (Quarrie et al., 1996).

### **2.3.6. Explosive leg power, maximal anaerobic power and anaerobic capacity**

Power is the rate of performing work, the product of force and velocity. The ability to drive in the tackle, to drive in the scrums, mauls and rucks, to jump in the lineouts and under the high ball, and to run fast are all influenced by muscular power (Turnbull et al., 1995).

When performing maximal bouts of strength and speed that last for up to six seconds the dominant metabolic pathway is that of the phosphagen system. Traditionally the term maximal anaerobic power has been used to represent the performance of this oxygen independent metabolic pathway (peak power output). As the duration of high intensity exercise increases beyond 6 seconds and up to approximately 30 seconds the oxygen independent glycolytic metabolic pathway becomes more dominant than the phosphagen and the oxygen dependent power systems. The term anaerobic capacity has traditionally been used as an index of performance of oxygen independent glycolytic metabolism (mean power output).

In most of the studies reviewed the term anaerobic metabolism is used to represent the performance of the phosphagen and anaerobic glycolytic metabolic pathways. However not all researches agree to this term anaerobic metabolism and prefer to use the term oxygen independent metabolism.

The position of the player (back or forward) will determine the relative importance of the strength and speed components of the power equation

(Power = force x velocity). The relative importance of the strength component increases as the load or external resistance that needs to be overcome increases (Turnbull, 1996), therefore the strength component of the equation is probably more important for the forwards (scrumming) compared to the backs.

The most commonly used test for the assessment of leg power in rugby players is the vertical jump test. It requires players to perform a counter movement jump for the determination of maximal jump height from which their standing height is deducted for the calculation of jump height. (Evans, 1973; Maud, 1983; Maud and Shultz, 1984; Hazeldine and McNab, 1991; Quarrie et al., 1995 and 1996; Turnbull et al., 1995; Turnbull, 1996; Noakes and Du Plessis, 1996; Clark, 1998). Less extensively used for the assessment of anaerobic power are the triple jump (Turnbull et al., 1995; Turnbull, 1996; Noakes and Du Plessis, 1996) and 5 - 6 s Wingate tests (Bell et al., 1993). Tests of anaerobic capacity (phosphagen and glycolytic pathways) have included 30 - 40 s Wingate tests, however each researcher has used a slightly different protocol (Bell, 1979; Maud and Shultz, 1984; Clark, 1998).

The vertical jump test has a validity coefficient of  $r = 0.78$  when correlated with four power events in field athletics, and a test-retest reliability coefficient of  $r = 0.93$  (Jensen and Hirst, 1980). In recent years the vertical jump test has been subject to the scrutiny of exercise scientists with respect to its usefulness and validity as a means of estimating leg power output (Umberger, 1998). However, a study by Wilson and Murphy (1995) found performance on a counter movement vertical jump to be significantly related to a 6 s stationary cycle test, and could be used to discriminate between individuals of different performance levels. Vertical jump scores and peak power output on the cycle performance test improved with 10 weeks of dynamic strength training and plyometrics (subjects were strength trained prior to the study), but improvements in the cycle test were not related to the percentage improvement in vertical jump height. The vertical jump was therefore unable to detect training induced changes in performance and the researchers recommended that alterations to training programmes should be based on change in actual performance, as opposed to tests of muscular function.

Table 2.19. reports the vertical jump heights attained for rugby union players. Generally backs score higher than the forwards. However, whilst some studies have found significant differences in jump height between the two playing groups (Quarrie et al., 1995), others have not (Maud, 1983; Maud and Shultz, 1984; and Turnbull, 1996).

Turnbull (1996) investigated the effects of three training phases on the vertical jump scores of South African senior A Provincial players (Natal) and found that scores at the end of pre-season and at mid-season were not significantly different from each other, but were significantly different from the end of the off-season. Clark (1998) assessed the effects of a 12 week pre-season training period on vertical jump height. The study comprised of three groups of senior high school rugby players. One group followed a training programme but were not supervised on a weekly basis (UTG), another group were supervised three times a week (STG) and a control group (CG) who did not participate in the training study and only performed the tests before and after a 12 week period in the pre-season. The results showed that the CG and UTG improved by 2.2 cm and 4.0 cm respectively, and the scores for the STG decreased by 0.3 cm. In the same study Clarke (1998) found peak watts (anaerobic power) and mean watts (anaerobic capacity) achieved during a Wingate test did not change significantly for any of the groups across the training period. Tong and Mayes (1995) found a non significant decrease in vertical jump height amongst senior Welsh National players after following a three month pre-season training programme.

**Table 2.19 Vertical jump height of rugby union players**

Players	Position	Jump height (cm)	Reference	Comment
<b>Wales</b> 17 - 19 yrs Adults club level	F vs B F vs B	54 vs 56 59 vs 61	Evans (1973)	
<b>USA</b> Club players	F vs B	50 vs 51	Maud (1983)	- In season - No significant differences between backs and forwards
<b>USA</b> National squad	F vs B	57 vs 57	Maud and Shultz (1984)	- In season - No significant differences between backs and forwards
<b>USA</b> Elite players	F vs B	59 vs 62	Carlson et al. (1994)	- Training squad includes national, junior and development players.
<b>New Zealand</b> Club senior 'A' Club senior 'B' Club U 21 School U 19/18	F vs B F vs B F vs B F vs B	60 vs 63 55 vs 60 58 vs 61 57 vs 63	Quarrie et al. (1995)	- No significant differences between age and grade of players - Within each grade backs performed significantly better than forwards
<b>New Zealand</b> Club senior 'A'	P vs H vs L vs LF IB vs MB vs OB	58 vs 56 vs 61 vs 62 63 vs 61 vs 65	Quarrie et al. (1996)	- No significant differences within the forwards or within the backs.
<b>England</b> National squad	Forwards Backs	56 60	Hazeldine and McNab (1991)	
<b>South Africa</b> Provincial 'A'	P & L vs LF & H vs B	59 vs 58 vs 64	Tumbull (1996)	- End of pre-season - No significant differences between the three positional categories
<b>Australia</b> 18 -20 yrs	TF vs LF vs H vs B	55 vs 60 vs 65 vs 65	Noakes and Du Plessis (1996)	- Elite players holding Australian Institute of Sport rugby scholarships

Abbreviations: F, forwards; B, backs; P, props; L, locks; H, hookers; LF, loose-forwards; IB, inside backs; MB, midfield backs; OB, outside backs; TF, Tight forwards; yrs, years

Bell et al. (1993) used a 30 second Wingate test protocol to the measure anaerobic power (peak watts) and anaerobic capacity (mean watts) of Welsh national players. They reported that there were no significant differences amongst three positional categories - props & locks, loose-forwards & hookers, and backs for total work, peak power, peak power output (PPO) relative to body mass, PPO

relative to lean body mass, mean power, or fatigue index. In this study coefficients of correlation were greater between fat free mass and anaerobic performance than between body mass and anaerobic performance, supporting the view that fat free mass contributes more to the production of anaerobic performance than body mass. In the forwards the greater the amount of total body fat the lower the anaerobic performance (Bell et al., 1993).

In summary, when the vertical jump is used as a measure of leg power backs generally perform better than forwards however, when body weight is supported such as in the cycle ergometer Wingate test peak power output (anaerobic power) performances between the two playing categories do not differ significantly. Fat free mass and total body fat influence anaerobic power performance highlighting the need for rugby players to identify the optimal status of body composition considering their playing position (Bell et al., 1993).

The evidence to suggest that leg power, as assessed by the vertical jump test, is improved with training is inconclusive with both improvements and decrement of performance being cited in the literature. Differences in the type of strength and power training included in the training programme, pretraining strength status of the players, and the duration of the training intervention may account for the lack of consistency in changes in vertical jump height scores. Alternatively, the lack of sensitivity of the vertical jump test to accurately detect changes in muscle power following strength and power training may account for the differing responses.

### **2.3.7. Speed**

Turnbull et al. (1995) identify three basic types of speed: accelerative speed, pure speed and speed endurance. Acceleration is the ability to build speed (Moreno, 1994) or to move quickly from either a stationary start or a moving start (Hazeldine and McNab, 1991). An example of accelerative speed is the scrum-half moving off the base of the scrum, or the lock 'driving' forward with the ball (Turnbull et al., 1995). Pure speed is the ability to maintain maximum velocity (Moreno, 1994). Speed endurance is the ability to repeat sprints of distances generally greater than

60 m (Turnbull et al., 1995). Speed endurance as defined by Turnbull et al. (1995) is referred to in this literature review as repeat sprint ability (section 2.3.3).

With the increase in pace at which the modern rugby game is being played, all components of speed are important. There are few studies reporting improvements in sprinting performance as a result of short term training programmes. Speed tends not to improve with training as rapidly as other fitness components, and this is primarily due to the fact that capacity for speed development is strongly influenced by intrinsic factors such as skeletal muscle fibre composition (Watson, 1995; Noakes and Du Plessis, 1996).

The major genetic factor determining speed is specific skeletal muscle composition. Human skeletal muscle is made up of varying proportions of slow twitch fibres designed for endurance activities and fast twitch fibres which are designed to produce very high rates of power output, but for short periods (McArdle et al., 1991). It is the fast twitch fibres that are ideally suited for explosive activities and short sprints lasting less than 20 seconds that characterise rugby union. Jardine et al. (1988) found rugby players, both forwards and backs to have a higher proportion of fast twitch muscle fibres compared to slow twitch (57 % and 53 % respectively).

Although short term training programmes have little effect on speed, extensive and systematic training carried out over a long period of time will invariably result in increases of speed (Watson, 1995). Training several components for example strength, power, flexibility, skill, rhythm, coordination and reaction time is common in training speed, but strength training on its own has been found to produce improvements in short sprint performance (Watson, 1995).

Most studies performed on rugby union players have used distances of 10 - 15 m to assess acceleration and 30 - 40 m to assess pure speed or maximum speed. Table 2.20 shows the times recorded over these distances.

**Table 2.20. Sprint performances of rugby union players**

Players	Position	Sprint time (s)	Reference	Comment
USA Elite players	F vs B	Distance = 36.6 m 5.12 vs 4.81	Carlson et al. (1994)	- Training squad includes national, junior and development players.
New Zealand Club senior 'A' Club senior 'B' Club U 21 U 19/18	F vs B F vs B F vs B F vs B	Distance = 30 m 4.5 vs 4.3 4.8 vs 4.5 4.5 vs 4.4 4.6 vs 4.4	Quarrie et al. (1995)	- Standing start - Times recorded by photocell sensors - Senior 'A' players were significantly quicker than senior 'B' players - Within each grade backs were significantly quicker than forwards
New Zealand Club senior 'A'	P vs H vs L vs LF IB vs MB vs OB	Distance = 30 m 4.6 vs 4.6 vs 4.5 vs 4.4 4.4 vs 4.3 vs 4.2	Quarrie et al. (1996)	- Standing start - Times recorded by photocell sensors - No significant differences within the forwards or within the backs.
England National squad	F vs B F vs B	Distance = 15 m 2.50 vs 2.21 Distance = 30 m 4.34 vs 3.86	Hazeldine and McNab (1991)	
England National squad	F vs B	Distance = 30 m 4.34 vs 3.90	Holmyard and Hazeldine (1993)	- Times recorded at mid season - Backs significantly quicker than forwards - Players started 1 m behind the first beam from a standing start
South Africa Provincial 'A'	P&L vs LF&H vs B P&L vs LF&H vs B	Distance 10 m 2.10 vs 1.78 vs 1.68 Distance 35 m 5.13 vs 4.96 vs 4.72	Turnbull (1996)	- Performed on well grassed and cut rugby field - Times recorded by photocell sensors - Times recorded at end of pre-season - For 10 m speed there was a significant difference between the props and locks and the backs. - For 35 m speed there was a significant difference between all three groups.
Australia 18 -20 yrs	TF vs LF vs H vs B	Distance = 35 m 5.4 vs 5.1 vs 4.8 vs 4.7	Noakes and Du Plessis (1996)	- Elite players holding Australian Institute of Sport rugby scholarships

Abbreviations: s, seconds; F, forwards; B, backs; P, props; L, locks; H, hookers; LF, loose-forwards; B, Backs, IB, inside backs; MB, midfield backs; OB, outside backs; TF, Tight forwards; yrs, years; m, meters

When comparing the performance of forwards to backs over distances of 30 - 40 m, Quarrie et al. (1996), Turnbull (1996), and Holmyard and Hazeldine (1993) found backs to be significantly quicker than forwards; whereas Carlson et al.

(1994) did not find a significant difference between these two groups. Turnbull (1996) found that when the forwards were divided into two groups, that the loose-forwards & hookers were significantly quicker than the props & locks, but only over 35 m and not over 10 m. Quarrie et al. (1996) found no significant differences within the backline players or within the forwards for 30 m speed with a standing start.

When comparing players of different proficiency levels and players belonging to different age groups, Quarrie et al. (1995) found club senior 'A' players significantly quicker than 'B' players, but not significantly quicker than the club under 21 players or under 19 / 18 players. Both Turnbull (1996) and Holmyard and Hazeldine (1993) found seasonal variations in speed. Turnbull (1996) found an improvement in 35 m times from the end of the off-season to the end of pre-season, and from the end of the pre-season to mid-season. 10 m times were significantly quicker mid-season compared to the end of the off-season. Compared to Turnbull (1996), Holmyard and Hazeldine (1993) found similar seasonal variations in speed (30 m) amongst English National players. They found that players recorded their fastest times over 30 m in the middle of the competitive season.

Quarrie et al. (1995 and 1996) calculated player's momentum (a function of speed over 30 m and body mass) and within all the grades assessed found forwards had significantly greater momentum than the backs. When comparisons between grades of play were made the senior A players achieved greater momentum than both the senior B players and the U21 players. The U21 players obtained greater momentum during the sprint than U18/19 players (Table 2.21).

**Table 2.21. Momentum obtained during a 30 m sprint.**

Players	Position	Momentum (kg.m.s <sup>-1</sup> )	Comment
<b>New Zealand</b>		<b>Distance = 30 m</b>	- Standing start
Club senior 'A'	F vs B	654 vs 573	- Times recorded by photocell sensors
Club senior 'B'	F vs B	570 vs 530	- Senior 'A' players achieved greater momentum than the senior B and U21 players
Club U 21	F vs B	603 vs 522	- U21 players performed significantly better than the U19/18 players.
U 19/18	F vs B	535 vs 496	- In all grades forwards achieved greater momentum than backs.
<b>New Zealand</b>		<b>Distance = 30 m</b>	- Standing start
Club senior 'A'	P vs H vs L vs LF IB vs MB vs OB	750 vs 666 vs 769 vs 742 589 vs 687 vs 680	- Times recorded by photocell sensors
			- Midfield and Outside backs performed significantly better than inside backs.
			- No significant differences between the forwards

Abbreviations: s, seconds; F, forwards; B, backs; P, props; L, locks; H, hookers; LF, loose-forwards; IB, inside backs; MB, midfield backs; OB, outside backs; yrs, years; m, meters

### 2.3.8. Agility

During a rugby game players are frequently required to stop or start suddenly, or change direction of their general body movement including side stepping or dodging a player. The pace at which players execute such movements is often near maximal and the control, coordination and speed with which they can execute such tasks is a reflection of their agility.

Factors contributing to agility include strength, speed of movement and reaction time. If strength is improved, agility will increase in movements involving heavy resistance including rapid stopping and starting, or other movements such as dodging (Jensen and Hirst, 1980).

Agility tests have not frequently been included in rugby union fitness test batteries, and the measurements that have been recorded are difficult to compare across studies due to the use of different test protocols. When agility tests have been included in a test battery (Table 2.22. ) they have failed to discriminate between proficiency of play and playing position, or between forwards and backs. Nicholas (1997) concludes that it is therefore difficult to assess the importance of agility in rugby union.

Clark (1995) included the agility T test (Semenick, 1995) in the fitness test battery recommended for the assessment of rugby players at the High Performance Laboratory at the Sports Science Institute of South Africa. Madole et al. (1997) assessed the validity and reliability of this test and found the test to require a combination of leg power, leg speed, agility and body control; and to have an interclass reliability of  $r = 0.97$  across three trials.

### **2.3.9. Flexibility**

Flexibility, the range of motion around a joint, appears to be the least evaluated component of physical fitness in rugby union. Although not scientifically proven, Hazeldine and McNab (1991) believe that poor flexibility negatively affects performance and technique, and that it possibly contributes to the strain and tear type injuries commonly seen in rugby union. For these reasons they include flexibility testing in their fitness test battery designed for rugby union players.

Flexibility is the property of individual muscles and joints (Watson, 1995) and it must therefore be considered that flexibility in one area of the body cannot be used as a measure of flexibility in other areas of the body.

The sit and reach test is the most commonly used test of flexibility in rugby union test batteries, and is the most reproduceable test of flexibility. Shepard et al. (1990) reported the interclass test / retest correlation over 8 months as  $r = 0.83$ , and Jackson and Pollock (1979) report reliability coefficients to range from  $r = 0.84$  -  $0.98$ . The sit and reach test is often administered under the assumption that it gives a composite measure of lumbar and hamstring flexibility (Noakes and Du Plessis, 1996; Seminick, 1995; Nicholas, 1997). However, a study by Liemohn et al. (1994) supported the validity of the sit and reach as a measure of hamstring flexibility, but not as a measure of lower back flexion range of motion.

Scores achieved by rugby union players for the sit and reach test are shown in Table 2.23 Maud (1983) found that forwards tended to score lower than the backs whilst Turnbull (1996) found the opposite. However, in both studies the differences between the forwards and backs were not statistically significant. Turnbull (1996)

found flexibility to improve in the hamstring muscle group from the off-season to the end of the pre-season, however, this flexibility did not change significantly by mid-season. This contrasts the findings of Clark (1998) who found no improvement in high school rugby player's hamstring flexibility after participating in a 12 week pre-season training programme which included twice weekly stretching sessions.

**Table 2.23. Sit and reach scores achieved by rugby union players.**

Level of play	Distance (cm)	Reference	Comment
South Africa Provincial 'A' P&L vs LF&H vs backs	11 vs 10 vs 9	Tumbull (1996)	- End of pre-season - Players warmed up before the test - No significant differences between positional categories.
South Africa High school Post a supervised programme Post an unsupervised programme Control group	9 3 5	Clark (1998)	- warmed up before the test

Abbreviations: cm, centimeters; P, props; L, locks; H, hookers; LF, loose-forwards

## Conclusion

The assessment of rugby union players serves a number of important functions which ultimately contribute to the development of the game and the player.

Physical fitness assessments allow for:

- I. Physiological and morphological profiling of players which contributes to an understanding of the physiological demands of the game (Quarrie et al., 1995). The profiles of elite players and their less successful counterparts can be compared, and distinguishing characteristics can be identified. Profiles also allow normative fitness data to be developed and assists players with setting fitness standards relative to their age, desired level of play, and position.
- II. Objectivity in the evaluation of player's individual strengths and weaknesses with regard to fitness. The data assist the fitness trainer to then address individual needs when prescribing training programmes.
- III. The monitoring of training programmes, and in turn appropriate programme adjustments. Repeat testing also motivates players to adhere to a programme.

IV. A useful measure of the comparison of fitness characteristics of players from different countries and their approach to fitness (Noakes and Du Plessis, 1996).

Only two published studies have provided anthropometric and physiological data on South African players (Jardine et al., 1988; Smit et al. as quoted in Quarrie et al., 1995). Only one of these studies was performed on elite players and both studies were conducted prior to the era of professionalism, the modern style of rugby, and prior to the re-entry of South Africa into international competition.

Optimal preparation of South African players for the 'modern' or current game requires (1) that research provide objective information with respect to the anthropometric and physical performance characteristics of players currently participating at an elite level in rugby union, and (2) that methods of enhancing these attributes are scientifically investigated so as to provide players with effective conditioning programmes.

The unpublished studies performed on South African players by Turnbull et al. (1996) and Clark (1998) are pioneer investigations performed in response to these needs. The anthropometric and physical performance assessments conducted in the current study on elite South African players serve to contribute to the scientific understanding of the 'modern' game with respect to its physical demands, and optimal physical conditioning of players.

### **3. GENERAL METHODS**

The study protocols were approved by the Ethics and Research Committee of the Faculty of Medicine and the University of Cape Town, and the tests were performed according to the principles of the Declaration of Helsinki. All subjects provided written informed consent.

#### **3.1. Subjects**

In this study the U19 subjects were members of an elite group of 44 players who had been identified by the South African Rugby Football Union (SARFU) as the group of players from which the SA U19 Team to play in France 1998 would be selected.

Players attended two camps in Cape Town. The first camp took place at the middle of the off-season (December 1997), and the second, 7 weeks later, in the middle of the pre-season (February 1998) two weeks prior to the SA team selection trials. During both camps players attended the High Performance Laboratory (HPL) at the Sports Science Institute of South Africa (SSISA) where they participated in a selection of anthropometric and physical performance assessments (described in section 3.12.). Players participated in all the tests unless they presented with musculoskeletal injuries that may have limited their performance or that may have been aggravated by a particular test or tests. 33 Players (17 forwards and 16 backs) were able to attend the first test session. The remainder of the squad were unavailable due to commitments to school tours of countries outside of South Africa. The full squad of 44 players attended the second test session. This squad included 22 forwards ( $17.9 \pm 0.4$  years) and 22 backs ( $17.7 \pm 0.4$  years).

At the November testing session players were advised to follow an off-season and early pre-season rugby fitness programme which was prescribed to them. Where needed, minor adjustments were made to the general programme to address factors including injuries, personal fitness requirements and circumstances. They received practical instruction from a strength training specialist regarding the

correct execution of all exercises in the training programme, and they attended workshops and lectures on various aspects of fitness training for rugby.

Testing took place over a two day period. The same physical performance and anthropometric testing routine was used on both testing occasions. During the first morning the forwards performed the following sequence of physiological tests: vertical jump, agility T test, speed, multistage shuttle run, whilst the backs underwent an anthropometric assessment, measurement of flexibility and attended an individual consultation with one of the two senior consultants to the High Performance Laboratory, who were both qualified Biokineticists. In the afternoon the backs performed the physiological tests, and the forwards underwent the same routine performed by the backs in the morning. On the second morning both the forwards and backs performed the following sequence of tests: bench press, incline leg press, pull ups, push ups, sit ups, and the repeat sprint test.

The Senior Provincial player subjects consisted of 58 A squad players from Boland (26 players) and Western Province Rugby Union (32 players). The group included 35 forwards ( $27.1 \pm 17.9$  years) and 23 backline players ( $24.6 \pm 17.8$  years) All players were tested mid pre-season (February) by staff of the High Performance Laboratory at the Sports Science Institute of South Africa. The physiological testing was performed in the same sequence as detailed above for the U 19 players, the only difference in the testing procedure being that the senior players had a 5 - 7 day interval between the two testing days, so as to accommodate player's training commitments with their respective Provincial and Super 12 squads, whereas the U 19 subjects performed these tests on consecutive days. The same testing surfaces were used throughout the experiment for the U19 and senior provincial players.

## **3.2. Anthropometric and physical performance assessment protocols**

### **3.2.1. Anthropometric measurements**

Body mass was recorded to the nearest 0.1 kg and stature was measured to the nearest 0.1 cm using an electronic digital scale (SECA Weighing and Measuring Systems, Hamburg, Germany). Skinfold thickness was determined at seven sites to the nearest 0.1 mm using a Holtain Caliper (Crymych, United Kingdom). The sites included triceps, subscapular, biceps, suprailiac, mid thigh, calf, and abdomen (Lohman et al., 1988). The calf, mid-thigh and forearm girths were assessed using a flexotape (Rabone Chesterman Anthropometric tape measure). Muscle mass was predicted as described by Martin et al. (1990), from height and mass and the following anthropometrical measurements; mid-thigh girth corrected for mid-thigh skinfold, uncorrected maximum forearm girth, calf girth corrected for calf skinfold.

### **3.2.2. Aerobic capacity**

The maximal multistage 20 m shuttle run test was used to assess aerobic capacity. This test was designed to predict the maximal aerobic power of those individuals performing in sports characterised by a stochastic, intermittent activity pattern (Léger et al.; 1988). This test has been reported to have excellent reliability ( $r = 0.97$ ) and validity ( $r = 0.84$ ) (Léger and Lambert, 1982) and has been used extensively in the New Zealand Rugby Injury and Performance Project (Quarrie et al.; 1995). The number of shuttles completed by each player was recorded and used to predict maximal oxygen uptake.

### **3.2.3. Repeat sprint ability**

The Welsh Rugby Union shuttle run test (WRUsrt) as described by Pendleton (1997), was used to measure the players ability to reproduce sequences of high energy bursts of running activity followed by limited opportunity for rest - an important "match specific" fitness component of rugby union. Performance in this test is dependent on a combination of fitness components: aerobic fitness, anaerobic capacity, speed, speed-endurance, local muscle endurance of the legs

and lower back, and agility. The test requires subjects to perform 6 x 30 s periods of high intensity sprint performance, interspersed with 35 s of recovery.

Six lines (at point 0 through to 5) at five meter intervals were painted on the floor of the laboratory in which the tests were conducted to serve as permanent markings for the WRUst. Players started the test, after a standardized 5 minute warm up, at a line painted at point 0 and upon an auditory signal, sprinted to line 1, touched the line with one hand, and returned to the line at point 0, reached down to touch the line, and then sprinted to line 2. The players continued in this manner and sprinted to the remaining lines (3, 4 and 5) and returned to line 0 between each outward shuttle. An auditory signal (whistle blow) was given after 30 seconds and indicated the end of the first “subshuttle”. Players walked back to point 0 and repositioned themselves just behind the line at point 0 during a 35 seconds recovery period. The player’s distance (to the nearest two and a half meters) covered during the 30 seconds exercise period was recorded, with the distance measured being taken from the position of the front foot of the player as the whistle was blown. The above format was repeated such that players ran six “subshuttles” and the total distance (m) covered in six repetitions was calculated as the player’s score.

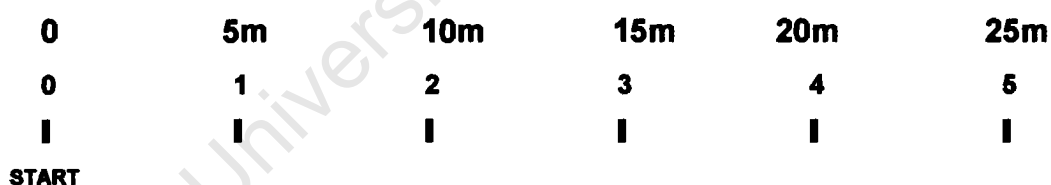


Fig. 3.1: Schematic layout of the WRUst

### 3.2.4. Vertical jump height

The vertical jump was used to assess the player’s instantaneous vertical jump displacement. The player stood, in athletic shoes, with his right side (hip) against a wall, onto which was mounted a calibrated measuring board. The player then reached with his right hand to touch the board at the highest possible point (heels of the feet staying on the ground), and this point was recorded as “standing height”. The player then placed chalk on his fingertips (dominant hand) and then, from a two-footed take-off position he flexed at the hip and knee joints and jumped

whilst reaching upwards with his arm closest to the board. At the top of the jump the player touched and marked the board with his fingertips. The score for the jump was the difference between the standing height and the jump height. Jumps were rendered invalid if the player took any form of step or shuffle prior to the jump. The highest of three separate trials was recorded as the player's maximum height.

### **3.2.5. Speed**

10 m, 20 m, 30 m and 40 m sprint times from a crouched start were recorded to assess the player's maximum sprint speed and their ability to accelerate from a stationary position. For this test, an electronic sprint timer with photo-electric sensors, was set at chest height and placed at 10, 20, 30 and 40 m intervals from the start line. After a thorough warm up the player was instructed to position himself, in a crouched start position, 30 cm from the start line. The player sprinted maximally for 40 m through the sensors. The player completed two maximal runs separated by a 5 -10 minute recovery period. The instantaneous times at 10, 20, 30 and 40 m for each run were recorded and the fastest split and total time attained during either run determined.

Momentum was calculated at 10 m, 20 m, 30 m, and 40 m using the formula mass x velocity expressed in kilograms per meter per second. Results therefore reflect momentum at 0 to 10 m, 0 – 20 m, 0 –30 m and 0 – 40 m.

### **3.2.6. Agility**

The agility T test (adapted from Semenick, 1994) was used to evaluate the players speed and agility. The test was set up as shown in Fig 3.2.

The player started the test standing behind point A. Upon an auditory signal (whistle) the timer was started and the player sprinted to point B and touched the base of the cone with the right hand. The player then moved laterally to point C and touched the base of the cone with the left hand; and then moved laterally to the right to point D and touched the base of the cone with the right hand. The

player then moved laterally back to point B and touched the base of the cone with the left hand and then ran backwards past point A to finish (the timer was stopped as the player passed point A). While moving laterally the player faced forwards and the feet were not allowed to cross. If the feet did cross then the player was given a restart after a rest period. The player completed two timed trials separated by a minimum of a two minute rest period and the fastest time was recorded as the players best effort.

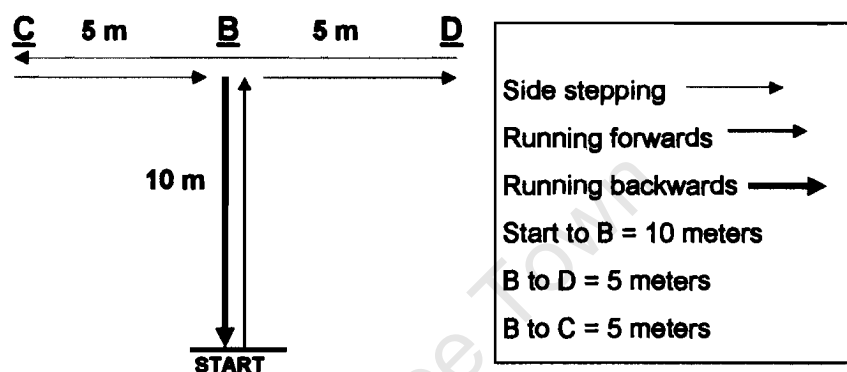


Fig 3.2. Schematic layout of the agility T test

### 3.2.7. Skeletal muscle strength

One repetition maximum (1RM) tests were used to determine the player's maximal strength. For the upper body, the bench press was the exercise of choice for testing maximal strength, while the incline leg press was used to test the lower body.

The following basics steps were followed for the 1RM testing (adapted from Kraemer and Fry, 1995):

1. A light warm up of 5 -10 repetitions at 40% of estimated maximum was performed.
2. After a 2 minute rest with light stretching, the weight was progressively increased from 60% to 80% using 3 - 5 repetitions to accomplish this.

3. Step 2 took the individual close to their 1RM, and they were allowed to rest for about 2 minutes prior to each increase in the weight. After each 1RM attempt the player rested 3 - 5 minutes, until a failed attempt occurred.
4. The 1RM value was reported as the weight of the last completed lift.

For the bench press the player lay supine on a bench with his feet flat on the floor and hips and shoulders in contact with the bench. An Olympic bar was gripped 5 - 10 cm wider than shoulder width, so that when the bar was placed on the chest, the elbow joints were flexed to approximately 90 degrees. The player started the lift by lowering the bar to the center of his chest (to the count of 2), touched his chest lightly and then extended upwards until his arms were in a fully locked position. Reasons for disqualifying a lift included: lifting the buttocks during the movement, bouncing the bar off the chest, uneven extension of the arms, and any touching of the bar by the spotter.

The leg press was performed on an inclined leg press machine (Challenger, South Africa). The player placed his toes on one of two lines. Either on a line drawn 5 cm from the top of the plate (the majority of players reached this line), or on a line drawn across the middle of the plate (for those players who could not comfortably reach the top line). The foot position was recorded to ensure reliable retesting. The plate was lowered to the point where a 90 degree angle was formed at the knee joint. The height of the foot plate along its pulley rail was then measured from the base of the pulley rail. This measurement was recorded to ensure standardization when the player was re-tested (it ensured the player descended to the identical knee angle on the second testing session).

#### **3.2.8. Pull ups**

The tests of muscle endurance included pull ups, sit ups and push ups. For the pull ups an underhand grip was used with hands placed shoulder width apart. The player started from a hanging position (arms fully extended). The player's chin had to reach above the bar on the ascent with arms fully extending (straightening) on the descent. The repetition was not counted if these requirements were not fulfilled. The player was permitted to pull his knees up in front of him during the

movement in order to avoid arching his back. This was a maximal test with the player continuing until he could no longer lift himself to the bar. The player warmed up on the lateral pulldown machine and then rested and stretched for 2-3 minutes prior to starting the pull ups test.

### **3.2.9. Sit ups**

Sit ups were performed on a sit up bench placed on the floor (no gradient) with knees bent, and feet fixed. The player's hands touched his ears, his elbows had to touch his knees at the end of the curl up, and he then had to descend in a controlled manner. The tester's hand was placed palm side up on the bench such that the wrist made contact with the spine in line with the inferior border of the scapulae. If the player's hands were taken off his ears, or his elbows did not touch his thighs, or his back did not touch the tester's hand then the sit up was not counted. The maximum number of sit ups performed in two minutes was recorded. Players were permitted to rest within the two minute period.

### **3.2.10. Push ups**

For the push up test the player assumed a position where his thumbs were shoulder width apart. Keeping the back and body straight the player descended to the tester's fist (which was placed below the player's sternum) and then ascended until his elbows were fully extended. If players did not adhere to these specifications the repetition was not counted. The number of repetitions performed in one minute were recorded. Players were permitted to rest within the one minute period.

### **3.2.11. Flexibility**

The sit and reach test was used to determine the joint range of motion and flexibility of the muscles around the hip joint. The reliability of the test has been documented previously (Johnson and Nelson, 1979). For this test the player sat on the floor with his knees extended, ankles flexed and bare feet against the vertical edge of the sit and reach box. The player then flexed at the hip and reached, with both hands together, towards his toes. The player was encouraged to flex

maximally at the hip joint without flexing the extended knees. The furthestmost point reached by both index fingers along a ruler fixed along the top of a box, was taken as the score. The best of three attempts was recorded as the score in centimeters. The point directly above the vertical edge that the foot was resting against was zero centimeters (cm). From this point onwards the score was recorded as positive, while distances scored short of 0 cm were recorded as negative.

### **3.3. Training programme**

The off-season and early pre-season training programme prescribed to the U19 players appears in appendix A.

During the latter part of the off-season (2 weeks) the programme consisted of 4 weight training sessions a week (two upper body and two lower body sessions), 1 medium-high intensity interval session, 2 easy - medium running sessions of 20 - 40 minutes each, and 1 non weight bearing aerobic session of 30 minutes. The first phase of the pre-season (4 weeks) was characterised by 3 weight training sessions a week, one of which included some plyometric exercises (jump squats), a shuttle run session, a 5 km time trial, a speed-endurance session, and a long easy run of 40 minutes.

Players had two weeks of phase two of the pre-season schedule, before the retesting took place. This phase contained a higher intensity shuttle run session than the previous phase, the long 40 minute run gave way to a session containing shorter distance sprints (34 -100 m), and there was an increase in the volume of plyometrics prescribed. Plyometric drills included repeated cone jumps performed during the shorter distance sprint session and squat jumps within the weight training programme. Weight training in this phase remained the same as in phase one.

Where needed, minor adjustments were made to the general programme to address factors such as injuries, personal fitness requirements and circumstances. Players received practical instruction from a strength training specialist on the

positional categories (the props & locks, the loose-forwards & hookers, and the backs) across the ages of players in the study (U19 and senior).

Where significant differences were found between the three positional groups, and / or between the age groups, or a significant interaction was identified, a Scheffe's post hoc analysis was performed.

Means and standard deviation were determined for all the variables measured on the 33 U19 players who attended both the mid off-season and the mid pre-season assessment sessions. A paired t-test for was used to assess the significance of any changes in anthropometric and physical performance data for these players.

University of Cape Town

## 4. RESULTS

### 4.1. Mid pre-season anthropometric and physical performance characteristics of U19 provincial rugby union players

Descriptive statistics (means  $\pm$  SD) and comparative analysis for anthropometry and physical performance characteristics of both the forwards and backs are presented in Tables 4.1. and 4.2., and those of props & locks, loose-forwards & hookers, and backs in Tables 4.3 and 4.4.

#### 4.1.1. Body size and body composition: Forwards and backs

There was no significant difference in age between forwards and backs. The forwards were taller (+ 11.2 cm,  $P < 0.01$ ) and heavier (+ 23.3 kg,  $P < 0.01$ ) than the backs. The sum of seven skinfolds (SUM 7) was used to give an indication of total subcutaneous adiposity, and SUM 7 was significantly higher in the forwards (101  $\pm$  43 mm) than in the backs (63  $\pm$  18 mm,  $P < 0.01$ ). Absolute muscle mass, as determined by the equation of Martin et al. (1990), was significantly greater in the forwards (54  $\pm$  6 kg) than in the backs (42  $\pm$  5 kg,  $P < 0.01$ ), but when expressed relative to body weight no significant difference existed in the muscle mass of the two positional categories.

Table 4.1. Anthropometric characteristics of forwards and backs during the mid pre-season.

Variable	Forwards (n = 22)	Backs (n = 22)	Statistical significance (P)
Age (yrs)	17.9 $\pm$ 0.4	17.7 $\pm$ 0.4	
Height (cm)	186.2 $\pm$ 8.1	175.0 $\pm$ 6.0	**
Body mass (kg)	97.9 $\pm$ 10.2	74.6 $\pm$ 10.2	**
Muscle mass (kg)	54 $\pm$ 6	42 $\pm$ 5	**
Relative muscle mass (%)	55 $\pm$ 4	58 $\pm$ 7	
Sum of skinfolds (mm)	101 $\pm$ 43	63 $\pm$ 18	**

Abbreviations: n, number of subjects; yrs, years; cm, centimeters; kg, kilograms; %, percentage; mm, millimeters, \*\*  $P < 0.01$

#### 4.1.2. Physical performance characteristics: Forwards and backs

The results of the physical performance assessments (Table 4.2) show that the forwards had greater absolute upper and lower body skeletal muscle strength than the backs as they were able to lift significantly greater weight on the one repetition maximum tests of bench press (100  $\pm$  19 kg vs 81  $\pm$  19 kg,  $P < 0.01$ ) and leg press (343  $\pm$  61 kg vs 285  $\pm$  61 kg,  $P < 0.01$ ). When the weight lifted was expressed relative to body weight no significant differences in upper or lower body

strength existed. The forwards achieved significantly greater momentum over 10 m (+ 124 kg.m.s<sup>-1</sup>), 20 m (+ 137 kg.m.s<sup>-1</sup>), 30 m (+ 145 kg.m.s<sup>-1</sup>) and 40 m (+ 147 kg.m.s<sup>-1</sup>) sprint intervals ( $P < 0.01$ ). The pull up test was the only other test in which a significant difference between the two playing units was identified, with the backs performing more pull ups in this test of upper body skeletal muscle endurance than the forwards ( $15 \pm 3$  vs  $10 \pm 4$  reps,  $P < 0.01$ ).

Backs tended to achieve better results on the multistage shuttle run, the WRUsrt, push ups, sit ups, speed over 10, 20, 30, and 40m, the vertical jump, and the sit and reach test, but there was not a significant difference between their performances and those of the forwards during these tests.

**Table 4.2. Physical performance characteristics of forwards and backs during the mid pre-season.**

Variable	Forwards (n = 22)	Backs (n = 22)	Statistical significance (P)
Aerobic shuttle (no.)	103 ± 16 (19)	113 ± 13 (19)	
VO <sub>2</sub> max (mlO <sub>2</sub> .kg <sup>-1</sup> .min <sup>-1</sup> )	55 ± 5 (19)	57 ± 4 (19)	
WRUsrt (m)	723 ± 25 (20)	739 ± 25 (19)	
Bench press (kg)	100 ± 19 (22)	81 ± 19 (21)	**
Bench press (kg.kgBM <sup>-1</sup> )	1.02 ± 0.18 (22)	1.08 ± 0.15 (21)	
Leg press (kg)	343 ± 61 (19)	285 ± 61 (19)	**
Leg press (kg.kgBM <sup>-1</sup> )	3.5 ± 0.7 (19)	3.8 ± 0.7 (19)	
Pull ups (no.)	10 ± 4 (20)	15 ± 3 (21)	**
Push ups (no.)	43 ± 9 (21)	49 ± 14 (19)	
Sit ups (no.)	79 ± 15 (21)	79 ± 15 (20)	
Speed 10m (s)	1.79 ± 0.12 (21)	1.78 ± 0.08 (18)	
Speed 20m (s)	3.07 ± 0.19 (21)	3.01 ± 0.10 (18)	
Speed 30m (s)	4.26 ± 0.13 (21)	4.14 ± 0.13 (18)	
Speed 40m (s)	5.42 ± 0.38 (21)	5.23 ± 0.16 (18)	
Momentum 10m (kg.m.s <sup>-1</sup> )	547 ± 54 (21)	423 ± 55 (18)	**
Momentum 20m (kg.m.s <sup>-1</sup> )	637 ± 56 (21)	500 ± 63 (18)	**
Momentum 30m (kg.m.s <sup>-1</sup> )	690 ± 59 (21)	545 ± 65 (18)	**
Momentum 40m (kg.m.s <sup>-1</sup> )	723 ± 61 (21)	576 ± 70 (18)	**
Vertical jump (cm)	54 ± 7 (21)	55 ± 6 (20)	
Agility (s)	11.11 ± 0.64 (21)	11.12 ± 0.53 (19)	
Sit and reach (cm)	11 ± 11 (22)	13 ± 7 (22)	

Abbreviations: n or ( ), number of subjects; no., number; mlO<sub>2</sub>.kg<sup>-1</sup>.min<sup>-1</sup>, milliliters of oxygen per kilogram of body mass per minute; WRUsrt, Welsh Rugby Union shuttle run test; m, meters; kg, kilograms; kg.kgBM<sup>-1</sup>, kilograms per kilogram body mass; s, seconds, cm, centimeters; \*,  $p < 0.05$ ; \*\*,  $p < 0.01$

#### **4.1.3. Body size and body composition: Props & locks, loose-forwards & hookers, and backs**

The props & locks were significantly taller (+ 13.4 cm,  $P < 0.01$ ) and heavier (+ 28.3 kg,  $P < 0.01$ ) than the backs, and also had significantly greater absolute muscle mass (+ 14 kg,  $P < 0.01$ ) and sum of seven skinfolds (+ 43 mm,  $P < 0.01$ ). Significant differences existed between the loose-forwards & hookers, and the backs with regards to body mass (+ 17.4 kg,  $P < 0.01$ ), height (+ 8.7 cm,  $P < 0.01$ )

and absolute muscle mass (+ 9 kg,  $P < 0.01$ ) Although the props & locks as a group were taller and heavier than the loose-forwards & hookers, these differences were not statistically significant.

**Table 4.3. Anthropometric characteristics of props & locks, loose-forwards & hookers, and backs during the mid pre-season.**

Variable	Positional categories			Statistical significance (P)		
	Props & locks (n = 12)	LF & hookers (n = 10)	Backs (n = 22)	P&L vs LF&H	P&L vs B	LF&H vs B
Age (yrs)	18 ± 0.4	17.8 ± 0.4	17.7 ± 0.4			
Height (cm)	188.4 ± 7.6	183.7 ± 8.3	175.0 ± 6.0		**	
Body mass (kg)	102.9 ± 9.3	92.0 ± 8.1	74.6 ± 10.2		**	**
Muscle mass (kg)	56 ± 4	51 ± 6	42 ± 5		**	**
Relative muscle mass (%)	55 ± 4	55 ± 4	58 ± 7			
Sum of skinfolds (mm)	106 ± 48	95 ± 38	63 ± 18		**	

Abbreviations: n, number of subjects; LF, loose-forwards; yrs, years; cm, centimeters; kg, kilograms; %, percentage; mm, millimeters; P&L, props and locks; LF&H, loose-forwards and hookers; B, backs; \*\*  $P < 0.01$

#### **4.1.4. Physical performance characteristics: Props & locks, loose-forwards & hookers, and backs**

The results of the physical performance assessments (Table 4.4) show that the props & locks had significantly greater momentum over 10 m, 20 m, 30 m, and 40 m than both the loose-forwards & hookers, and the backs ( $P < 0.01$ ). Over 40 m the backs were significantly quicker than the props & locks ( $5.23 \pm 0.16$  s vs  $5.56 \pm 0.43$  s,  $P < 0.05$ ), and there was little difference in the mean speed achieved by the loose-forwards & hookers, ( $5.26 \pm 0.24$  s) and the backs ( $5.23 \pm 0.16$  s).

Although the backs performed significantly better than the props & locks in the pull ups test ( $15 \pm 3$  reps vs  $8 \pm 4$  reps,  $P < 0.01$ ) they did not perform significantly better than the loose-forwards & hookers ( $13 \pm 3$  reps).

There were no significant differences between the three playing position categories with regards to their performances on the multistage shuttle run and the WRUsrt, but interestingly the loose-forwards & hookers, and the backs were closely matched on both the multistage shuttle run ( $110 \pm 16$  shuttles vs  $113 \pm 13$  shuttles) and the WRUsrt ( $741 \pm 31$  m vs  $739 \pm 25$  m). Although there were no significant differences between the three categories for muscle strength the loose-forwards & hookers performed better than the props & locks, and the backs on both the bench and leg press. There were no significant differences between the

three playing categories for push ups, sit ups, speed over 10 m ,20 m and 30 m, vertical jump, agility and the sit and reach test.

**Table 4.4. Physical performance characteristics of props & locks, loose-forwards & hookers, and backs during the mid pre-season.**

Variable	Positional categories			Statistical significance (P)		
	Props & locks (n = 12)	LF & hookers (n = 10)	Backs (n = 22)	P&L vs LF&H	P&L vs B	LF&H vs B
Aerobic shuttle (no.)	98 ± 16 (11)	110 ± 16 (10)	113 ± 13 (19)			
VO <sub>2</sub> max (mlO <sub>2</sub> .kg <sup>-1</sup> .min <sup>-1</sup> )	52 ± 4 (11)	56 ± 5 (10)	57 ± 4 (19)			
WRUert (m)	709 ± 37 (11)	741 ± 31 (9)	739 ± 25 (19)			
Bench press (kg)	98 ± 23 (12)	102 ± 15 (10)	81 ± 19 (21)			
Bench press (kg.kgBM <sup>-1</sup> )	0.96 ± 0.20 (12)	1.10 ± 0.11 (10)	1.08 ± 0.15 (21)			
Leg press (kg)	328 ± 73 (10)	359 ± 44 (9)	285 ± 61 (19)			
Leg press (kg.kgBM <sup>-1</sup> )	3.2 ± 0.7 (10)	3.9 ± 0.4 (9)	3.8 ± 0.7 (19)			
Pull ups (no.)	8 ± 4 (10)	13 ± 3 (10)	15 ± 3 (21)		**	
Push ups (no.)	37 ± 9 (11)	49 ± 7 (10)	49 ± 14 (19)			
Sit ups (no.)	74 ± 18 (11)	85 ± 17 (10)	79 ± 15 (20)			
Speed 10 m (s)	1.84 ± 0.14 (11)	1.74 ± 0.08 (10)	1.78 ± 0.08 (18)			
Speed 20 m (s)	3.14 ± 0.23 (11)	3.00 ± 0.12 (10)	3.01 ± 0.10 (18)			
Speed 30 m (s)	4.36 ± 0.33 (11)	4.15 ± 0.14 (10)	4.14 ± 0.13 (18)			
Speed 40 m (s)	5.56 ± 0.43 (11)	5.26 ± 0.24 (10)	5.23 ± 0.17 (18)		*	
Momentum 10 m (kg.m.s <sup>-1</sup> )	563 ± 5 5 (11)	528 ± 50 (10)	423 ± 55 (18)		**	**
Momentum 20 m (kg.m.s <sup>-1</sup> )	658 ± 51 (11)	614 ± 54 (10)	500 ± 63 (18)		**	**
Momentum 30 m (kg.m.s <sup>-1</sup> )	712 ± 54 (11)	685 ± 57 (10)	545 ± 65 (18)		**	**
Momentum 40 m (kg.m.s <sup>-1</sup> )	744 ± 52 (11)	700 ± 65 (10)	576 ± 70 (18)		**	**
Vertical jump (cm)	51 ± 8 (11)	56 ± 5 (10)	55 ± 6 (20)			
Agility (s)	11.46 ± 0.55 (11)	10.73 ± 0.53 (10)	11.12 ± 0.53 (19)			
Sit and reach (cm)	9 ± 12 (11)	14 ± 8 (10)	13 ± 7 (22)			

Abbreviations: n, number of subjects; no., number; mlO<sub>2</sub>.kg<sup>-1</sup>.min<sup>-1</sup>, milliliters of oxygen per kilogram of body mass per minute; WRUert, Welsh Rugby Union shuttle run test; m, meters; kg; kilograms; kg.kgBM<sup>-1</sup>, kilograms per kilogram body mass; s, seconds; cm, centimeters; P&L, props and locks; LF&H, loose-forwards and hookers; B, backs; \*, P < 0.05; \*\* P < 0.01

## **4.2. Mid pre-season anthropometric and physical performance characteristics of senior A provincial rugby union players**

Descriptive statistics (means ± SD) and comparative analysis for anthropometry and physical performance characteristics of both the forwards and backs are presented in Tables 4.5. and 4.6, and those of props & locks, loose-forwards & hookers, and backs in Tables 4.7 and 4.8.

### **4.2.1. Body size and body composition: Forwards and backs**

The forwards were significantly older (+ 2.4 yrs, P < 0.01), taller (+ 11.2 cm, P < 0.01) and heavier (+ 23.7 kg, P < 0.01) than the backs. The sum of seven skinfolds (SUM 7) was used to give an indication of total subcutaneous adiposity, and SUM 7 was found to be higher in the forwards (100 ± 30 mm) than in the backs (67 ± 17 mm, P < 0.01). Muscle mass, as predicted using the Martin et al. (1990) equation, was significantly greater in the forwards compared to the backs

(+ 11 kg,  $P < 0.01$ ), but when expressed relative to body mass the backs had a greater percentage muscle mass than the forwards ( $56 \pm 5\%$  vs  $59 \pm 4\%$ ,  $P < 0.05$ ).

**Table 4.5. Anthropometric characteristics of forwards and backs in the mid pre-season.**

Variable	Forwards (n = 35)	Backs (n = 23)	Statistical significance (P)
Age (yrs)	27.0 $\pm$ 3.5	24.6 $\pm$ 3.1	**
Height (cm)	190.1 $\pm$ 8.2	178.9 $\pm$ 6.3	**
Body mass (kg)	109.7 $\pm$ 10.5	86.0 $\pm$ 8.8	**
Muscle mass (kg)	61 $\pm$ 7	50 $\pm$ 5	**
Relative muscle mass (%)	56 $\pm$ 5	59 $\pm$ 4	*
Sum of skinfolds (mm)	100 $\pm$ 30	67 $\pm$ 17	**

Abbreviations: n, number of subjects; yrs, years; cm, centimeters; kg, kilograms; %, percentage; mm, millimeters; \*\*,  $P < 0.01$ ; \*,  $P < 0.05$

#### 4.2.2. Physical performance characteristics: Forwards and backs

The forwards had greater absolute upper body strength demonstrated by the significantly greater amount of weight they were able to lift on the one repetition maximum bench press test ( $116 \pm 18$  kg vs  $101 \pm 17$  kg,  $P < 0.01$ ), but when expressed relative to body weight the backs were significantly stronger in their upper bodies than the forwards ( $1.18 \pm 0.17$  kg.kgBM<sup>-1</sup> vs  $1.06 \pm 0.19$  kg.kgBM<sup>-1</sup>,  $P < 0.05$ ). Although the forwards lifted a greater weight during the one repetition maximum leg press test ( $426 \pm 64$  kg vs  $384 \pm 74$  kg) the difference was not statistically significant, but when expressed relative to body mass the backs were found to have greater lower body strength than the forwards ( $+ 0.5$  kg.kgBM<sup>-1</sup>). The forwards were able to produce significantly greater momentum than the backs over 10 m ( $+ 108$  kg.m.s<sup>-1</sup>), 20 m ( $+ 113$  kg.m.s<sup>-1</sup>), 30 m ( $+ 128$  kg.m.s<sup>-1</sup>), and 40 m ( $+ 117$  kg.m.s<sup>-1</sup>) sprint distances; ( $P < 0.01$  over all four distances).

The backs performed significantly better than the forwards during the tests of muscle endurance; for pull ups ( $15 \pm 4$  vs  $9 \pm 5$ ;  $P < 0.01$ ) and push ups ( $65 \pm 13$  vs  $48 \pm 9$ ;  $P < 0.05$ ), and for situps ( $96 \pm 14$  vs  $85 \pm 15$ ;  $P < 0.05$ ), and they had significantly greater leg power as measured by the vertical jump test ( $61 \pm 7$  cm vs  $54 \pm 7$  cm,  $P < 0.01$ ). The backs were significantly faster over 10 m ( $1.78 \pm 0.07$  s vs  $1.86 \pm 0.08$  s), 20 m ( $3.00 \pm 0.12$  s vs  $3.21 \pm 0.14$  s), 30 m ( $4.09 \pm 0.09$  s vs  $4.47 \pm 0.19$  s), and 40 m ( $5.23 \pm 0.19$  s vs  $5.66 \pm 0.28$  s) sprint intervals ( $P < 0.01$  over all four distances) than the forwards. The backs completed significantly more

shuttles during the multistage shuttle run test ( $115 \pm 16$  shuttles vs  $99 \pm 15$  shuttles,  $P < 0.01$ ) and covered more distance during the WRUsrt ( $739 \pm 11$  m vs  $684 \pm 38$  m,  $P < 0.01$ ).

**Table 4.6. Physical performance characteristics of forwards and backs during the mid pre-season.**

Variable	Forwards (n = 35)	Backs (n = 23)	Statistical significance (P)
Multistage shuttle (no.)	99 ± 15 (30)	115 ± 16 (21)	**
VO <sub>2</sub> max (mlO <sub>2</sub> .kg <sup>-1</sup> .min <sup>-1</sup> )	52 ± 4 (30)	57 ± 5 (21)	**
WRUsrt (m)	684 ± 38 (22)	739 ± 11 (14)	**
Bench press (kg)	116 ± 18 (33)	101 ± 17 (23)	**
Bench press (kg.kgBM <sup>-1</sup> )	1.06 ± 0.19 (33)	1.18 ± 0.17 (23)	*
Leg press (kg)	426 ± 64 (24)	384 ± 74 (19)	
Leg press (kg.kgBM <sup>-1</sup> )	3.9 ± 0.6 (24)	4.4 ± 0.7 (19)	*
Pull ups (no.)	9 ± 5 (31)	15 ± 4 (23)	**
Push ups (no.)	48 ± 9 (14)	65 ± 13 (11)	**
Sit ups (no.)	85 ± 15 (25)	96 ± 14 (20)	*
Speed 10m (s)	1.86 ± 0.08 (31)	1.78 ± 0.07 (20)	**
Speed 20m (s)	3.21 ± 0.14 (31)	3.00 ± 0.12 (18)	**
Speed 30m (s)	4.47 ± 0.22 (21)	4.09 ± 0.09 (13)	**
Speed 40m (s)	5.66 ± 0.28 (31)	5.23 ± 0.19 (20)	**
Momentum 10m (kg.m.s <sup>-1</sup> )	594 ± 51 (31)	486 ± 50 (20)	**
Momentum 20m (kg.m.s <sup>-1</sup> )	689 ± 55 (31)	576 ± 61 (20)	**
Momentum 30m (kg.m.s <sup>-1</sup> )	747 ± 64 (21)	619 ± 70 (13)	**
Momentum 40m (kg.m.s <sup>-1</sup> )	781 ± 59 (31)	664 ± 71 (19)	**
Vertical jump (cm)	54 ± 7 (30)	61 ± 7 (21)	**
Agility (s)	11.72 ± 0.86 (30)	10.89 ± 0.35 (19)	**
Sit and reach (cm)	6 ± 8 (33)	7 ± 8 (23)	

Abbreviations: ( ) or n, number of subjects; no., number; mlO<sub>2</sub>.kg<sup>-1</sup>.min<sup>-1</sup>, milliliters of oxygen per kilogram of body mass per minute; WRUsrt, Welsh Rugby Union shuttle run test; m, meters; kg, kilograms; kg.kgBM<sup>-1</sup>, kilograms per kilogram body mass; s, seconds, cm, centimeters; \*,  $P < 0.05$ ; \*\*  $P < 0.01$

#### 4.2.3. Body size and body composition: Props & locks, loose-forwards & hookers and backs

The props & locks ( $27.9 \pm 3.5$  yrs) were significantly older than the backs ( $24.6 \pm 3.1$  yrs), and the mean age of the loose-forwards & hookers ( $26.1 \pm 3.5$  yrs) was between, but not significantly different from either of the other two groups. Both the props & locks (+ 14.0 cm,  $P < 0.01$ ), and the loose-forwards & hookers (+ 7.9 cm,  $P < 0.05$ ) were significantly taller than the backs. Body mass was significantly different ( $P < 0.01$ ) between all three positional categories with the props & locks being heaviest ( $116.4 \pm 8.1$  kg) followed by the loose-forwards & hookers ( $101.6 \pm 6.8$  kg), and then the backs ( $86 \pm 8.8$  kg). Absolute muscle mass was significantly greater ( $P < 0.01$ ) in the props & locks ( $63 \pm 7$  kg) compared to the backs ( $50 \pm 5$  kg) but the not significantly greater compared to the loose-forwards & hookers ( $59 \pm 5$  kg). When expressed relative to body mass both the loose-forwards & hookers, and backs tended to have a greater percentage of muscle mass compared to the props & locks, but these differences were not statistically

significant. The props & locks had significantly greater subcutaneous adiposity when compared to the backs ( $110 \pm 32$  mm vs  $67 \pm 17$  mm,  $P < 0.01$ ) but neither the 22 mm difference between the props & locks, and loose-forwards & hookers; or the 21 mm difference between the loose-forwards & hookers, and backs was significant.

**Table 4.7. Anthropometric characteristics of props & locks, loose-forwards & hookers, and backs during the mid pre-season.**

Variable	Positional category			Statistical significance		
	Props & locks (n = 19)	LF & hookers (n = 16)	Backs (n = 23)	P&L vs LF&H	P&L vs B	LF&H vs B
Age	27.9 ± 3.5	26.1 ± 3.5	24.6 ± 3.1		**	
Height (cm)	192.9 ± 9.2	186.8 ± 5.3	178.9 ± 6.3			*
Body mass (kg)	116.4 ± 4.4	101.6 ± 6.8	86.0 ± 8.8	**	**	**
Muscle mass (kg)	63 ± 7	59 ± 5	50 ± 5		**	**
Relative muscle mass (%)	54 ± 6	58 ± 3	58 ± 7			
Sum of skinfolds (mm)	110 ± 32	88 ± 25	67 ± 17		**	

Abbreviations: n and ( ), number of subjects; LF, loose-forwards; yrs, years; cm, centimeters; kg, kilograms; %, percentage; mm, millimeters, P&L, props and locks; LF&H, loose-forwards and hookers; B, backs; \*,  $P < 0.05$ ; \*\*  $P < 0.01$

#### 4.2.4. Physical performance characteristics: Props & locks, and loose-forwards & hookers, and backs

The backs completed significantly more shuttles during the the multistage shuttle run test than the props & locks ( $115 \pm 16$  shuttles vs  $93 \pm 13$  shuttles,  $P < 0.01$ ); and both the backs ( $740 \pm 11$  m,  $P < 0.01$ ) and the loose-forwards & hookers ( $712 \pm 37$  m,  $P < 0.05$ ) covered more distance on the the WRUsht, than the props & locks ( $665 \pm 26$  m). The performance of the backline players on multistage shuttle run and the WRUsrt were not significantly better than those of the loose-forwards & hookers. There were no significant differences in upper and lower body strength, both absolute and relative, between the three groups. The backs performed significantly better than props & locks on all three tests of muscle endurance (pull ups, push ups and sit ups) while the loose-forwards & hookers performed better than the props & locks on the pull ups test. Although the backs, on average, scored better than the loose-forwards & hookers on the tests of muscle endurance, the performance differences between these two positional categories were not significant. The backs had the best vertical jump height ( $61 \pm 7$  cm) with their performance on the vertical jump test being significantly better than that of the props & locks ( $52 \pm 8$  cm,  $P < 0.01$ ), but not the loose-forwards & hookers ( $57 \pm 6$  cm).

The backs were significantly quicker than the props & locks ( $P < 0.01$ ), but not the loose-forwards & hookers, over 10 m, 20 m, 30 m and 40 m. The loose-forwards & hookers were significantly quicker than the props & locks only over 40 m. When speed was measured in relation to body weight it was found that the props & locks generated significantly greater momentum than both the loose-forwards & hookers, and the backs over 10m, 20m, and 40m ( $P < 0.01$ ). The backs however, performed best in the agility test; and both the backs ( $10.89 \pm 0.35$  s) and the loose-forwards & hookers ( $11.17 \pm 0.64$  s) had significantly ( $P < 0.01$ ) better agility than the props & locks ( $12.20 \pm 0.75$  s).

**Table 4.8. Physical performance characteristics of props & locks, loose-forwards & hookers, and backs during the mid pre-season.**

Variable	Positional category			Statistical significance (P)		
	Props and locks (n = 19)	LF and hookers (n = 16)	Backs (n = 23)	P&L vs LF&H	P&L vs B	LF&H vs B
Aerobic shuttle (no.)	93 ± 13 (17)	107 ± 15 (13)	115 ± 16 (21)		**	
VO <sub>2</sub> max (mlO <sub>2</sub> .kg <sup>-1</sup> .min <sup>-1</sup> )	50 ± 4 (17)	54 ± 4 (13)	57 ± 5 (21)		**	
WRUart (m)	665 ± 26 (13)	712 ± 37 (9)	740 ± 11 (14)	*	**	
Bench press (kg)	116 ± 16 (18)	115 ± 20 (15)	101 ± 17 (23)			
Bench press (kg.kgBM <sup>-1</sup> )	1.00 ± 0.16 (18)	1.13 ± 0.21 (15)	1.18 ± 0.17 (23)			
Leg press (kg)	449 ± 64 (14)	395 ± 53 (10)	384 ± 74 (19)			
Leg press (kg.kgBM <sup>-1</sup> )	3.8 ± 0.6 (14)	3.9 ± 0.6 (10)	4.4 ± 0.7 (19)			
Pull ups (no.)	7 ± 4 (17)	12 ± 5 (14)	15 ± 4 (23)	**	**	
Push ups (no.)	44 ± 8 (8)	52 ± 9 (6)	65 ± 13 (11)		**	
Sit ups (no.)	78 ± 12 (14)	93 ± 14 (11)	96 ± 14 (20)		**	
Speed 10m (s)	1.89 ± 0.07 (17)	1.83 ± 0.08 (14)	1.78 ± 0.07 (20)		**	
Speed 20m (s)	3.28 ± 0.12 (11)	3.12 ± 0.11 (10)	3.00 ± 0.12 (18)		**	
Speed 30m (s)	4.59 ± 0.19 (12)	4.32 ± 0.16 (9)	4.09 ± 0.09 (13)		**	
Speed 40m (s)	5.81 ± 0.26 (17)	5.48 ± 0.18 (14)	5.23 ± 0.19 (20)	*	**	
Momentum 10m (kg.m.s <sup>-1</sup> )	621 ± 39 (17)	562 ± 47 (14)	486 ± 50 (20)		**	**
Momentum 20m (kg.m.s <sup>-1</sup> )	716 ± 45 (17)	657 ± 50 (14)	576 ± 61 (20)		**	**
Momentum 30m (kg.m.s <sup>-1</sup> )	783 ± 45 (12)	699 ± 54 (9)	619 ± 70 (13)		**	
Momentum 40m (kg.m.s <sup>-1</sup> )	809 ± 49 (17)	748 ± 53 (14)	664 ± 71 (19)		**	*
Vertical jump (cm)	52 ± 8 (17)	57 ± 6 (13)	61 ± 7 (21)		**	
Agility (s)	12.20 ± 0.75 (16)	11.17 ± 0.64 (14)	10.89 ± 0.35 (19)	**	**	
Sit and reach (cm)	4 ± 8 (19)	8 ± 8 (14)	7 ± 8 (23)			

Abbreviations: ( ) and n, number of subjects; no., number; mlO<sub>2</sub>.kg<sup>-1</sup>.min<sup>-1</sup>, milliliters of oxygen per kilogram of body mass per minute; WRUart, Welsh Rugby Union shuttle run test; m, meters; kg, kilograms; kg.kgBM<sup>-1</sup>, kilograms per kilogram body mass; s, seconds, cm, centimeters; P&L, props and locks; LF&H, loose-forwards and hookers; B, backs; \*,  $P < 0.05$ ; \*\*  $P < 0.01$

**4.3. A comparison of anthropometric and physical performance characteristics of senior A provincial and U19 provincial rugby union players during the mid pre-season.**

**4.3.1. Body size and body composition: SA provincial senior forwards vs SA provincial U19 forwards, and SA Provincial senior backs vs SA U19 backs**

The anthropometric characteristics and comparative analysis for the senior and U19 forwards are shown in Table 4.9., and for the backs in Table 4.10.

**Table 4.9. Mid-preseason anthropometric characteristics of SA Provincial senior A and SA U19 rugby playing forwards.**

Variable	Provincial forwards (n = 38)	U19 forwards (n = 22)	Statistical significance (P)
Age	27.0 ± 3.5	17.9 ± 0.4	**
Height (cm)	190.1 ± 8.2	186.2 ± 8.1	
Body mass (kg)	109.7 ± 10.5	97.9 ± 10.2	**
Muscle mass (kg)	61 ± 7	54 ± 6	**
Relative muscle mass (%)	56 ± 5	55 ± 4	
Sum of skinfolds (mm)	100 ± 30	101 ± 43	

Abbreviations: n, number of subjects; yrs, years; cm, centimeters; kg; kilograms; %, percentage; mm, millimeters; \*\*, P < 0.01

**Table 4.10. Mid pre-season anthropometric characteristics of SA Provincial senior A and SA U19 backline players.**

Variable	Provincial backs (n = 23)	U 19 Backs (n = 22)	Statistical significance (P)
Age	24.6 ± 3.1	17.7 ± 0.4	**
Height (cm)	178.9 ± 6.3	175.0 ± 6.0	*
Body mass (kg)	86.0 ± 8.8	74.6 ± 10.2	**
Muscle mass (kg)	50 ± 5	42 ± 5	**
Relative muscle mass (%)	59 ± 4	58 ± 7	
Sum of skinfolds (mm)	67 ± 17	63 ± 18	

Abbreviations: n, number of subjects; yrs, years; cm, centimeters; kg; kilograms; %, percentage; mm, millimeters; \*\*, P < 0.01; \* P < 0.05

For both the forwards and backs there were significant differences between the age groups in body size, with the senior forwards being on average 11.8 kg heavier than the U19 forwards (P < 0.01), and the backline senior players being both taller (178.9 ± 6.3 cm vs 175.0 ± 6.0 cm, P < 0.05) and heavier (+ 11.4 kg, P < 0.01) than the U19 backline players. Absolute muscle mass, as estimated by the equation of Martin et al. (1990), was significantly greater in both the senior forwards (+ 7 kg, P < 0.01) and backs (+ 8 kg, P < 0.01) when compared to their U19 counterparts. However, when expressed relative to body mass muscle mass was not significantly different between the senior and U19 forwards (56 ± 5 % vs 55 ± 4 %), or between the senior and U19 backs (59 ± 4 % vs 58 ± 7 %). The

differences in subcutaneous adiposity as measured by SUM 7 were not significant between the senior and U19 forwards (1 mm difference) or between the backs (4 mm difference).

#### 4.3.2. Physical performance characteristics: SA provincial senior forwards vs SA provincial U19 forwards

The physical performance characteristics and comparative analysis for the senior and U19 forwards are shown in Table 4.11. There was no significant difference in aerobic capacity between the senior and U19 players with the U19 players running on average 4 shuttles further than the senior players. However, on the WRUsrt which gives an indication of repeat sprint ability, the U19 forwards performed significantly better than the senior forwards ( $723 \pm 25$  m vs  $684 \pm 38$  m,  $P < 0.01$ ).

Table 4.11. Mid pre-season physical performance characteristics of SA provincial senior A and provincial U19 rugby playing forwards.

Variable	Provincial Forwards	U19 Forwards	Statistical significance (P)
Aerobic shuttle (no.)	99 ± 15 (n = 30)	103 ± 16 (n = 19)	
VO <sub>2</sub> max (mlO <sub>2</sub> .kg <sup>-1</sup> .min <sup>-1</sup> )	52 ± 4 (n = 30)	55 ± 5 (n = 19)	
WRUsrt (m)	684 ± 38 (n = 22)	723 ± 25 (n = 20)	**
Bench press (kg)	116 ± 18 (n = 33)	100 ± 19 (n = 22)	**
Bench press (kg.kgBM <sup>-1</sup> )	1.06 ± 0.19 (n = 33)	1.02 ± 0.18 (n = 22)	
Leg press (kg)	426 ± 64 (n = 24)	343 ± 61 (n = 19)	**
Leg press (kg.kgBM <sup>-1</sup> )	3.9 ± 0.6 (n = 24)	3.5 ± 0.7 (n = 19)	
Pull ups (no.)	9 ± 5 (n = 31)	10 ± 4 (n = 20)	
Push ups (no.)	48 ± 9 (n = 14)	43 ± 9 (n = 21)	
Sit ups (no.)	85 ± 15 (n = 25)	79 ± 15 (n = 21)	
Speed 10m (s)	1.86 ± 0.08 (n = 31)	1.79 ± 0.12 (n = 21)	*
Speed 20m (s)	3.21 ± 0.14 (n = 31)	3.07 ± 0.19 (n = 21)	**
Speed 30m (s)	4.47 ± 0.22 (n = 21)	4.26 ± 0.13 (n = 21)	**
Speed 40m (s)	5.66 ± 0.28 (n = 33)	5.42 ± 0.38 (n = 21)	**
Momentum 10m (kg.m.s <sup>-1</sup> )	594 ± 51 (n = 31)	547 ± 54 (n = 21)	**
Momentum 20m (kg.m.s <sup>-1</sup> )	689 ± 55 (n = 31)	637 ± 56 (n = 21)	**
Momentum 30m (kg.m.s <sup>-1</sup> )	747 ± 64 (n = 21)	690 ± 59 (n = 21)	**
Momentum 40m (kg.m.s <sup>-1</sup> )	781 ± 59 (n = 31)	723 ± 61 (n = 21)	**
Vertical jump (cm)	54 ± 7 (n = 30)	54 ± 7 (n = 21)	
Agility (s)	11.72 ± 0.86 (n = 30)	11.11 ± 0.64 (n = 21)	**
Sit and reach (cm)	6 ± 8 (n = 33)	11 ± 11 (n = 22)	*

Abbreviations: ( ) or n, number of subjects; no., number; mlO<sub>2</sub>.kg<sup>-1</sup>.min<sup>-1</sup>, milliliters of oxygen per kilogram of body mass per minute; WRUsrt, Welsh Rugby Union shuttle run test; m, meters; kg, kilograms; kg.kgBM<sup>-1</sup>, kilograms per kilogram body mass; s, seconds, cm, centimeters; \*,  $P < 0.05$ ; \*\*  $P < 0.01$

The senior forwards had superior upper and lower body muscle strength as measured by the maximum weight lifted on the one repetition maximum tests of bench press and leg press. However, this significant difference was only apparent in absolute terms, and not when the weight lifted was expressed relative to the players' body mass.

The U19 forwards were significantly quicker than the senior forwards over 10 m ( $1.79 \pm 0.12$  vs  $1.86 \pm 0.08$  s,  $P < 0.05$ ), 20 m ( $3.07 \pm 0.19$  s vs  $3.21 \pm 0.14$  s,  $P < 0.01$ ), 30 m ( $4.26 \pm 0.13$  s vs  $4.47 \pm 0.22$  s,  $P < 0.01$ ), and 40 m ( $5.42 \pm 0.38$  vs  $5.66 \pm 0.28$  s,  $P < 0.01$ ); and they also recorded significantly faster times on the agility test. However, with their significantly greater body mass the senior forwards were able to generate significantly greater momentum over the 10 m ( $+ 47 \text{ kg.m.s}^{-1}$ ,  $P < 0.01$ ), 20 m ( $+ 52 \text{ kg.m.s}^{-1}$ ,  $P < 0.01$ ), 30 m ( $+ 57 \text{ kg.m.s}^{-1}$ ,  $P < 0.01$ ), and 40m ( $+ 58 \text{ kg.m.s}^{-1}$ ) sprint intervals.

The U19 forwards had significantly greater lower back and hamstring flexibility, as measured by the sit and reach test, compared to the seniors ( $11 \pm 11$  cm vs  $6 \pm 8$  cm,  $P < 0.05$ ). There were no significant differences on the tests of muscle endurance (pull ups, push ups and sit ups) or leg power (vertical jump) between the two groups of forwards.

#### **4.3.3. Physical performance characteristics: SA provincial senior backs vs SA U19 backs**

The physical performance characteristics and comparative analysis for the senior and U19 backs are shown in Table 4.12. The senior backs had significantly greater absolute upper body strength, and absolute and relative lower body strength when compared to the U19 backs ( $P < 0.01$ ). On average the two groups performed the same number of pull ups (15 reps), but the senior players performed better than the U19 players in the tests of muscle endurance including push ups ( $65 \pm 13$  reps vs  $49 \pm 14$  reps,  $P < 0.01$ ), and sit ups ( $96 \pm 14$  reps vs  $79 \pm 15$  reps,  $P < 0.01$ ). The senior backline players had better leg power than their U19 counterparts, jumping on average 6 cm higher on the vertical jump test; and generated significantly greater momentum over 10 m ( $+ 63 \text{ kg.m.s}^{-1}$ ,  $P < 0.01$ ), 20 m ( $+ 76 \text{ kg.m.s}^{-1}$ ,  $P < 0.01$ ), 30 m ( $+ 74 \text{ kg.m.s}^{-1}$ ,  $P < 0.01$ ) and 40 m ( $+ 88 \text{ kg.m.s}^{-1}$ ,  $P < 0.01$ ) sprint intervals.

**Table 4.12. Mid-preseason physical performance characteristics of SA provincial senior A and SA provincial U19 backline players.**

Variable	Provincial backs	U19 backs	Statistical significance (P)
Aerobic shuttle (no.)	115 ± 16 (n = 21)	113 ± 13 (n = 19)	
VO <sub>2</sub> max (ml O <sub>2</sub> .kg <sup>-1</sup> .min <sup>-1</sup> )	57 ± 5 (n = 21)	57 ± 4 (n = 19)	
WRUprt (m)	739 ± 11 (n = 14)	739 ± 25 (n = 19)	
Bench press (kg)	101 ± 17 (n = 23)	81 ± 19 (n = 21)	**
Bench press (kg.kgBM)	1.18 ± 0.17 (n = 23)	1.08 ± 0.15 (n = 21)	
Leg press (kg)	384 ± 74 (n = 19)	285 ± 61 (n = 19)	**
Leg press (kg.kgBM)	4.4 ± 0.7 (n = 19)	3.8 ± 0.7 (n = 19)	*
Pull ups (no.)	15 ± 4 (n = 23)	15 ± 3 (n = 21)	
Push ups (no.)	65 ± 13 (n = 11)	49 ± 14 (n = 19)	**
Sit ups (no.)	96 ± 14 (n = 20)	79 ± 15 (n = 20)	**
Speed 10m (s)	1.78 ± 0.07 (n = 20)	1.78 ± 0.08 (n = 18)	
Speed 20m (s)	3.00 ± 0.12 (n = 20)	3.01 ± 0.10 (n = 18)	
Speed 30m (s)	4.09 ± 0.09 (n = 13)	4.14 ± 0.13 (n = 18)	
Speed 40m (s)	5.23 ± 0.19 (n = 20)	5.23 ± 0.16 (n = 18)	
Momentum 10m (kg.m.s <sup>-1</sup> )	496 ± 50 (n = 20)	423 ± 55 (n = 18)	**
Momentum 20m (kg.m.s <sup>-1</sup> )	576 ± 61 (n = 20)	500 ± 63 (n = 18)	**
Momentum 30m (kg.m.s <sup>-1</sup> )	619 ± 70 (n = 13)	545 ± 65 (n = 18)	**
Momentum 40m (kg.m.s <sup>-1</sup> )	664 ± 71 (n = 19)	576 ± 70 (n = 18)	**
Vertical jump (cm)	61 ± 7 (n = 21)	55 ± 6 (n = 20)	**
Agility (s)	10.89 ± 0.35 (n = 19)	11.12 ± 0.53 (n = 19)	
Sit and reach (cm)	7 ± 8 (n = 23)	13 ± 7 (n = 22)	*

Abbreviations: ( ) or n, number of subjects; no., number; ml O<sub>2</sub>.kg<sup>-1</sup>.min<sup>-1</sup>, milliliters of oxygen per kilogram of body mass per minute; WRUprt, Welsh Rugby Union shuttle run test; m, meters; kg, kilograms; kg.kgBM<sup>-1</sup>, kilograms per kilogram body mass; s, seconds, cm, centimeters; \*, p < 0.05; \*\* p < 0.01

The U19 backs had significantly greater lower back and hamstring flexibility compared to the seniors (7 ± 8 cm vs 13 ± 7 cm, P < 0.05) as measured using the sit and reach test.

The performances of the senior and U19 players were closely matched for speed, particularly over 10 m (mean speed 1.78 s for both groups) and 40 m (mean speed 5.23 s for both groups), aerobic capacity (115 ± 16 shuttles vs 113 ± 13 shuttles), and repeat sprint ability as measured by the distance covered on the WRUprt (distance = 739 m for both groups).

#### **4.3.4. Body size and body composition of senior provincial players vs U19 provincial players: props & locks, loose-forwards & hookers, and backs.**

The senior props & locks were significantly heavier than the U19 players in this positional category (116.4 ± 4.4 kg vs 102.9 ± 9.3 kg, P < 0.01), as were the senior backs compared to their U19 counterparts (86.0 ± 8.8 kg vs 74.6 ± 10.2 kg, P < 0.01). The 9.6 kg difference between the senior and U19 loose-forwards & hooker's category was not statistically significant. In all three categories the senior

players were taller than the U19 players, but these differences in height were not significant. Absolute muscle mass between the two age groups was significantly greater for the senior players within all three positional categories - the props & locks (+ 7 kg,  $P < 0.01$ ), loose-forwards & hookers (+ 8 kg,  $P < 0.01$ ), and backs (+ 8 kg,  $P < 0.01$ ). When expressed relative to body mass there was no difference between or within either age group and any positional category (see Table 4.13 and 4.14). Within the same positional category there were no significant differences between the senior and U19 players in subcutaneous adiposity as measured by the sum of seven skinfolds (SS 7).

Table 4.15. shows that the pattern of body size and composition differences between the three positional categories within the same age group are similar for the senior and U19 players. The most notable finding was that there was a significant difference in body mass between all three positional groups in the senior players. Amongst the U 19 players the props & locks (+ 28.3 kg,  $P < 0.01$ ) and the loose-forwards & hookers (+ 17.4 kg,  $P < 0.01$ ) were heavier than the backs; but the 10.9 kg difference in body mass between the loose-forwards & hookers, and the props and locks was not significant. For both the U19 and seniors levels of body fat differed significantly only between the backs and the props & locks.

**Table 4.13. Mid-preseason anthropometric characteristics of SA Provincial A Rugby players and SA elite provincial U19 players: props & locks, loose-forwards & hookers, and backs.**

Variable	Level	Positional category			Statistical significance (P)		
		Props & locks	LF & hookers	Backs	A	Pos	Int
Age (yrs)	Prov	27.9 ± 3.5	26.1 ± 3.5	24.6 ± 3.1			
	U19	18 ± 0.4	17.8 ± 0.4	17.7 ± 0.4	**	.	.
Height (cm)	Prov	192.9 ± 9.2 (19)	186.8 ± 5.3 (16)	178.9 ± 6.3 (23)			
	U19	188.4 ± 7.6 (12)	183.7 ± 8.3 (10)	175.0 ± 6.0 (22)	.	**	
Body mass (kg)	Prov	116.4 ± 4.4 (19)	101.6 ± 6.8 (16)	86.0 ± 8.8 (23)			
	U19	102.9 ± 9.3 (12)	92.0 ± 8.1 (10)	74.6 ± 10.2 (22)	**	**	
Muscle mass (kg)	Prov	63 ± 7 (19)	59 ± 5 (16)	50 ± 5 (23)			
	U19	56 ± 4 (12)	51 ± 6 (10)	42 ± 5 (22)	**	**	
Relative muscle mass (%)	Prov	54 ± 6 (19)	58 ± 3 (16)	58 ± 7 (23)			
	U19	55 ± 4 (12)	55 ± 4 (10)	58 ± 7 (22)		**	
Sum of skinfolds (mm)	Prov	110 ± 32 (19)	88 ± 25 (16)	67 ± 17 (23)			
	U19	106 ± 48 (12)	95 ± 38 (10)	63 ± 18 (22)		**	

Abbreviations: ( ), number of subjects; LF, loose-forwards; A, Age group; Pos, positional category; Int, interaction; yrs, years; cm, centimeters; kg, kilograms; %, percentage; mm, millimeters; .,  $P < 0.05$ ; \*\*  $P < 0.01$

**Table 4.14. Comparison of the anthropometric characteristics of the positional categories between the senior provincial A players and the U19 provincial elite players during the mid pre-season.**

	P&L senior vs P&L U19	P&L senior vs LF&H U19	P&L senior vs B U19	LF&H senior vs LF&H U19	LF&H senior vs P&L U19	LF&H senior vs B U19	B senior vs B U19	B senior vs P&L U19	B senior vs LF&H U19
Age (yrs)	**	**	**	**	**	**	**	**	**
Height (cm)			**			**		**	
Body mass (kg)	**	**	**			**	**	**	
Muscle mass (kg)	*	**	**	**		**	**		
Relative muscle mass (%)									
Sum of skinfolds (mm)			**					*	

Abbreviations: P&L, props and locks; LF&H, loose-forwards and hookers; B, backs; yrs, years; cm, centimeters; kg, kilograms; %, percentage; mm, millimeters; \*, P < 0.05; \*\* P < 0.01

**Table 4.15. Comparison of the anthropometric characteristics of positional categories within the U19 provincial players and within the senior provincial A players during the mid pre-season.**

Variable	U19 provincial players			Senior provincial players		
	P&L vs LF&H	P&L vs B	LF&H vs B	P&L vs LF&H	P&L vs B	LF&H vs B
Age (yrs)					**	
Height (cm)		**			**	*
Body mass (kg)		**	**	**	**	**
Muscle mass (kg)		**	**		**	**
Relative muscle mass (%)						
Sum of skinfolds (mm)		**			**	

Abbreviations: ( ), number of subjects; P&L, props and locks; LF&H, loose-forwards and hookers; B, backs; yrs, years; cm, centimeters; kg, kilograms; %, percentage; mm, millimeters; \*, P < 0.05; \*\* P < 0.01

#### **4.3.5. Physical performance characteristics of senior provincial players vs U19 rugby provincial players: props & locks, loose-forwards & hookers, and backs.**

Table 4.16. shows the anthropometric variables for each of the three playing position categories for both the senior and U19 players, and indicates for each variable whether significant differences existed between the senior and U19 players, the position of play, or whether a significant interaction between the senior and U19 groups was found. The results of post hoc analysis are displayed in Tables 4.17. and 4.18.

The following description focuses on identifying significant differences between the senior and U19 players within the same category of positional play (props & locks, or loose-forwards & hookers, or backs). These differences are displayed in addition to significant differences between the senior and U19 players playing in different categories in Table 4.17.

**Table 4.16. Mid pre-season physical performance characteristics of SA Provincial A Rugby players and SA provincial U19 players: props & locks, loose-forwards & hookers, and backs.**

Variable	Level	Positional category			Statistical significance		
		Props & locks	LF & hookers	Backs	A	Pos	Int
Aerobic shuttle (no.)	Prov	93 ± 13 (17)	107 ± 15 (13)	115 ± 16 (21)			
	U19	98 ± 16 (11)	110 ± 16 (10)	113 ± 13 (19)		**	
VO <sub>2</sub> max (mlO <sub>2</sub> .kg <sup>-1</sup> .min <sup>-1</sup> )	Prov	50 ± 4 (17)	54 ± 4 (13)	57 ± 5 (21)			
	U19	52 ± 4 (11)	56 ± 5 (10)	57 ± 4 (19)		**	
WRUsrt (m)	Prov	665 ± 26 (13)	712 ± 37 (9)	740 ± 11 (14)			
	U19	709 ± 37 (11)	741 ± 31 (9)	739 ± 25 (19)	**	**	*
Bench press (kg)	Prov	116 ± 16 (18)	115 ± 20 (15)	101 ± 17 (23)			
	U19	98 ± 23 (12)	102 ± 15 (10)	81 ± 19 (21)	**	**	
Bench press (kg.kgBM <sup>-1</sup> )	Prov	1.00 ± 0.16 (18)	1.13 ± 0.21 (15)	1.18 ± 0.17 (23)			
	U19	0.96 ± 0.20 (12)	1.10 ± 0.11 (10)	1.08 ± 0.15 (21)		**	
Leg press (kg)	Prov	449 ± 64 (14)	394 ± 53 (10)	384 ± 74 (19)			
	U19	328 ± 73 (10)	359 ± 44 (9)	285 ± 61 (19)	**	**	
Leg press (kg.kgBM <sup>-1</sup> )	Prov	3.8 ± 0.6 (14)	3.9 ± 0.6 (10)	4.4 ± 0.7 (19)			
	U19	3.2 ± 0.7 (10)	3.9 ± 0.4 (9)	3.8 ± 0.7 (19)	**	**	
Pull ups (no.)	Prov	7 ± 4 (17)	12 ± 5 (14)	15 ± 4 (23)			
	U19	8 ± 4 (10)	13 ± 3 (10)	15 ± 3 (21)		**	
Push ups (no.)	Prov	44 ± 8 (8)	52 ± 9 (6)	65 ± 13 (11)			
	U19	37 ± 9 (11)	49 ± 7 (10)	49 ± 14 (19)	**	**	
Sit ups (no.)	Prov	78 ± 12 (14)	93 ± 14 (11)	96 ± 14 (20)			
	U19	74 ± 18 (11)	85 ± 17 (10)	79 ± 15 (20)	**	**	
Speed 10m (s)	Prov	1.89 ± 0.07 (17)	1.83 ± 0.08 (14)	1.78 ± 0.07 (20)			
	U19	1.84 ± 0.14 (11)	1.74 ± 0.08 (10)	1.78 ± 0.08 (18)	**	**	
Speed 20m (s)	Prov	3.28 ± 0.12 (11)	3.12 ± 0.11 (10)	3.00 ± 0.12 (18)			
	U19	3.14 ± 0.23 (11)	3.00 ± 0.12 (10)	3.01 ± 0.10 (18)	**	**	*
Speed 30m (s)	Prov	4.59 ± 0.19 (12)	4.32 ± 0.16 (9)	4.09 ± 0.09 (13)			
	U19	4.36 ± 0.33 (11)	4.15 ± 0.14 (10)	4.14 ± 0.13 (18)	**	**	*
Speed 40m (s)	Prov	5.81 ± 0.26 (17)	5.48 ± 0.18 (14)	5.23 ± 0.19 (20)			
	U19	5.56 ± 0.43 (11)	5.26 ± 0.24 (10)	5.23 ± 0.17 (18)	**	**	
Momentum 10m (kg.m.s <sup>-1</sup> )	Prov	621 ± 39 (17)	562 ± 47 (14)	486 ± 50 (20)			
	U19	563 ± 55 (11)	528 ± 50 (10)	423 ± 55 (18)	**	**	
Momentum 20m (kg.m.s <sup>-1</sup> )	Prov	716 ± 45 (17)	657 ± 50 (14)	576 ± 61 (20)			
	U19	658 ± 51 (11)	614 ± 54 (10)	500 ± 63 (18)	**	**	
Momentum 30m (kg.m.s <sup>-1</sup> )	Prov	783 ± 45 (12)	698.7 ± 54 (9)	619 ± 70 (13)			
	U19	712 ± 54 (11)	665 ± 57 (10)	545 ± 65 (18)	**	**	
Momentum 40m (kg.m.s <sup>-1</sup> )	Prov	809 ± 49 (17)	748 ± 53 (14)	664 ± 71 (19)			
	U19	744 ± 52 (11)	700 ± 65 (10)	576 ± 70 (18)	**	**	
Vertical jump (cm)	Prov	52 ± 8 (17)	57 ± 6 (13)	61 ± 7 (21)			
	U19	51 ± 8 (11)	56 ± 5 (10)	55 ± 6 (20)		**	
Agility (s)	Prov	12.20 ± 0.75 (16)	11.17 ± 0.64 (14)	10.89 ± 0.35 (19)			
	U19	11.46 ± 0.55 (11)	10.73 ± 0.53 (10)	11.12 ± 0.53 (19)	*	**	*
Sit and reach (cm)	Prov	4 ± 8 (19)	8 ± 8 (14)	7 ± 8 (23)			
	U19	9 ± 12 (12)	14 ± 8 (n = 10)	13 ± 7 (22)	**		

Abbreviations: P&L, props and locks; LF&H, loose-forwards and hookers; B, backs; A, Age group; Pos, positional category; Int, interaction; ( ), number of subjects; no., number; mlO<sub>2</sub>.kg<sup>-1</sup>.min<sup>-1</sup>, milliliters of oxygen per kilogram of body mass per minute; WRUsrt, Welsh Rugby Union shuttle run test; m, meters; kg, kilograms; kg.kgBM<sup>-1</sup>, kilograms per kilogram body mass; s, seconds, cm, centimeters; \*, P < 0.05; \*\* P < 0.01

Aerobic capacity was not significantly different between the seniors and U19 players within the same positional category, but the U19 props & locks covered significantly more distance than the senior props & locks on the WRUsrt (709 ± 37 m vs 665 ± 26 m, p < 0.05). A significant interaction between age and positional category (P < 0.05) was found for the WRUsrt. The performance difference on the WRUsrt between the loose-forwards & hookers compared to the backs was negligible in the U19 age group, and quite marked within the senior player group. Within the senior players the loose-forwards & hookers had a mean score of 28 m

less than that of the backs, yet in the U19 age group the mean distance covered by the loose-forwards & hookers was 1 m further than that achieved by the backs.

The senior backs had significantly greater absolute upper ( $P < 0.05$ ) and lower ( $P < 0.01$ ) body strength compared to the U19 backs. The senior props & locks had significantly greater lower body strength, but not upper body strength when compared to their U 19 counterparts. Although the senior loose-forwards & hookers lifted a heavier weight on the one repetition maximum leg press and bench press tests compared to the U19 players in the same positional category, the performance differences on these tests were not significant.

The muscle endurance performances for the push ups and sit ups were significantly superior amongst the senior compared to the U19 backs. Within the other two positional categories there were no significant differences between the senior and U19 players, although the mean scores of the seniors were better than those of the U19 players. Within the same positional category there were no differences in 10 m, 20 m, 30 m and 40 m speed between the senior and U19 players. However, there was a significant difference between the senior and U19 players in the pattern of performances between the positional categories for speed over 20 m and 30 m. There was little difference between the performances of the U19 loose-forwards & hookers vs the U19 backs over 20 m (+ 0.01 s) and 30 m (- 0.01 s), whereas the senior loose-forwards & hookers were 0.12 seconds slower over 20 m and 0.23 seconds slower over 30 m compared to the senior backs. Over the 10 m, 20 m, 30 m and 40 m distances, the senior players were able to generate greater momentum than their U19 positional category counterparts, but only between the senior and U19 backline players were the differences in momentum significant.

No significant differences existed between senior and U19 players within the same positional category for the other physical performance characteristics of relative upper and lower body strength, agility, leg power (vertical jump), and flexibility. However, the pattern of performances for agility between the positional categories was significantly different when the two age groups were compared. The backs

were the most agile of the senior positional categories, and the loose-forwards & hookers were the most agile of the U19 positional categories.

**Table 4.17. Comparison the physical performance characteristics of the positional categories between the senior provincial A players and the U19 provincial players during the mid-preseason.**

Variable	P&L senior vs P&L U19	P&L senior vs LF&H U19	P&L senior vs B U19	LF&H senior vs LF&H U19	LF&H senior vs P&L U19	LF&H senior vs B U19	B senior vs B U19	B senior vs P&L U19	B senior vs LF&H U19
Aerobic shuttle (no.)			**						
VO2 max (mlO <sub>2</sub> .kg <sup>-1</sup> .min <sup>-1</sup> )			**						
WRUart (m)	*	**	**						
Bench press (kg)			**			**	*		
Bench press (kg.kg.BM <sup>-1</sup> )								*	
Leg press (kg)	**		**			**	**		
Leg press (kg.kg.BM <sup>-1</sup> )								**	
Pull ups (no.)		*	**					**	
Push ups (no.)							*	**	
Sit ups (no.)							*	*	
Speed 10 m (s)		**	*						
Speed 20 m (s)		**	**						
Speed 30 m (s)		**	**					*	
Speed 40 m (s)		**	**					*	
Momentum 10 m (kg.m.s <sup>-1</sup> )		**	**			**	**	*	
Momentum 20 m (kg.m.s <sup>-1</sup> )		**	**			**	**	*	
Momentum 30 m (kg.m.s <sup>-1</sup> )		**	**			**	**	*	
Momentum 40 m (kg.m.s <sup>-1</sup> )		**	**			**	**	*	
Vertical jump (cm)								*	
Agility (s)		**	**						
Sit and reach (cm)			*						

Abbreviations: P&L, props and locks; LF&H, loose-forwards and hookers; B, backs; no., number; mlO<sub>2</sub>.kg<sup>-1</sup>.min<sup>-1</sup>, milliliters of oxygen per kilogram of body mass per minute; WRUart, Welsh Rugby Union shuttle run test; m, meters; kg, kilograms; kg.kgBM<sup>-1</sup>, kilograms per kilogram body mass; s, seconds, cm, centimeters; \*, P < 0.05; \*\* P < 0.01

Table 4.18. gives an indication of the pattern of physical performance characteristics between the three positional categories within the same age group. There is greater differentiation between the positional categories of the senior players compared to the U19 players in the physical performance characteristics of aerobic capacity (multistage shuttle run), repeat sprint ability (WRUart), speed over 10 m, 20 m, 30 m and 40 m, agility and leg power.

**Table 4.18. Comparison of the physical performance characteristics of positional categories within the U19 provincial players and within the senior provincial A players during the mid pre-season.**

Variable	U19 provincial players			Senior provincial players		
	P&L vs LF&H	P&L vs B	LF&H vs B	P&L vs F&H	P&L vs B	LF&H vs B
Aerobic shuttle (no.)					**	
VO2 max (mlO <sub>2</sub> .kg <sup>-1</sup> .min <sup>-1</sup> )					**	
WRUsrt (m)				*	**	
Bench press (kg)						
Bench press (kg.kg.BM <sup>-1</sup> )						
Leg press (kg)						
Leg press (kg.kg.BM <sup>-1</sup> )						
Pull ups (no.)		**		**	**	
Push ups (no.)					**	
Sit ups (no.)					**	
Speed 10 m (s)					**	
Speed 20 m (s)					**	
Speed 30 m (s)					**	
Speed 40 m (s)		*		*	**	
Momentum 10 m (kg.m.s <sup>-1</sup> )		**	**		**	**
Momentum 20 m (kg.m.s <sup>-1</sup> )		**	**		**	**
Momentum 30 m (kg.m.s <sup>-1</sup> )		**	**		**	
Momentum 40 m (kg.m.s <sup>-1</sup> )		**	**		**	*
Vertical jump (cm)					**	
Agility (s)				**	**	
Sit and reach (cm)						

Abbreviations: n, number of subjects; no., number; mlO<sub>2</sub>.kg<sup>-1</sup>.min<sup>-1</sup>, milliliters of oxygen per kilogram of body mass per minute; WRUsrt, Welsh Rugby Union shuttle run test; m, meters; kg, kilograms; kg.kgBM<sup>-1</sup>, kilograms per kilogram body mass; s, seconds, cm, centimeters; P&L, props and locks; LF&H, loose-forwards and hookers; B, backs; \*, P < 0.05; \*\* P < 0.01

#### **4.4. The effects of a prescribed training programme on anthropometric and physical performance characteristics of U19 provincial rugby union players .**

##### **4.4.1. Body size and body composition**

The mean age for the group at the off-season testing session was 17.8 ± 0.4 years. There were no significant changes in body mass, or subcutaneous fat levels during the off and early pre-season period of training (Table 4.19).

**Table 4.19. Body size and body composition in the off-season compared to the mid pre-season**

Variable	Off-season (n = 33)	Mid pre-season (n = 33)	SD of Δ	% Δ
Body mass (kg)	85.3 ± 15.5	86.1 ± 15.4	2.4	1
Sum of skinfolds (mm)	80 ± 40	82 ± 40	9	3

Abbreviations: n, number of subjects; SD of Δ, standard deviation of differences; % Δ, percentage change; kg, kilograms; mm, millimeters; \*, P < 0.05; \*\* P < 0.01

##### **4.4.2. Changes in physical performance characteristics**

The U 19 players showed significant improvements in aerobic capacity (multistage shuttle run), repeat sprint ability (WRUsrt), absolute and relative upper and lower body strength, muscle endurance (push ups, pull ups, and sit ups), speed and momentum over 10m, agility and flexibility after following a 7 week unsupervised

training programme. During the training period leg power (vertical jump), and speed and momentum over 20 m, 30 m and 40 m did not improve significantly.

Table 4.20. Physical performance characteristics in the off-season compared to the mid pre-season.

Variable	n.	Off-season	Mid pre-season	SD of $\Delta$	% $\Delta$	P
VO <sub>2</sub> max (mlO <sub>2</sub> .kg <sup>-1</sup> .min <sup>-1</sup> )	29	51 ± 4	55 ± 5	3	8	**
WRUsrt (m)	29	700 ± 37	735 ± 34	20	5	**
Bench press (kg)	32	84 ± 21	91 ± 22	10	8	**
Bench press (kg.kgBM <sup>-1</sup> )	32	0.98 ± 0.17	1.04 ± 0.15	0.10	6	**
Leg press (kg)	30	284 ± 68	322 ± 66	67	13	**
Leg press (kg.kgBM <sup>-1</sup> )	30	3.4 ± 0.7	3.9 ± 0.4	0.7	15	**
Pull ups (no.)	32	10 ± 4	13 ± 4	2	30	**
Push ups (no.)	29	39 ± 10	44 ± 10	6	13	**
Sit ups (no.)	31	65 ± 18	79 ± 17	12	22	**
Speed 10 m (s)	28	1.81 ± 0.10	1.78 ± 0.11	0.08	2	*
Speed 20 m (s)	28	3.05 ± 0.16	3.03 ± 0.17	0.09	1	
Speed 30 m (s)	28	4.19 ± 0.23	4.19 ± 0.24	0.11	0	
Speed 40 m (s)	28	5.32 ± 0.31	5.32 ± 0.33	0.13	0	
Momentum 10 m (kg.m.s <sup>-1</sup> )	28	482 ± 76	496 ± 82	29	3	*
Momentum 20 m (kg.m.s <sup>-1</sup> )	28	572 ± 84	581 ± 89	28	2	
Momentum 30 m (kg.m.s <sup>-1</sup> )	28	625 ± 91	631 ± 93	29	1	
Momentum 40 m (kg.m.s <sup>-1</sup> )	28	657 ± 95	663 ± 96	29	1	
Vertical jump (cm)	30	54 ± 6	54 ± 7	3	0	
Agility (s)	29	11.45 ± 0.68	11.10 ± 0.63	0.44	3	**
Sit and reach (cm)	32	9 ± 8	12 ± 7	4	33	**

Abbreviations: n, number of subjects; SD of  $\Delta$ , standard deviation of differences; %  $\Delta$ , percentage change; no., number; mlO<sub>2</sub>.kg<sup>-1</sup>.min<sup>-1</sup>, milliliters of oxygen per kilogram of body mass per minute; WRUsrt, Welsh Rugby Union shuttle run test; m, meters; kg, kilograms; kg.kgBM<sup>-1</sup>, kilograms per kilogram body mass; s, seconds; cm, centimeters; \*, P < 0.05; \*\* P < 0.01

## **5. DISCUSSION**

### **5.1 Mid pre-season anthropometric and physical performance characteristics of SA U19 provincial rugby union players**

#### **5.1.1. Introduction**

The aims of this part of the study were to;

- I. provide South African (SA) rugby coaches, trainers and players with descriptive data (means  $\pm$  SD) for SA U19 provincial level rugby players so that realistic targets for body size, body composition and physical performance variables can be set for aspiring players which are relative to playing position, age (U19 age group) and desired level of play, and
- II. compare the anthropometric and physical performance characteristics of SA U19 provincial rugby players to those of rugby players of a similar age.

#### **5.1.2. Comparative analysis of SA U19 provincial players**

For this section of the study the body size and composition, and the physical performance characteristics of the U19 players of the current study have been compared to data reported for rugby union players of similar age participating at various proficiency levels (Clark, 1995; Quarrie et al., 1995, Mayes and Thompson, 1995; Mayes and Nuttall, 1995).

##### **5.1.2.1. Body size and body composition**

The most significant observation when comparing the body size and body composition of U19 provincial SA rugby players to rugby players of a similar age was the greater body mass of these elite players compared to their less proficient age group counterparts.

Clark (1998) assessed 20 high school rugby players (mean age of 17 years) before and after they had completed either a supervised or unsupervised 12 week

pre-season rugby fitness training programme. Although the players were not provincial schools level they were considered to be the most promising players in their penultimate year at high school, and the four schools from which the boys were selected were competing at the highest schoolboy level of rugby in the Western Cape, SA. The anthropometric and physical performance characteristics were presented for both the unsupervised and supervised training groups. Within each training group players were not categorised according to playing position but the number of forward and backline players within each of the two training groups was similar.

In comparison to the rugby players in the study of Clark (1998), the players in the current study were 13 months older (18 years), and they were the most elite players in each province under the age of 19 years.

Although 13 months younger, the rugby players in the study of Clark (1998) serve as a useful comparison to those in the current study. The Clark (1998) study was conducted in the same laboratory as the current study, using the same anthropometric procedures. Furthermore, the players in the Clark (1998) study participated in a rugby fitness programme which included strength training, as had the players in the current study. It is a reasonable assumption that the players in the Clark (1998) study are probably fairly representative of the players who participate at a competitive level just below that of the SA U19 provincial players.

To assist with the identifying of differences between two levels of South African players within a similar age bracket the results of supervised and unsupervised training groups of the Clark (1998) study are presented compositely as are the results of the U19 provincial forwards and backs of the current study (as presented in Table 4.1 of section 4.1.1.). Data presented for the purpose of comparison are therefore mean values rather than mean values plus / minus standard deviation.

The mean body mass of 86.3 kg of the U19 provincial players was 12.6 kg greater than that of the standard nine rugby players whose mean weight was 73.7 kg. A 3 cm difference in height existed between the two groups, the standard nine players

being shorter. The U19 provincial players had 5 kg more skeletal muscle than the standard nine players, but also had greater levels of subcutaneous adipose tissue as determined by their mean sum of seven skinfolds (82.0 mm) being 28.6 mm greater than that of the standard nine players. Considering that the mean sum of seven skinfolds for senior provincial "A" players was 83.5 mm and that of the 1998 Springbok squad (11 forwards, 12 backline players) was 78.6 mm (Durandt and Scales 1998, unpublished data) at mid pre-season it would seem that the U19 provincial players had similar body fat levels to their senior provincial and national level counterparts. These observations tend to support the findings of Quarrie et al. (1995), that body mass, height and mesomorphy differ significantly between players of different proficiency levels of play. However, Quarrie et al's. (1995) finding pertained to senior level rugby, and some of the differences between these two SA adolescent groups could be due to differences in physical maturity (the 13 month age difference).

As part of their study on a cross-section of New Zealand (NZ) rugby players Quarrie et al. (1995) assessed height, weight and somatotype of 54 U19/18 NZ high school rugby players (mean age of 16.9 years, a year younger than the SA U19 provincial players) and group of 65 U21 New Zealand Club players (mean age of 18.9 years, a year older than the SA U19 provincial players). It is likely these NZ players were competing at similar proficiency levels relative to their respective age groups and although the age difference was two years, the difference in body mass was only 5.2 kg. It therefore seems plausible to suggest that the 12.6 kg body mass difference between the SA U19 provincial players and the SA standard nine players of the Clark (1998) study was only a small part due to the 13 month age difference (maturation). Body mass therefore appears to be an attribute that influences the likelihood of players being selected for teams participating at the highest level of play.

Quarrie et al. (1995) classified the players within the U19/18 school level and U21 club level players as either forwards or backs. The mean results show that the U19/18 group was on average 9 kg lighter than the SA U19 provincial players, with the greatest difference in weight being between the forwards. The SA forwards

weighed  $97.9 \pm 10.2$  kg compared to 82.6 kg for the NZ forwards (15.3 kg difference), whereas the difference between the backline players was less marked,  $74.6 \pm 10.2$  for SA U19 provincial players compared to 72.0 kg for NZ players. Although the SA U19 provincial forwards were markedly taller than the NZ forwards (180.2 cm vs 186.2 cm), the backline players were similar in height (175.4 cm vs 175 cm).

Although the U21 Club players of the study of Quarrie et al. (1995) were on average a year older than the SA U19 provincial players, the SA players as a group still had greater body mass than the group of NZ players (3.8 kg heavier), but it was only amongst the forwards that this difference was marked. The SA forwards were on average 8.5 kg heavier and 2.9 cm taller than the NZ forwards, whereas the NZ backline players were heavier (0.9 kg) and taller (2.5 cm) than the SA U19 provincial backs.

From the studies available the Welsh U21 elite squad (Mayes and Thompson, 1995, Mayes and Nuttall, 1995) are likely to be the rugby population to which the U19 provincial players in the current study can be most accurately compared on the basis of proficiency level, although with respect to age the Welsh players have the advantage of being one to two years older than the SA players. The Welsh players were similar in body mass to the SA U19 provincial players. Compared to the players in the Mayes and Thompson (1995) study the SA forwards were 0.9 kg heavier and the backs were 3.8 kg lighter than the Welsh players. The mean body mass of the SA U19 players compared favourably to that of the U21 players in the study of Mayes and Nuttall (1995) (86.3 kg vs 88.7 kg).

The above comparative analysis suggests that body mass is a critical distinguishing factor between elite schools players and those players who progress to provincial or national teams, particularly amongst the forwards. Furthermore, the SA U19 provincial players of the current study have appropriate body mass for participation at an international level considering they are similar in mass to U21 elite Welsh players.

The most talented of players may be restricted in their potential proficiency level of participation during and after maturation due to genetic factors being the chief determinants of body size. After maturation, players may have to adjust their goals in terms of desired level or standard of participation, and or change their playing positions if their growth during maturation does not result in body size gains that are optimal for their desired level of play, or pre-maturation position of play. Body size and its influence on rugby playing performance has important implications for talent identification. Time and money will be better invested in talented young players (particularly when it comes to the selection of forwards) who have genetically large physiques compared to those who are genetically more ectomorphic and small in body size. Players demonstrating immense talent and skill but who lack the body size required to play at a level commensurate with their skill need to be identified, and given the opportunity to increase their body mass via individualised nutritional programmes, well designed strength training programmes, and the use of non-steroidal ergogenic aids including creatine (Balsom et al., 1993) before they are considered 'too small' to play successfully at the level warranted by their skill.

#### 5.1.2.2. Physical performance characteristics

Comparisons between the SA U19 provincial players and players of similar age and proficiency level (Clark, 1988; Quarrie et al., 1995; Noakes and Du Plessis, 1996) can be made for aerobic endurance, muscle strength, vertical jump height, speed and momentum. Although comparisons are made, it must be considered that although the protocols used were very similar to those in the current study, any performance differences identified could be in part due to subtle differences in the protocol such as the testing surface used, the time of day testing occurred (Bernard et al., 1998), and physical activity prior to the testing day.

The aerobic fitness of both the SA provincial U19 forwards and backs is comparable to that of the New Zealand U19/18 schoolboy players, the NZ U21 Club players, and the Welsh elite U21 players. The SA forwards and backs completed on average only 5 less shuttles than the Welsh forwards (103 vs 108

shuttles, or Level 11 Shuttle 11 vs Level 12 Shuttle 4) and backs (113 vs 118 shuttles, or Level 12 Shuttle 9 vs Level 13 Shuttle 2).

The lack of difference in the aerobic fitness of the NZ school and club level players, compared to the Welsh and SA players who were participating at a higher playing level than the NZ players may be partly due to the larger body mass of players in the latter two groups, the NZ players having the advantage of being lighter. Another explanation may be that the multistage shuttle run does not differentiate between junior players (under the age of 21) competing at different proficiency levels, in the same way it does not differentiate between senior players competing at different levels (Quarrie et al., 1995).

Clark (1998) found that after 12 weeks of strength training, elite standard nine SA rugby players were able to lift a weight just greater than their body mass (75 kg or  $1.02 \text{ kg.kgBM}^{-1}$ ) on a bench press one repetition maximum (1 RM) test. By comparison the SA provincial U19 players had greater absolute upper body strength lifting on average 90.5 kg ( $1.05 \text{ kg.kgBM}^{-1}$ ) for the 1RM bench press test. The difference in absolute strength may be largely accounted for by the differences in body mass (12.5 kg) as both populations were strength trained, familiar with the correct bench press lifting technique, and had similar levels of upper body strength relative to body mass.

Australia and NZ express strength requirements for rugby players in absolute rather than relative terms, indicating the importance of absolute strength for a high level of play. The bench press performances of the SA U19 provincial players closely matched the required weight to be lifted by 18 year old elite NZ players. NZ tight forwards, loose-forwards and backline players are required to lift 105 kg, 95 kg and 85 kg respectively (Noakes and Du Plessis, 1996). The SA U19 loose-forwards & hookers compared favorably with this requirement, lifting 102 kg, whereas the props & locks, and backs score just below the NZ requirement, lifting 98 kg and 81 kg respectively. Therefore, the SA U19 provincial players after having completed an off - and early pre-season strength training programme generally have comparable upper body absolute strength to that required of 18

year old elite NZ players. Due to differences in test selection for the assessment of lower body strength (squat vs leg press) comparisons between the U19 players and NZ players cannot be made accurately.

Vertical jump height was greater amongst the SA U19 provincial players when compared to the standard nine players of the Clark (1998) study, the difference in vertical jump height being 2.5 cm (54.5 cm vs 52.0 cm). The required vertical jump height for 18 year old elite tight-forwards, loose-forwards and backline players in NZ are 50 cm, 52.5 cm and 55 cm respectively (Noakes and Du Plessis, 1996). The SA U19 players compared favorably with these recommendations with the props & locks, loose-forwards & hookers, and backs achieving jump heights of 51 cm, 56 cm and 55 cm respectively. The NZ U19 /18 school level forwards and backs despite being a year younger had superior vertical jump height to SA U19 provincial players and attained vertical jump heights of 57 cm and 63 cm respectively (Quarrie et al., 1995). The fact that the NZ U18/19 players were on average 9 kg lighter than the SA U19 players may account for their superior vertical jump height compared to the SA U19 provincial players.

Tight forwards, loose-forwards, and backs who hold AIS rugby scholarships, typically cover 35 m in 5.40 s, 5.10 s, and 4.70 s respectively (Noakes and Du Plessis, 1996). Assuming that a constant velocity was maintained over the 10m interval between 30 m and 40 m on the 40 m sprint, it can be estimated that 35 m speed times for the SA U19 provincial props and locks, loose-forwards and hookers, and backs were 4.96 s, 4.71s, and 4.69 s respectively. The speed performances of the SA national U19 players were therefore better than those of 18 - 20 year old AIS rugby scholarship holders (Noakes and Du Plessis, 1996).

Quarrie et al. (1995) assessed the speed and momentum of NZ U19 /18 rugby playing scholars and the NZ U21 Club players over 30 m. A standing start and an electronic timing system with light reflecting switches were used. The SA provincial U19 forwards (despite being heavier than the NZ players) and backs were quicker than both NZ school and club players and had greater momentum over 30 m.

The NZ U19/18 and U21 forwards averaged 4.60 s (momentum of 535 kg.kgBM<sup>-1</sup>) and 4.50 s (momentum of 603 kg.kgBM<sup>-1</sup>) respectively, compared to the mean time of 4.26 s (momentum of 654 kg.kgBM<sup>-1</sup>) recorded by SA provincial U19 forwards. The NZ backline players for both age groups averaged 4.40 s for the 30 m sprint (momentum of 496 kg.kgBM<sup>-1</sup> for the U19/18 and 522 kg.kgBM<sup>-1</sup> for the U21 players), compared to 4.14 s (momentum of 573 kg.kgBM<sup>-1</sup>) for the SA provincial U19 backline players.

Factors including the surface on which the sprint was performed, the method of timing (hand or electronic), the time of day, the distance players start running behind the start line and the type of start (running start versus crouched start) are all variables that should be carefully considered, before attributing differences in sprint times to sprint ability alone. Unfortunately, none of these variables are reported by Noakes and Du Plessis (1996) for the testing of the AIS rugby scholarship holders, and only the type of start and timing method are reported by Quarrie et al. (1995).

SA U19 provincial players therefore performed better on tests of speed than both Australian players of similar age (18-20 years) and proficiency (AIS scholarship holders), and NZ school and club level players of similar age and lighter in body mass. Although it must be considered that subtle protocol differences may account in part or full for the sprint time differences observed, the consistently faster sprint times recorded by the SA U19 provincial players compared to Australian elite and NZ, school, and club level players suggests that the South African players may have superior natural sprint ability compared to NZ and Australian players.

In summary, discounting the influence that subtle protocol differences may have had on the player's physical fitness test performances, the SA U19 provincial players had similar physical fitness performances to elite junior players (under the age of 21) from other 'world dominant' rugby nations, or matched the physical performance requirements for elite junior rugby players in New Zealand and Australia.

## **5.2. Mid pre-season anthropometric and physical performance characteristics of SA senior A provincial rugby union players.**

### **5.2.1. Introduction**

The aims of this part of the study were to;

- I. provide South African (SA) rugby coaches, trainers and players with descriptive data (means  $\pm$  SD) for SA senior provincial level rugby players so that realistic targets for body size, body composition and physical performance variables can be set for players relative to playing position, and desired level of play, and
- II. compare the anthropometric and physical performance characteristics of SA senior A provincial players to other elite senior players of provincial or national level.

### **5.2.2. Comparative analysis of SA senior A provincial players.**

#### **5.2.2.1. Body size and body composition.**

Although the extent of difference between the body mass of the SA senior A provincial players of the current study and those players of other studies cannot be statistically determined it can be seen from Table 5.1 that both the forwards and the backs of the current study had greater body mass than Welsh, English, and American national level players (Mayes and Tong, 1995; Holmyard and Hazeldine, 1993; Carlson et al., 1994) and New Zealand senior A club players (Quarrie et al., 1995).

The forwards were significantly heavier than the backs (+ 23.7 kg), a finding consistent with the majority of rugby descriptive studies ( Bell, 1979; Maud and Shultz, 1984; Jardine et al., 1988; Casagrande and Viviani, 1993; Holmyard and Hazeldine, 1993; Carlson et al., 1994; Quarrie et al., 1995; Nicholas and Baker, 1995; Mayes and Thompson, 1995).

**Table 5.1. Body mass (kilograms) of national and provincial players.**

	Forwards		Backs
SA senior A players (current study)	109.7 ± 10.5 kg		86.0 ± 8.8 kg
NZ senior A club players @	98.5 kg		81.8 kg
Welsh national players \$	105.6 ± 8.1 kg		81.5 ± 5.9 kg
English national players *	100.3 ± 10.4 kg		83.0 ± 5.2 kg
USA national squad #	99.1 ± 9.06 kg		80.8 ± 7.25 kg
	P & L	LF & H	Backs
SA senior A players (current study)	116.4 ± 4.4 kg	101.6 ± 6.8 kg	86.0 ± 8.8 kg
SA senior A provincial players+	110.1 ± 10.6 kg	104.6 ± 5.66 kg	85.1 ± 8.1 kg
English national players **	102.5 ± 2.6 kg	100.9 ± 12.8 kg	85.0 ± 7.0 kg

Abbreviations: kg, kilograms; @, Quarrie et al. (1995); \$, Mayes and Tong (1995); \*, Holmyard and Hazeldine (1993); #, Carlson et al. (1994); +, Turnbull (1996); \*\*, Bell et al. (1993); P, props; L, locks; LF; loose-forwards; H, hookers

When the forwards are further differentiated into props & locks and loose-forwards & hookers it can be seen from Table 5.1 that the English national loose-forwards & hookers, and backs were similar in body mass to the provincial South African players. However, the English national playing props & locks were 7.6 kg lighter than the SA provincial props & locks of the Turnbull (1996) study. Furthermore, the props & locks of the Turnbull (1996) study were 6.3 kg lighter than the SA provincial props & locks of the current study. Turnbull (1996) and Bell et al. (1993) as in the current study found the props & locks, and loose-forwards & hookers to be significantly heavier than the backs. However, in the current study there was further distinction between the forwards, with the props & locks being significantly heavier than the loose-forwards & hookers.

With respect to height the SA provincial A forwards were taller than Welsh, English and American players. The backs of the current study were similar in height to American backline players and marginally taller than Welsh and English players (Table 5.2). The height of the props & locks, and loose-forwards & hookers, and backs were similar to the English national squad players assessed by Bell et al. (1993).

**Table 5.2. Stature (centimeters) of national and provincial players.**

	<b>Forwards</b>		<b>Backs</b>
SA senior A players (current study)	<b>190.1 ± 8.2 cm</b>		<b>178.9 ± 6.3 cm</b>
Welsh national players \$	188.0 ± 9.0 cm		177.0 ± 4.0 cm
English national players *	184.0 ± 10.1 cm		175.0 ± 2.0 cm
USA national squad #	186.8 ± 7.18 cm		178.9 ± 5.3 cm
	<b>P &amp; L</b>	<b>LF &amp; H</b>	<b>Backs</b>
SA senior A players (current study)	<b>192.9 ± 9.2 cm</b>	<b>186.8 ± 5.3 cm</b>	<b>178.9 ± 6.3 cm</b>
English national players **	190.7 ± 11.4 cm	184 ± 7.9 cm	178.1 ± 6.3 cm

Abbreviations: cm, centimeters; \$, Mayes and Tong (1995); \*, Holmyard and Hazeldine (1993); #, Carlson et al. (1994);\*\*, Bell et al. (1993); P, props; L, locks; LF; loose-forwards; H, hookers

In terms of body size (body mass and stature) the SA senior A provincial players were comparable to English, Welsh and American national class players, and it appears that the SA props & locks of the current study had significantly greater body mass than other provincial and national level players. Body mass, particularly fat free body mass is an important variable determining on the field performance and has been shown to differ significantly between players of different proficiency - higher level players being heavier (Quarrie et al., 1995).

Quarrie et al. (1995) observed that forwards are prepared to compromise their mobility to some extent for the greater momentum that a greater body mass enables them to produce. The body mass differences between the players of this study and those of the studies quoted above may be related to the fact that the players in the current study were assessed more recently (1998), compared to those players assessed between the period 1990 and 1995. The players of the current study (with respect to body mass) may have benefited from the emphasis that has been placed over the past few years on players increasing their fat free mass through participation in scientifically structured strength training programmes, dietary regimens and the use of non-steroidal nutritional ergogenic aids including creatine.

The methods for assessing body fat in rugby players have been varied, making comparisons between studies difficult. However, Carlson et al. (1994) measured nine skinfolds on American national level players. By summing the same seven

skinfolds to those used in this study it can be seen that the Americans score marginally less on the sum of seven skinfolds. The American forwards had 94 mm of subcutaneous fat compared to 100 mm for the SA provincial players, and the American backs had 66 mm compared to 67 mm for the SA provincial players. As found in the majority of studies that have assessed the body composition of forwards and backs ( Bell, 1973; Bell, 1979; Maud and Shultz, 1984; Carlson et al., 1994; Nicholas and Baker, 1995; Mayes and Thomson, 1995; Turnbull, 1996) the forwards in the current study had significantly greater body fat compared to the backs.

The muscle mass of senior rugby union players has not often been assessed. Clark (1998) made reference to the absolute and relative muscle mass of SA provincial and national level players but presented these data for the entire squad rather than differentiating between positions of play. He reported provincial and national level adult players to have absolute muscle values of 58.1 kg and 59.0 kg respectively and relative muscle mass values of 59 % and 60 % respectively. In the current study the provincial senior forwards had an absolute muscle mass of 61.0 kg, compared to 50.0 kg for the backs, and a relative muscle mass of 56 % compared to 58 % for backs.

An interesting finding in the current study was that although the backs had significantly less body mass and muscle mass than both the loose-forwards & hookers, and props & locks; the same pattern did not follow between the loose-forwards & hookers and the props & locks. Although the loose-forwards & hookers had significantly less body mass (-14.8 kg) than the props and locks, they did not have significantly less muscle mass (- 4.0 kg).

#### 5.2.2.2. Physical performance characteristics

With respect to physical performance characteristics, comparisons between the SA senior A provincial players of the current study and other senior players can be made for aerobic capacity, muscle strength, vertical jump height, speed and momentum. It must be considered that despite the protocols being very similar to

those used in the current study performance differences identified could in part be due to subtle differences including the testing surface used, the time of day testing occurred (Bernard et al., 1998) and physical activity prior to the testing day.

The SA senior A provincial forwards and backs of the current study completed 99 and 115 shuttles on the multistage shuttle run test respectively. These performances fell short of those recorded for Welsh national forwards and backline players (106 and 124 shuttles, tested end of pre-season) (Tong and Mayes, 1995), English national forwards and backline players (120 and 126 shuttles respectively, tested mid pre-season) (Hazeldine and McNab, 1991), and NZ senior A club forwards and backline players (109 and 127 shuttles respectively).

Consistent with the findings of Quarrie et al. (1995) (NZ Club players), and Nicholas and Baker (1995) (First and second class Welsh players), the aerobic capacity of the backs compared to the forwards in the current study was significantly different. In contrast, Holmyard and Hazeldine (1993) (English national squad members) and Mayes and Thomson (1995), (Elite senior and elite U21 Welsh players), did not find significant differences in the number of shuttles completed during the multistage shuttle run between forwards and backs. Turnbull (1996) found SA senior A provincial backs (players matched in proficiency level to those in the current study) to have significantly greater aerobic capacity than the loose-forwards & hookers, and the props & locks, whereas in the current study the backs only had significantly greater aerobic capacity than the props & locks. In contrast to the study of Turnbull (1996) body fat between the backs and loose-forwards & hookers did not differ significantly. This may account for the similarity in the aerobic capacity between loose-forwards & hookers and backs, however this has not been statistically analysed. This finding seems to support the de-differentiation of physical performance characteristics between backline players and loose-forwards and hookers with respect to aerobic capacity.

Most studies have not included strength testing in their test batteries. However, if one compares the bench press one repetition maximum performances of 116 kg, 115 kg and 101 kg for the props & locks, loose-forwards & hookers, and backs

respectively it is apparent that the upper body strength expected of the 1995 Australian World Cup Squad (AWCS) far exceeds that of the strength of current SA provincial players. The Australian Institute of Sport expected the 1995 AWCS players to perform the 3 RM bench press with a weight of between 140 - 160 kg for props, 130 - 150 kg for locks, 120 - 140 kg for loose-forwards, 100 - 120 for inside backs, and 120 - 140 kg for outside backs (Turnbull, 1996). The programme of scientific testing and training for Australian rugby players began in 1989 whereas in South Africa fitness training, and strength training for players only started to be practiced in the majority of provinces in 1995 (Noakes and Du Plessis, 1996). The differences in strength scores between the Australian national players and the 1998 SA provincial players may be attributable to both level of proficiency (provincial vs national), and years of participation in strength training.

Vertical jump heights attained by the SA senior A provincial forwards (54 cm) and backs (61 cm) of the current study, were not as high as those recorded for other SA senior A provincial players (Turnbull, 1996) at the end of the pre-season, American and English national squad players, or NZ senior A club players. Neither were they close to the targets set for the 1995 AWCS of 60 - 70 cm for forwards and 70 - 80 cm for backs. These findings indicate that the SA senior A provincial players of the current study have poor vertical jump height relative to other rugby players. However, the following should be considered:

- 1) Testing commenced at mid pre-season, and it would be expected that the volume of power training would have steadily progressed to the end of the pre-season. End of pre-season performances may therefore have been better than those achieved at mid pre-season.

- 2) The greater body mass of the players in the current study (particularly the forwards) compared to other club and national level players (discussed in section 5.2.2.1.) may have had a negative impact on their vertical jump height.

**Table 5.1. Vertical jump heights (centimeters) of national and provincial players.**

	Forwards		Backs
SA senior A players (current study)	54 cm		61 cm
English national players *	56 cm		66 cm
USA national squad #	59 cm		62 cm
NZ senior A club players \$	60 cm		63 cm
	P & L	LF & H	Backs
SA senior A players (current study)	52 cm	57 cm	61 cm
SA senior A provincial players+	59 cm	58 cm	64 cm

Abbreviations: cm, centimeters; \*, Hazeldine and Mc Nab (1991); #, Carlson et al. (1994); \$, Quarrie et al. (1995); +, Turnbull (1996); P, props; L, locks; LF; loose-forwards; H, hookers

The SA senior A provincial forwards were quicker over 30 m than NZ A club forwards (4.47 s vs 4.50 s), despite being 11.2 kg heavier, while the SA backs who were 4 kg heavier than their NZ counterparts were quicker by 0.21 s (4.09 s vs 4.30 s). With the SA players being both heavier and quicker, the SA forwards had greater momentum than the NZ senior A club players ( $747 \text{ kg.m.s}^{-1}$  vs  $654 \text{ kg.m.s}^{-1}$ ) as did the backs ( $619 \text{ kg.m.s}^{-1}$  vs  $573 \text{ kg.m.s}^{-1}$ ). When compared to English national level players the performances of the SA provincial players were slower over 30 m with English forwards recording 4.34 s (Hazeldine and McNab, 1991; Holmyard and Hazeldine, 1993) and backs 3.86 s and 3.90 s (Hazeldine and McNab, 1991; Holmyard and Hazeldine, 1993). The surface used for the English players was not described, but electronic timing was used (photo-electric cells) and players started 1 m behind the start line. The SA players started only 30 cm behind the start line and therefore had less of a rolling start which may account partly for their slower times compared to the English players. The greater body mass of the SA players may also account for their slower times.

The SA provincial backs were significantly quicker than the forwards, a finding consistent with most other studies on elite senior players (Quarrie et al., 1996; Holmyard and Hazeldine, 1993; Mayes and Thompson, 1995).

Speed over 35 m for the loose-forwards & hookers, and backs was similar to that of the SA provincial players in the study of Turnbull (1996). Assuming that a constant velocity was maintained over the 10 m interval between 30 m and 40 m

during the 40 m sprint it can be estimated that the 35 m speed times for loose-forwards & hookers, and backs of the current study were 4.90 s and 4.66 s compared to 4.96 s and 4.72 s for these categories in the study of Turnbull (1996). The props & locks of the current study were 0.07 s slower than those in Turnbull (1996) study, but this may have been due to their additional body mass (+ 7.0 kg). The players in the Turnbull (1996) study performed the sprint on a different surface (freshly cut grass) to the players of the current study, however the times between the two groups of SA senior A provincial players are similar. In the Turnbull (1996) study there were significant differences between all three positional categories, but in the current study although the props & locks were significantly slower than both loose-forwards & hookers, and backs, there was no significant difference between the latter two groups. Over 10 m the backs of the Turnbull (1996) study were 0.10 s faster and the props & locks 0.21 s slower than players in these respective categories in the current study.

The nature of the protocol selected for assessment of repeat sprint ability has varied considerably between studies and therefore makes comparisons between studies difficult. In the current study players covered on average between 100 m and 130 m per 30 s sprint and the entire test lasting about 6 minutes. The protocol is described in section 2.3.3. The SA provincial forwards covered significantly less distance than the backs. By comparison most RSA tests performed on rugby players have consisted of repeated sprints ( $\pm 8$  reps) of 35 m - 40 m each taking between 8 -10 s, and the entire test lasting about 4 minutes. Total sprint time and fatigue index have been used as indicators of repeat sprint ability. On such a test Mayes and Thompson (1995) found senior backs to have significantly shorter total sprint times than forwards but forwards did not have significantly different fatigue indexes from backs. A fatigue index was not calculated in the current study. Turnbull (1996) found significant differences on the index of total sprint time (8 x 35 m) between all three positional categories of props and locks, loose-forwards and hookers, and backs. Due to the differences in RSA tests administered to rugby players comparisons are difficult.

In summary the South African senior A provincial players of the current study were heavier than most other provincial and national players to which they could be compared, and the larger size of the South African players was most marked amongst the forwards.

The SA provincial players of the current study displayed de-differentiation of the physical performance attributes of aerobic capacity and speed between playing position categories when compared to the SA provincial players assessed in 1995. This finding may be attributable to the current expansive style of play, that has developed subsequent to 1995, which requires the loose-forwards & hookers and props & locks to have faster speed and greater aerobic capacity than previously considered adequate.

SA provincial players of the current study compared to national class players from 'world dominant' rugby nations do not have as great aerobic capacity, skeletal muscle strength, vertical jump height or speed. They are as fast as other SA provincial players Turnbull (1996) and faster than NZ A club players. Although their vertical jump height is poor relative to these two groups the momentum advantage of a greater body mass may outweigh the disadvantage the additional body mass may have on vertical jump height.

**5.3. A comparison of anthropometric and physical performance characteristics between senior A and U19 provincial rugby union players during the mid pre-season.**

The most significant finding of this part of the study was that compared to the senior players there was homogeneity of physical performance attributes between the playing position categories (forwards vs backs, and props & locks vs loose-forwards & hookers vs backs) amongst the U19 players.

Although the U19 forwards were heavier than the U19 backs (+ 23.3 kg,  $P < 0.01$ ) and had significantly greater absolute lower and upper body strength, could produce greater momentum over 10 m, 20 m, 30 m and 40 m sprint distances, and were slower over 40 m, there was generally not a significant difference in the mobility of the forwards compared to the backs. There were no significant differences between the two positional groups for aerobic capacity, repeat sprint ability, speed over 10 m, 20 m and 30 m, agility or vertical jump height. In contrast to the U19 players the senior forwards and backs, who had a similar body mass difference to the U19 players (23.7 kg,  $P < 0.01$ ), differed significantly on all the physical performance attributes mentioned above.

Most studies have described the physique and physical fitness attributes of rugby union players according to the playing positions of forwards and backs. Quarrie et al. (1995) administered a comprehensive test battery to NZ school and club players and found similar differences between the forwards and backs as was observed for the senior players in the current study. They found that the backs had significantly greater aerobic capacity, speed, agility, vertical jump height, and muscle endurance compared to the forwards, and attributed the performance differences to the significantly greater body mass of the forwards. They suggested that forwards were willing to compromise mobility for the greater momentum that a greater body mass enabled them to produce. Holmyard and Hazeldine (1993) and Mayes and Thompson (1995) found that national level (England) and elite senior and U21 (Wales) backline players were significantly quicker than forwards but that

they did not have significantly greater aerobic capacity than the forwards as assessed by the multistage shuttle run (Ramsbottom et al., 1988).

The homogeneity of physical performance attributes of the U19 players compared to the senior players was also evident when the U19 props & locks vs loose-forwards & hookers vs backs were compared to the senior players in these categories. Despite the body mass differences between the props and locks and the backs being similar for the two groups (28.3 kg for the U19 players,  $P < 0.01$ ; and 30.0 kg for the senior players,  $P < 0.01$ ) the physical performance profile for the U19 props & locks differed only for momentum and pull ups, whereas the senior props & locks, and backs differed significantly in aerobic capacity, repeat sprint ability, all tests of muscle endurance, 10 m, 20 m, 30 m and 40 m speed, momentum, vertical jump and agility. The senior props & locks in this study differed in their physical performance attributes from the backs to a similar extent to that found by Turnbull (1996). He found SA senior A provincial backline players to have significantly greater aerobic capacity, repeat sprint ability, muscle endurance, and speed compared to the props & locks.

There were no significant differences between the U19 props & locks and the U19 loose-forwards & hookers; yet amongst the senior players the props & locks were significantly heavier than the loose-forwards and less mobile, as the loose-forwards and hookers had significantly better repeat sprint ability, speed over 40m, upper body muscle endurance as assessed by pull ups, and agility. Turnbull (1996) found similar differences between senior loose-forwards & hookers, and props and locks with the former group having better abdominal / hip flexor muscle endurance, speed and repeat sprint ability.

The U19 loose-forwards & hookers and U19 backline players had similar mobility, despite the former being significantly heavier (17.4 kg,  $P < 0.01$ ). The margin of difference between the U19 loose-forwards & hookers, and the U19 backs was significantly less for the tests of mobility when compared to the margin of difference between these two positional categories in the senior age group. For the Welsh Rugby Union shuttle run test (WRUsrt) (which assessed repeat sprint

ability) the U19 loose-forwards & hookers ran 1 m further than the backs, whereas the senior loose-forwards & hookers ran 28 m less than the backs. For 20 m and 30 m speed the U 19 loose-forwards & hookers were only 0.01 s slower than the U 19 backs compared to the senior loose-forwards & backs being 0.12 s over 20 m and 0.23 s over 30 m slower than the senior backs. On the test of agility the U19 loose-forwards and hookers were quicker by 0.39 s compared to the backs, whilst amongst the senior players the loose-forwards & hookers were slower than the backs by 0.28 s. The physical performance attributes of the senior loose-forwards & hookers compared to the senior backs were not different, a finding in contrast to that of Tumbull (1996) who found that players in these two categories differed significantly with respect to aerobic capacity, repeat sprint ability and pull ups.

The homogeneity of physical performance characteristics may be attributable to the fact that the U19 players lack the body size associated with complete musculoskeletal maturity. In particular the U19 forwards do not have the absolute body mass of the senior forwards. The similarity in the body mass differences between the U19 forwards and backs, compared to the body mass difference between the senior forwards and backs seems to indicate that it is the absolute mass of the senior forward players that puts them at a disadvantage with respect to the fitness components of speed, agility and repeat sprint ability. However, in the current study the senior backs have significantly greater body mass than the U19 backs yet their mobility was not compromised. Furthermore, the U19 loose-forwards & hookers have greater body mass than the senior backs but the two groups have similar mobility, and as was identified in section 5.1. the U19 forwards were heavier than other elite junior players yet they tended to be faster over 30 m - 40 m sprint distances.

It therefore seems that it is absolute body mass rather than greater or additional body mass per se that adversely effects mobility. It may be that there is an inverse non-linear relationship between body mass and speed, and at an absolute body mass not characteristic of 17 to 18 year old elite rugby union players (probably in the range of 103 - 107 kg) speed and mobility is dramatically compromised. The

senior forwards were significantly older than the senior backs, therefore age may also have contributed to the compromised mobility of the senior forwards.

Alternatively, the homogeneity of physical performance attributes amongst the U19 players may be a reflection of these young players representing the "new breed" of players (forwards who can run and backs who can ruck and maul), selected to suit the modern expansive game in which speed and mobility amongst the forwards, particularly the loose-forwards is important. Although the senior players were also participating at a provincial level and participating in the more modern style of play the clear distinction between senior forwards and backs may be attributable to the fact that many had been playing provincial rugby for a number of years and their skills, technical and tactical knowledge may have been compensating for their more 'traditional' physical fitness profiles.

In 1996 Noakes and Du Plessis (1996) commented that rugby union needed to develop into a more flowing game in which the ball would be in play for much longer. This would enable rugby union to compete successfully with other football codes with respect to attracting players and spectators. They suggested that the modern game needed to be characterised by strategies (similar to those adopted by New Zealand and to some degree by South Africa during the 1995 World Cup) that encourage play to be stretched across the field.

Traditionally expansive play has been limited with the initial axis of attack being through the inside center and close to the scrum. In this zone, the opposition is forced to tackle front-on. This is a difficult tackle and increases the chances of retaining possession of the ball. By playing the ball wide, beyond the inside center, the attacking team take a greater risk in losing possession, because the attacking player (wing, or outside center) often loses control of the ball once being grounded by a tackle from the side. The wider the ball is played the longer it takes support players to arrive to assist in the ensuing maul (Noakes and Du Plessis, 1996).

To play the expansive game successfully, teams need to increase their chances of retaining possession when the ball is played beyond the first center. Noakes and Du Plessis (1996) identified that this could be achieved (and already was being achieved by NZ in the 1995 World Cup) by reducing the time it took for the supporting players, particularly the loose-forwards, to cross the field. In addition, ball retention could also be improved by charging the backline players who would be closest to the tackled player with the responsibility of retaining possession in the maul that would develop. To fulfill these new roles forwards needed to become more mobile, and the loose-forwards in particular needed to be pre-selected for their speed, and trained to sprint across the field. The backs needed to take on some of the physical characteristics of the loose-forwards so that they could be effective in rucks and mauls. Essentially, the expansive game of modern rugby requires the de-differentiation of body types and physical performance attributes usually associated with forwards and backs (Noakes and Du Plessis, 1996).

The most significant finding when comparing the senior and U19 forwards and backs was that the U19 forwards had significantly better mobility compared to their senior counterparts, whilst the mobility of the U19 and senior backline players was similar. The senior backs had similar speed, agility and repeat sprint ability to the U19 players, whereas the senior forwards had significantly less speed and agility, and covered significantly less distance on the repeat sprint test compared to the U19 forwards.

Although the compromised mobility of senior forwards may have been due to their greater body mass compared to the U19 players, it is interesting to note that compared to the U19 players both the senior forwards and backs are both heavier in body mass (+ 11.8 kg,  $P < 0.01$  for the forwards; and +11.4 kg,  $P < 0.01$ ) for the backs) and muscle mass (+ 7 kg,  $P < 0.01$  for the forwards, + 8 kg,  $P < 0.01$  for the backs) by a similar margin. If the mobility of the senior forwards is compromised by additional weight, intuitively one would have expected that the mobility of the senior backline players would also be adversely effected by their greater body mass. As explained earlier, it is perhaps the absolute weight of the senior forwards combined with their greater age that adversely effects their

mobility. An alternative explanation is that the U19 forwards have been selected specifically for their mobility.

By further differentiating the forwards into the playing positional categories of props & locks, and loose-forwards & hookers, it was found that there were no significant differences in the physical performance characteristics between the following groups: the U19 loose-forwards & hookers and the senior backs, the U19 props & locks and the senior loose-forwards & hookers, and the U19 loose-forwards & hookers and the senior loose-forwards & hookers.

Although the U19 loose-forwards & hookers tended to be 6 kilograms heavier than the senior backs, they were equally as mobile as the senior backs. This observation is based on the fact that compared to the senior backs the U19 loose-forwards & hookers ran 1 m further on the WRUsrt, 0.04 s faster over 10 m, 0.01 s slower over 20 m, 0.06 s slower over 30 m, 0.03 s slower over 40 m, and 0.16 s faster on the agility T test.

Although the senior loose-forwards & hookers were 9.6 kg greater in body mass and had 7.1 mm less subcutaneous adipose tissue than the U19 loose-forwards & hookers, the only significant differences in body composition between the senior and U19 players was the 7.8 kg greater muscle mass of the senior players. There were no significant differences in the physical performance attributes of senior and U19 players in the loose-forwards & hookers category.

The U19 props and locks had speed and agility that was more similar to that of the senior loose-forwards & hookers than to the senior props & locks. An important finding was that the U19 props & locks had significantly better repeat sprint ability than the senior props & locks, as they covered 44 m more on the WRUsrt than the senior props and locks, and only 3 m less than senior loose-forwards and hookers. The body mass difference between the U19 props and locks and the senior loose-forwards and hookers was 1.3 kg.

The category in which there were the most significant differences in the physical performance characteristics of the U19 and senior players was that of the backs. The backs had significantly greater upper and lower body strength (absolute), muscle endurance (push ups and sit ups), and momentum over 10 m, 20 m, 30 m, and 40 m.

Quarrie et al. (1995) identified momentum as an important attribute required for rugby. Momentum is a vector quantity, and if two players are moving toward one another at an identical pace (velocity) and collide, as in a rugby tackle, the change in their respective velocities will be inversely proportional to their body mass. After impact the players will tend to move in the direction in which the player with the greater mass was traveling before impact. Thus the greater speed that players with higher body mass can obtain is an advantage in all rugby body contact situations such as tackles, scrums, rucks and mauls (Quarrie et al. 1995).

Consistent with the current study, Quarrie et al. (1995) found forwards to have greater momentum than backs. However, when comparing seniors to U21 and U19 players Quarrie et al. (1995) grouped the forwards and backs, and found that senior players were able to produce greater momentum over 30 m compared to the U21 and U19 players. As there were no significant differences between the age groups with respect to speed, he attributed the significantly greater momentum of the seniors compared to the U21's and the U21's compared to the U19/18's to the significant differences in body mass between the age groups. In the current study senior props & locks, loose-forwards & hookers, and backs were able to produce greater momentum than the U19 players in these playing categories. The younger forwards negated the body mass advantage of the senior players (13.5 kg,  $P < 0.01$  for the props & locks and 9.6 kg, for the loose-forwards & hookers) by being quicker over 10 m, 20 m, 30 m, and 40 m than their senior counterparts. However, only amongst the backs was the difference in momentum statistically significant. The senior backs were able to generate significantly greater momentum than the U19 backs as their speed was almost identical to that of the U19 players (both scored 1.78 s for 10 m, and 5.23 s for 40 m) and their body mass was significantly greater.

With respect to skeletal muscle strength, there were no significant differences in absolute or relative upper and lower body strength between the three positional categories of props and locks, loose-forwards and hookers, and backs within either the U19 squad or the senior players. This lack of difference in absolute strength occurred despite the fact that there were significant differences in body mass between these three groups in the senior players, and between two groups within the U19 squad (namely between the backs and the loose-forwards & hookers, and between the backs and props & locks). The U19 backs had significantly less absolute upper and lower body strength when compared to all the senior positional categories (and were significantly lighter in body mass), yet they did not differ to the seniors with respect to relative muscle strength. The only significant difference in muscle strength between the U19 props and locks and the senior players was their absolute leg strength, whilst the U19 loose-forwards and hookers did not differ significantly from any of the senior categories with respect to measures of muscle strength. The seniors performed better than the U19's in 1 RM leg press by 33 kg for the loose-forwards & hookers, 99 kg ( $P < 0.01$ ) for the backs and 110 kg ( $P < 0.01$ ) for the props & locks. For 1 RM bench press the senior loose-forwards & hookers lifted 13 kg more than the U19's while the senior backs lifted 20 kg ( $P < 0.05$ ) and the senior props & locks 18 kg more than their U19 positional counterparts.

Mayes and Nuttall (1995) compared the body mass, body fat and physical performance variables of elite Welsh U21 and senior players. Players were not differentiated into groups relative to playing position and it was found that the senior players were heavier and had greater upper body strength when compared to the U21 players. The two groups of players did not differ with respect to body fat, aerobic capacity or vertical jump. Although in the current study seniors did not differ with respect to the U19 players with respect to body fat and aerobic capacity, the magnitude of difference in vertical jump height and upper body strength differed according to position of play. For instance the U19 and senior backline players differed with respect to upper body strength, but the U19 vs senior loose-forwards & hookers, and props & locks did not differ significantly in upper body strength. Compared to the study by Mayes and Nuttall (1995) the categorization of

players in the current study has the advantage of providing useful 'playing position specific' information with respect to the differences in body mass, body composition and physical performance attributes between junior and senior players.

In summary, the U19 loose-forwards & hookers have greater absolute and relative strength than the U19 props & locks, and U19 backs. Furthermore, compared to the U19 props & locks and U19 backs the U19 loose-forwards & hookers have muscle strength that is more closely matched to their senior positional counterparts. The vertical jump of the U19 players is similar to that of the senior players for the props & locks, and the loose-forwards & hookers, but the senior backs tended to have greater vertical jump height than the U19 players (ANOVA analysis).

There were no significant differences between the aerobic capacity and repeat sprint ability of the U19 loose-forwards & hookers, and backs compared to their senior positional counterparts. As has been previously mentioned the U19 props & locks had significantly greater repeat sprint ability than the senior props & locks, despite there being no significant differences with respect to speed and aerobic fitness between the two groups. The U19 props & locks tended to be quicker over all the sprint distances.

The muscle endurance test in which there was the greatest performance difference between positional categories was that of pull ups. For pull ups the senior and U19 backs, and senior and U19 loose-forwards & hookers performed significantly better than the senior props & locks; and the U19 and senior backs performed significantly better than the U19 props & locks. An important consequence of this finding is that although it may be realistic to expect all three positional categories to perform equally well on the push ups, and sit up tests, it is unrealistic to set similar targets on the pull ups test for the props and locks as for the other two positional categories due to the influence of body weight on the performance of pull ups.

Both the U19 forwards and backs were more flexible than their senior counterparts. This finding may be due to the significant difference in age between the players, or alternatively flexibility may decrease as a function of the number of years spent playing rugby. Senior players should therefore pay particular attention to stretching techniques aimed at maintaining flexibility.

Some important observations from the comparisons between the U19 and senior players between positional categories and within the same positional category included:

1) The U19 loose-forwards & hookers were not significantly different from the senior loose-forwards & hookers with respect to body size, mobility, and muscle strength. They had greater absolute strength than the U19 props & locks despite being 10 kg lighter in body mass and having 5.2 kg less muscle. In addition, they were almost identical in their attributes of speed, repeat sprint ability and agility to the senior backline players. This finding suggests that at a body mass of 92 kilograms mobility need not be compromised.

This finding has important implications for senior backs wanting to take on the physical characteristics of the loose-forwards so as to effectively assume the responsibilities of rucking and mauling required in the modern expansive style of play. Backline players could probably afford to increase their body mass to about 92 kg, (provided weight gain is due to increases predominately in skeletal muscle mass) without adversely affecting their sprint ability. In addition, selectors should also be aware that players with larger physiques may not have compromised speed due to their size. Backline players who could increase their body mass and retain their speed would substantially increase their momentum. With the modern backline player having to be more active in the mauls and having to retain possession of the ball for longer, momentum has become a more important component of their physical performance profile than traditionally has been the case. However, as players increase their body mass it is suggested that they be monitored to detect any decrements in speed. In this way body mass and speed can be monitored in such a way that momentum is optimised.

Based on these findings it appears that the U19 loose-forwards & hookers, with respect to their body composition and physical performance attributes, represent the players most adapted to advance to more senior levels of play.

2) The U19 backs, although as mobile, lacked the strength and power of their senior counterparts. They were lighter, had less absolute upper body and lower body skeletal muscle strength, had less momentum over 10 m, 20 m and 30 m, and tended to be poorer with respect to vertical jump height. Speed and agility have traditionally been considered the distinguishing physical attribute of the backs. However, to play the modern more expansive game backs now need to display greater strength and power on the field. They need to be able to tackle, be effective in rucks and mauls and have the strength to fend off attackers when running down the wing and thereby retain the ball for longer. Considering these changes to the role and responsibilities of the backline player, it appears that the U19 backline players do not possess the physical attributes to be considered for more senior ranks of play at the same proficiency level (provincial).

The practical implication is that team selectors must consider the player's size, strength and general physical presence on the field, and not only mobility, speed, and skill when considering a younger backline player for a place in more senior team. In addition backline players who have relied on their attributes of speed and skill during their prepubescent years to excel in rugby union should participate in a strength training programme during their adolescent years. This will ensure that their rate of progression to more senior ranks of play is not delayed due to poor skeletal muscle strength and development.

On the basis of the observations discussed in 1 and 2 an additional practical recommendation is that schoolboy playing loose-forwards are taught the skills of backline play. In this way these players who are as mobile as senior backline players could move to the backline on entering senior level of play. This could be particularly important for smaller loose-forward players unable to succeed as elite loose-forwards at senior level. Considering that the junior loose-forwards are

heavier than the senior backline players and have been drilled in skills of tackling required by the forwards, they have the potential to improve ball retention in the outer field of play which is critical to the success of the expansive style of play. These mobile and skilled loose-forwards can then serve as a pool of players from which selectors can replace those junior backline players who are too small to play at an elite senior or international level.

3) The U19 props & locks although having significantly less body mass and absolute lower body strength than the senior props & locks, did not differ significantly in terms of momentum due to their better speed. They were similar to senior loose-forwards & hookers with respect to their repeat sprint ability despite tending to be slightly slower on the 40m sprints and not completing as many shuttles on the multistage shuttle run. Accordingly they had better repeat sprint ability relative to their speed, aerobic capacity and body mass (although age difference may have been to the U19's advantage).

In conclusion, in contrast to the senior players there was lack of evidence of differentiation of physical performance attributes between the playing position categories and relative to the U19 players, the senior forwards had compromised mobility which was not found in the senior backline players. Until the U19 players are playing in the senior ranks and have reached physical maturity, it cannot be determined whether the homogeneity of physical performance characteristics exhibited by the U19 players was a function of selection for the modern style of play or whether it was due to their not having completed the final stages of musculoskeletal development (specifically in body mass), or a combination of both.

**5.4. Changes in body composition and physical performance characteristics following the prescription of an unsupervised seven week off-season and early pre-season training programme.**

**5.4.1. Introduction**

The SA U19, SA U21 and SA Development teams participate in a comprehensive programme of anthropometric and physical performance assessments bi-annually, and at each assessment session players receive a training programme specific to the phase of the season. Due to the geographical spread of the players and financial constraints it is impossible to provide training supervision for these players. Although the training programme initially involves a large educational component including practical weight training workshops, it has been debated as to how effective these unsupervised training programmes are. Based on this background, this study was performed to give an indication as to the extent an unsupervised training programme can be successfully implemented with respect to enhancing body composition and physical performance characteristics of elite U19 rugby union players.

**5.4.2. Changes in body composition and physical performance attributes**

The 7 week unsupervised off-season and early pre-season training period had the desired effect of concurrently increasing the general athletic fitness components of skeletal muscle strength, skeletal muscle endurance, aerobic capacity and flexibility. In addition the sports-specific athletic fitness components of speed (acceleration over 10 m), agility, and repeat sprint ability improved significantly during the training period. No changes occurred in body mass, subcutaneous body fat, speed over 20 m, 30 m and 40 m or vertical jump height.

The prescribed training programme was designed according to the guidelines of Kibler and Chandler (1994) for the development of optimal sport-specific conditioning. The U19 players were initially assessed toward the end of the off-season, about nine weeks before the SA selection trials. Therefore, the off -

season programme comprised of only two weeks of training aimed to promote the development primarily of aerobic capacity, skeletal muscle strength and endurance, and flexibility (general athletic fitness components). This was followed by five weeks of early pre-season training which aimed to introduce training methods to promote the development of sport specific athletic fitness (speed, repeat sprint ability, power, and agility). The programme aimed to induce adaptations of the musculoskeletal system to prepare the players for intensive participation in sprint training, high intensity aerobic interval training, high velocity weight training and plyometrics. To promote further development of player's skeletal muscle strength, the volume of weight training was reduced and the intensity increased during the pre-season phase.

Physical fitness is one of a number of components, including tactics and skills, that contribute to rugby performance. The relevance of the positive adaptive responses to the prescribed programme relate to the contribution that the improvements in aerobic capacity, skeletal muscle strength and endurance, flexibility, repeat sprint ability, acceleration, and agility will make to enhancing playing performance on the field.

#### **5.4.3. Compatibility of weight training and cardiorespiratory endurance training**

Off and early pre-season training for rugby requires simultaneous training for skeletal muscle strength and cardiovascular endurance (Kibler and Chandler, 1994). Whilst some studies have reported that concurrent training of the skeletal muscle strength and aerobic capacity impairs the development of skeletal muscle strength (Fleck and Kraemer, 1997; Dudley and Djamil, 1985), other studies have reported that combined training can induce substantial concurrent and compatible increase in aerobic capacity and skeletal muscle strength (Sale et al., 1990; McCarthy et al., 1995).

The results of the study of McCarthy et al. (1995) showed that weight training and aerobic training for 50 minutes at an intensity of 70 % of heart rate reserve

performed on alternate days, 3 times a week, did not interfere with both skeletal muscle strength and aerobic capacity development when compared to strength training or aerobic training alone. The programme design of the current study was similar to that of McCarthy et al. (1995) during the two week off-season period, but during the 5 week early pre-season period it differed in that the aerobic exercise included high intensity intermittent running twice a week.

The U19 players did not improve to the same order of magnitude as the subjects in the study of McCarthy et al. (1995) with respect to aerobic capacity (8 % vs 16 %), 1RM bench press (8 % vs 18 %) and 1RM leg press (13 % vs 22 %). A possible explanation for the SA U19 players not improving to as great an extent as the subjects in the study of McCarthy et al. (1995) study may be that the subjects in the current study were elite rugby players as opposed to sedentary subjects, and that 70 % of the players acknowledged to having previously participated in weight training. In addition the differences in duration of the studies (7 weeks vs 10 weeks) may account for the greater improvements shown by the subjects in the McCarthy et al. (1995) study.

During the off and early pre-season period rugby players frequently report feeling overtrained. These players present with typical overuse musculoskeletal injuries and / or feel lethargic, 'heavy legged' and exhausted. There is a tendency for physical fitness trainers to attempt to combine high volumes of both weight and aerobic training (usually in the form of running sessions) during this period as players have more time available for fitness training compared to later in the pre-season and during the season. Fleck and Kraemer (1997) suggest that overtraining may have been the ultimate cause of incompatibility of concurrent weight and endurance training reported by Hickson (1980) as cited in Fleck and Kraemer (1997) and Dudley and Djamil (1985).

The findings of the current study suggest the volume of training included in the prescribed training programme allowed for concurrent significant improvements in both skeletal muscle strength and aerobic capacity. It cannot be discounted that in the current study aerobic training did not interfere with the extent of adaptation to

weight training. However, performances during the physical tests indicated that players had a positive adaptive response to the stresses imposed by participation in the prescribed training programme, and did not suggest that players were overtrained.

#### **5.4.4. Comparative analysis of adaptive responses to off- and pre-season fitness training for rugby players**

Body mass of the SA U19 players did not change over the training period. Although this finding is in agreement with that of Tong and Mayes (1995) it contrasts with that of Turnbull (1996) and Clark (1998). Tong and Mayes (1995) and Clark (1998) both reported body fat decreased significantly after players followed a 12 week pre-season programme, Turnbull (1996) reported small but significant decreases in body fat over an 8 week off-season training programme, and Holmyard and Hazeldine (1993) reported that English national players experienced largest falls in percentage body fat during the off-season (April - September) and the first half of the playing season (September - January).

It is not known why the SA U19 players did not decrease their body fat over the training period, especially considering that the volume of aerobic training was similar to that prescribed by Turnbull (1996) and that players received nutritional counseling and individual eating plans at the initial testing session.

The lack of change in body mass and body fat indicate that muscle hypertrophy did not occur in response to weight training and furthermore suggest that the 8 % upper and 13 % lower body strength gains were possibly neurally mediated. These strength gains fall toward the low end of the range of increases reported by strength training studies. Increases in 1RM bench press strength range from 44 % in 12 weeks to 8 % in 10 weeks, and increases in 1RM leg press strength range from 71 % in 12 weeks to 7 % in 10 weeks (Fleck and Kraemer, 1997). The wide range of increases in strength is probably caused by a combination of factors including differences in frequency, volume and intensity of weight training prescribed, subjects pretraining status, and familiarity with the exercise tests.

Of the studies that have reported changes in physical performance characteristics after participation in an off and / or pre-season training programme, only Clark (1998) has reported on changes in skeletal muscle strength. Increases in 1RM bench press strength were significantly greater amongst elite high school rugby players who participated in either a supervised (14 %) or unsupervised (15 %) training programme compared to those who did not (4 %). Increases in 1RM leg press strength were 8 %, 17 %, and 1 % for the supervised, unsupervised and control groups respectively, with the only unsupervised training group improving to a significantly greater extent than the control group. Although Clark (1998) found that players who did not participate in a prescribed training programme improved significantly in 1RM leg and bench press strength, the magnitude of improvement was greater amongst SA U19 players of the current study (bench press: 8 vs 4 %, and leg press: 13 % vs 1 %).

Compared to the SA U19 provincial players of the current study, the high school rugby players in the study of Clark (1998), who participated in either an unsupervised or supervised 12 week training programme, had greater increases in skeletal muscle strength (Table 5.4.).

**Table 5.4. Percentage increases in 1RM bench and leg press strength.**

1RM Exercise	SA U19 provincial players (7 week training programme)	Elite SA Std 9 high school players (12 week training programme)	
		Supervised	Unsupervised
Bench press	8 %	15 %	14 %
Leg press	13 %	8 %	17 %

Abbreviations: 1RM, one repetition maximum; SA, South Africa; Std, standard; %, percentage

Possible reasons for the greater adaptive response of elite SA high school include:

- I. 70 % of the SA U19 provincial players reported that they had previous weight training experience. The SA players may have had greater weight training experience than the SA high school players and this may have attenuated the SA U19 players adaptive response to weight training relative to the high school players,

- II. The training period of the players in the current study was 5 weeks shorter than that of the training period of the Clark (1998) study,
- III. The players in the Clark (1995) study completed fewer aerobic training sessions than the SA U19 players. The higher volume of aerobic training completed by the SA U19 players may have 'blunted' their adaptive response to weight training.

Upper body, and abdominal and hip flexor skeletal muscle endurance improved significantly over the training period. The number of pull ups, push ups and sit ups that players could complete after the seven week training programme increased by 30 %, 13 %, and 22 % respectively. After a 12 week training programme the elite high school rugby players of the Clark (1998) study had greater increases in a push ups test compared to the SA U19 players (32 % increase for the supervised group and 51 % increase for the unsupervised training group). However, this may have been due to the nature of the muscular endurance test. The players in the Clark (1995) study had to perform a maximum number of push ups at a set pace, whilst those in the current study had to perform a maximum number in a limited time (1 minute). In contrast to the SA U19 players the elite high school players did not improve with respect to performance on the sit up test. The 22 % improvement by the SA U19 players on the sit up test compared to the 9 % improvement by SA senior provincial players (after an 8 week off-season programme) (Turnbull , 1996) may be attributable to the protocol. The senior players only had 1 minute in which to complete as many sit ups as possible, whereas the SA U19 players had a longer time limit of 2 minutes - therefore greater scope for improvement. The pull ups protocol was identical for both groups of players and the SA U19 players improved to a far greater extent than the SA senior provincial players (30 % vs 9%).

The U19 rugby player's 8 % improvement in aerobic capacity related to an increase in 14 shuttles completed during the multistage shuttle run (players increased from a level 11 shuttle 2 to a level 12 shuttle 4). This improvement compares favorably with the findings that SA senior provincial rugby players improved their aerobic capacity (relative maximal oxygen uptake estimated from

the Coopers 12 minute run) by 5 % over an 8 week off-season training period, and by a further 6 % during a 4 week pre-season training period (Turnbull, 1996). The off and pre-season programmes prescribed by Turnbull (1996) were similar in structure to those of the current study. The 8 % improvement by the SA U19 players during the 7 week off and early pre-season training period was comparable to the 12 % improvement made by the SA provincial rugby players over a 12 week off and pre-season training period (Turnbull, 1996).

Clark (1998) reported that peak power output and predicted absolute maximal oxygen uptake ( $VO_{2max}$ ) increased significantly amongst elite high school rugby players after a 12 week training period.  $VO_{2max}$  improved by 5 % in the unsupervised training group, and 3 % in the supervised training group. The differences in improvement were not significant, but the greater increase shown by the unsupervised training group may have been due to the latter group having completed 16 aerobic training runs during the 12 week period compared to the unsupervised group who completed on average only 9 training runs over the training period. The greater improvement in aerobic capacity demonstrated by the rugby players in the current study may be attributable to a combination of factors. Although no data on the number of training runs completed by the U19 players were recorded, the players were prescribed 3 - 4 running sessions a week compared to Clark (1998) having prescribed only 2 sessions a week. A greater number of training runs may therefore have been completed by the SA U19 players over the 7 week training period compared to the high schools players over a 12 week training period. An alternative explanation may be lack of specificity in the testing and training modes of aerobic capacity in the study of Clark (1995). The players in the Clark (1998) study performed a maximal aerobic test on a cycle ergometer, whilst their aerobic training consisted of running, whereas, in the current study testing and training both involved running.

The SA U19 players also improved their aerobic capacity to a greater extent than players from the Welsh senior squad after following a 12 week pre-season training programme. No details are provided as to the frequency and intensity of aerobic training study. However, only the backline players improved on the multistage

shuttle run test increasing their predicted  $VO_{2max}$  by 3 %, equating to players running on average 6 shuttles further during the multistage shuttle run test. The Welsh forwards did not improve their aerobic capacity and on average ran only 2 shuttles further after the 12 week training period.

Flexibility was an important component of the training programme prescribed for the SA U19 players. The significant 33 % improvement in hamstring flexibility achieved by the players in the current study was greater than the 9 % improvement achieved by the senior provincial players of Tumbull's (1996) study. The players participating in the studies of Clark (1998) and Tong and Mayes (1995) did not improve hamstring flexibility over a 12 week training period during which flexibility exercises were performed. The only reason that may be suggested for the greater improvement in the SA U19 players flexibility (distance reached on the sit and reach test) after training, relates to the educational component of the initial testing session at the Sports Science Institute of South Africa. During lectures and practical sessions on stretching, players were informed that lack of hamstring flexibility was related to hamstring muscle tightness. This may have had a positive effect on increasing the players' participation in the prescribed stretching routine.

The early pre-season programme, although primarily designed to continue the development of skeletal muscle strength and aerobic capacity, did incorporate low volumes of sports specific training modes including sprint training, high intensity aerobic interval training, high velocity weight training and plyometrics. The early pre-season aimed to prepare the player's musculoskeletal system for more intensive participation in sports specific training modes.

Significant increases in 10 m speed (2 %), repeat sprint ability (5 %) and agility (3%) occurred by the end of the seven week training period. Although the low volumes of sport - specific conditioning introduced during the third week of the training may account for these adaptations, the improvements in the components of general athletic fitness may have contributed to the improvements in speed,

repeat sprint ability and agility. Significant changes did not occur in vertical jump height and speed of 20 m, 30 m and 40 m.

Contrasting reports with respect to both changes in speed and vertical jump performance following participation in an off-season and / or pre-season training programme. Turnbull (1996) found vertical jump height to improve significantly after participation in both off and pre-season training programmes. Clark (1998) found that the vertical jump height decreased significantly in the supervised training group of high school rugby players whilst the unsupervised training group improved significantly. Mayes and Tong (1995) found vertical jump height to decrease after Welsh senior players had participated in a 12 week pre-season training programme. The power training included in the early pre-season programme was low in volume and intensity, and may account for the lack of improvement in vertical jump height in the current study.

The improvement in 10 m speed (acceleration) by the players in the current study was consistent with the findings of Turnbull (1996). The senior provincial players of the Turnbull (1996) study improved their speed over 10 m during the 4 week pre-season training period. In contrast to the findings in this study speed over 35 m and distance covered in 6 seconds (45 - 48 m) improved significantly in the studies of Turnbull et al. (1996) and Clark et al. (1998).

#### **5.4.5. Limitations to the training intervention component of the study**

It is acknowledged that the interpretation of the improvements in the general and sport specific fitness components and their relationship to the prescribed training programme is limited for the following reasons:

1. Lack of an adequate control group: To accurately assess the efficacy of the training programme this section of the study should ideally have incorporated a control group. However, no control group was assessed due to the difficulty in finding a valid control group for this experimental group of elite provincial U19 players.

2. Documentation of previous weight training experience: Although 70 % of the players acknowledged that during the individual consultations that they had participated in weight training previously, the extent of previous weight training experience was not quantified. Previous weight training experience attenuates the extent of skeletal muscle strength gains after a weight training programme when compared to novice participants (Hetzler et al.; 1997; Fleck and Kraemer, 1997).

3. Quantification of training: Thirty one of the players were felt to have participated in the programme to a satisfactory level. The players cited factors such as the unavailability of certain pieces of gym equipment, transport problems, acute injury, time constraints and illness influencing the extent to which they adhered to the training programme. Two players, although having completed the prescribed running sessions and muscular endurance exercises admitted to not having participated in weight training. Unfortunately training diaries were not kept by the players, therefore objective quantification of participation in the training programme cannot be reported. However, all players were included in the statistical analysis regardless of the extent to which they participated in the training programme.

4. Motivation: All the players in the study were aspiring to be selected to represent their country at the World U19 Rugby Union Cup. How this goal influenced their participation in the unsupervised training programme cannot be quantified, but it is reasonable to assume that this contributed positively to the players' commitment to adhering to the training programme.

5. Education and practical instruction: An important aspect of the initial training camp was educating the players about the benefits of weight training, and how to progress the prescribed weight training programmes according to their individual rates of adaptation. Instruction for both flexibility and weight training was both verbal and practical, and prior to leaving the training camp all players could correctly execute all the prescribed exercises.

6. Dietary intervention and nutritional supplementation: An eating plan was prescribed for each player by a registered dietitian based on an individual dietary assessment. The extent to which the modifications of their eating patterns influenced the adaptations to training cannot be quantified. Although it is presumed players were not using anabolic steroids, the possibility of this cannot be discounted. The extent to which the use of other ergogenic aids, including creatine (Balsom et al. 1993), contributed to the improvements in skeletal muscle strength also cannot be quantified.

In summary, despite these limitations some important conclusions can be made. Firstly, skeletal muscle strength and endurance, aerobic capacity, flexibility, acceleration, agility and repeat sprint ability all influence players performance on the rugby field, and it is reasonable to assume therefore that the improvements in these physical performance attributes of the SA U19 players would have translated to an enhanced performance on the field.

On the basis of the finding that this programme had the desired effect of concurrently enhancing skeletal muscle strength and aerobic capacity, it therefore can be recommended for use by coaches and trainers who are structuring off and early pre-season conditioning programmes for their rugby players.

The magnitude of strength gains experienced by the players in this study were not as great as those found by McCarthy et al. (1995) and Clark (1998). Smaller increases in strength may have been due to differences in weight training experience prior to the training period, and or the shorter duration of the training period. However, the greater aerobic training load combined with the weight training in this study may have 'blunted' the adaptive response to the weight training.

Further training studies that manipulate the intensity, duration, and frequency of simultaneous weight and aerobic training for the enhancement of fitness for rugby performance should to be performed to determine the optimal loads required to bring about optimal adaptive responses.

## **6. SUMMARY AND CONCLUSIONS**

The anthropometric and physical performance assessments of the SA U19 provincial players and the SA senior A provincial players contribute to the scientific understanding of the 'modern' game with respect to its physical demands, and optimal conditioning of players. The important findings of the descriptive, comparative and intervention studies of this thesis are summarized below.

The first study of the thesis found that body mass was the distinguishing characteristic differentiating elite high school players from those players participating in rugby union at a provincial and national team level. The SA U19 players were 12.6 kg heavier than elite SA high school players and 9 kg heavier than U19/18 players in New Zealand. This important finding highlights the contribution body mass makes to playing performance on the field. The SA U19 provincial players were similar in most components of physical performance to elite junior players from other 'world dominant' rugby nations including Australia, New Zealand and Wales.

Important findings from the second study of the thesis included that the SA senior A provincial players had greater body mass than the English, Welsh, and American national players, and this was most prominent amongst the forwards. The SA senior A provincial players tended to perform below the standard of national English, Welsh, and Australian players with respect to aerobic capacity, skeletal muscle strength, vertical jump height and speed. Compared to New Zealand club players the SA senior A provincial players had greater speed and momentum. The greater body mass of the SA senior A players of the current study, in particular the forwards, may account for the poor vertical jump height they achieved relative to SA provincial players assessed in 1995, national level players (Australian, English, Welsh) and club level players (New Zealand).

A further important finding was that the senior A provincial players displayed de-differentiation with respect to the physical performance attributes of aerobic capacity and speed when compared to SA provincial players assessed in 1995.

This finding may be attributable to the current expansive style of play that has developed subsequent to 1995, which requires the loose-forwards & hookers and the props & locks to have greater speed and aerobic capacity than was previously considered adequate.

The third study of the thesis compared the body composition and physical performance attributes of the SA U19 provincial players and the senior A provincial players. Compared to the senior players, there was homogeneity of physical performance attributes amongst the U19 players. Assuming that physical fitness components of aerobic capacity, repeat sprint ability, speed and agility reflect mobility of players on the field, it was found that the mobility of the senior backline players was greater than that of the forwards. This contrasted with the finding that amongst the U19 players' mobility was not different between the forward and backline players. The lack of difference in mobility between the U19 forwards and backs may be attributable to the greater absolute body mass of the senior players. The body mass difference between both the senior forwards and backs, and the U19 forwards and backs was 23 kg compared to the U19 players. Alternatively, it may be a function of selection for the current expansive style of play.

The U19 and senior loose-forwards & hookers were not significantly different with respect to any anthropometric or physical performance attributes. In contrast, significant differences were found between the U19 and senior backline players. Although players from the two age groups had similar mobility, the senior backs were significantly heavier, stronger and more powerful than the U19 backs. Based on these findings it is reasonable to suggest that the U19 loose-forwards & hookers are most physically adapted to advance to more senior levels of play of the same proficiency (provincial). The U19 backs perhaps need to substantially increase their body mass, strength and power before successfully progressing to a senior provincial standard of play. A practical implication of the above finding is that the junior forwards, particularly the loose-forwards are taught the skills of backline play. These players will then be able to move to the backline as replacements for junior backs who lack the body mass and physical performance attributes required for elite senior and national level of play.

The final study of this thesis was performed to assess the efficacy of prescribing a 7 week unsupervised off-and early pre-season training programme to junior players. The programme had the desired effect of concurrently increasing skeletal muscle strength and aerobic capacity. In addition, the player' s flexibility, speed over 10 m (acceleration), agility and repeat sprint ability improved significantly over the training period. The programme therefore resulted in adaptations in physical performance attributes that are associated with improved rugby performance. The training programme did not have a measurable effect on body mass and body fat, or the physical fitness components of vertical jump height and speed over distances greater than 10 m.

In conclusion, the comparative section of this study (U19 vs senior) shows how the changing nature of the game and the its demands on the players may be reflected in body composition and physical performance attributes of players. An important observation was that speed was not compromised amongst U19 loose-forwards & hookers when compared to the senior backs, despite being 6 kg heavier than the senior backs. This finding suggests that senior backs could afford to increase their body mass and thereby momentum without compromising their speed. The relationship between body mass and speed in rugby players is an area requiring further scientific investigation.

The finding that the unsupervised training study did not result in the magnitude of skeletal muscle strength gains reported by researchers including Clark (1998) and McCarthy et al. (1995) suggests the need for further training studies. Studies that manipulate the intensity, duration, and frequency of simultaneous weight and aerobic training for the enhancement of fitness for rugby performance should be performed to determine the optimal loads required to bring about optimal adaptive responses.

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## 8. APPENDIX

### 8.1 Appendix A: Training programme

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#### RESISTANCE AND POWER TRAINING GUIDELINES

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- Resistance training is essential to set up a base on which to perform power training.
- Use free weights in preference to machines.
- Progressive overload is essential. If you have no previous experience with weight training or if you are beginning weight training for the first time this year, then use your first week as an introduction only completing one set of each exercise in the first week, in your second week (2 sets) and in your third week (3 sets). Do this to avoid injury.
- Do not perform two hard training sessions involving the same muscle groups within 24 hours. Muscles may need up to 48 hours to recover from a hard workout.
- Always complete a warm up set using 50% of the weight you intend to lift.
- If a specific exercise causes pain then immediately decrease the amount of weight you are using, if this is not successful then give the exercises a skip for one week. If the pain is still present after one week when retrying the exercise, then leave that specific exercise out of your routine. If possible ask the team trainer for an alternative (pain free) exercise that works the same muscle group.
- Complete the special back programme 2 - 3 times a week

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#### OFF-SEASON

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- Gym training 4x a week.
- Emphasis on base strength using the low intensity high volume principle (hypertrophy).
- Time to complete core and supplementary exercises.
- Core exercises are usually multijoint movements that recruit a large amount of muscle mass when executed.

The following exercises according to this programme are classified as core exercises:

Bench press, incline or pulley row, squat, power clean and shoulder press
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These core exercises should be performed all year round.

- Exercises not listed above are classified as supplementary exercises.
- Generally exercises in the off- season are started using 3 sets of 12 repetitions. This allows the individual to progressively begin their off-season training. A recent study has shown that a relatively high volume (e.g. 3 x 12) load used during the initial phase of training is successful in producing maximal strength gains in moderately trained subjects. This phase should last 4-6 weeks depending on the seasonal time restraints. Volume is important in this phase!

How heavy should your weights be?

The number of reps, determines how heavy the weight should be.

If 3 x 12 are prescribed then you first complete a warm up set at 50% of the weight you would normally use. Then you begin your first set.

In the first set you must be able to just reach 12 reps, in the second set 10-12 reps and in third set 8-10 reps.

On your last set if you can't reach 8 reps then the weight you have chosen is too heavy, if you can do more than 12 reps then the weight is too light.

- How long should my rest period between sets be in this phase ?

➔ 1-2 minutes for all exercises

### OFF-SEASON WEEKLY SCHEDULE

15 - 30 DECEMBER

	Morning	Afternoon
Monday	Rest	Weight training (lower body)
Tuesday	Rest	Weight training (upper body)
Wednesday	Session 1	Rest
Thursday	Rest	Weight training (lower body)
Friday	5km run	Weight training (upper body)
Saturday	Rest	Optional Session 30 min swim, surf, stairmaster, rowing or cycle (any low impact cardio activity) no running skipping or jumping etc
Sunday	30 min run (props and locks, on grass if possible) 40 min run (all other players)	Rest

#### Session 1:

(use grass surface if possible)

Warm up and stretch

4 min jog

2 min at 70% pace (followed by 1 min slow jog)

1.30 min at 80% (followed by 1 min slow jog)

1min at 90% pace (followed by 1 min slow jog)

30 sec at 90% pace (followed by 1 min slow jog)

Week 1-3 Repeat once

Week 4 Repeat twice

## OFF-SEASON WEIGHT TRAINING PROGRAMME

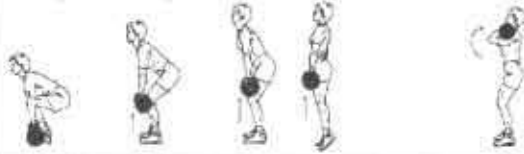
### MONDAY

#### WARM UP AND STRETCH

#### POWER CLEANS

( 2 x 5 reps )

- \* If you have not completed this exercises previously then use only a 20 kg bar, for two weeks before adding extra weight
- \* Don't do if not sure of technique
- \* Stop if back pain



#### SQUATS

( 3 x 12 reps )

- \* Rather complete leg press if squats cause knee or back pain
- \* Do not go further down then 90 degrees
- \* Keep back straight.



#### LEG CURLS

( 3 x 12 reps )

- \* Keep head down
- \* 2 count up 4 down



#### STANDING CALF RAISES

( 3 x 12 reps )

- \* 2 sec hold at top of movement
- \* slow release

#### LUNGES

( 2 x 10 reps )

- \* After two weeks if no knee discomfort add 5kg d/b's in each hand
- \* alternate between right and left



**ISOMETRIC NECK HOLDS**

( 2 x 5 sec on each side)

\*ALL PLAYERS EXCEPT PROPS & LOCKS

**NECK EXT ON LEG CURL MACHINE**

\* Do not hyper extend the neck

\* 3 x 10 Reps (PROPS & LOCKS ONLY)

\* first set straight up, second to the right, third to left

\* Do not go heavy on this exercise, use 5-10 kg

**STOMACH CRUNCHES**

( 3 x 10 - 15 reps)

\* Straight crunches

\* Side to side                      Superset

\* Touch toes

**TUESDAY****WARM UP AND STRETCH****PUSH UPS**

( 2 x 10 reps )

\* Buttocks up.

**PUSH PRESS**

(3 x 5 reps)

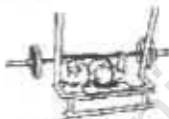
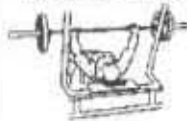
\* remember slow warm up set

**BENCH PRESS**

( 4 X 12 reps )

\* Keep feet on bench

\* Do not arch back

**INCLINE D/B OR B/B PRESS**

( 3 X 12 reps )

**PULL UPS**

( 2 x max overhand - 5 half reps )

( 2 x max underhand - 5 half reps)

\* Use cheating principle on 3 & 4 sets.

\* keep your knees up in front of you in order not to strain your back.

**INCLINE D/B BICEP CURLS**

\* Use 45 degree seated bench

**3 x 12 reps**



**ONE ARM DUMBBELL ROW**

**( 4 x 12 reps )**



**SEATED D / B SHOULDER PRESS**

**(4 x 12 reps )**

\* Seat at 90 degrees

\* Change bench incline to 45 degrees if shoulder discomfort

**CHAIR TRICEP DIPS**

**( 3 x 12 reps )**

\* Upper arm not to go below being parallel with the ground

\* If wrist pain rather do tricep push downs or seated **overhead tricep extensions**

**BACK EXTENSIONS OR ALTERNATE ARM / LEG RAISE (if no back extension)**

**( 2 x 10 reps )**



\* Do not come up further than being parallel to the ground.

\* 2 second hold at 45



**THURSDAY**

**WARM UP AND STRETCH**

**DEAD LIFT (props only)**

**( 2 x 5 reps )**

\* look slightly upwards

\* Tighten lower stomach prior to lifting

\* Stop if back pain



**LUNGES**

(1 x 10) alternating between left and right leg

\* Complete slowly as a warm up for jump lunges

**JUMP SQUATS (no weight)**

(complete by all players, except those who are injured)

\* Week 1: 1 set of 5 reps (5 sec rest between each jump)

\* Increase by 1 set every week for three weeks until you are doing 3 sets of 5 jumps

\* 100 % effort when jumping up, followed by soft landing

\* Do not complete this exercise if you experience knee pain or discomfort

**SQUATS**

( 3 X 12 reps )

\* Do not go further down than 90

\* keep back straight

**LEG CURLS**

( 3 X 12 reps )

\* Keep head down

\* 2 secs up, 4 secs down

**KNEE EXTENSIONS**

( 3 X 12 reps )

\* With 2nd set point toes outwards to activate muscles on the inner part of the knee

\* 2 secs up, 4 seconds down

**SEATED CALF RAISES**

Set 1: feet pointed slightly outwards with weight on outer part of foot

Set 2: feet pointed slightly inwards with weight on inner part of foot

Set 3: feet pointed slightly outwards with weight on outer part of foot

**ISOMETRIC NECK HOLDS ( 2 x 5 sec on each side)****NECK EXT ON LEG CURL MACHINE**

\* 2 x 10 REPS (Props & locks Only)

**STOMACH CRUNCHES**

( 3 x 10 - 15 reps )

\* Straight crunches

\* Side to side                      Superset

\* Touch toes

**FRIDAY****WARM UP AND STRETCH****PUSH UPS**

( 2 x 10-15 reps )

\* Buttocks up

**BENCH PRESS**

( 4 X 12 reps )

\* Keep feet on bench

\* Do not arch back

### D / B FLYS

( 3 x 12 reps )

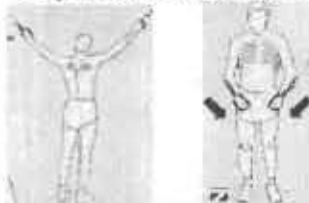
- \* Keep elbows bent
- \* Do not lower the weight beyond shoulder level.



OR

### CABLE CROSSOVERS (if cables available)

- \* superset between crossover and coming straight down



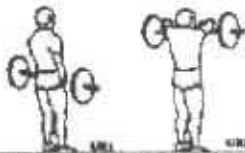
### PULL UPS

( 3 x half your max number you can complete overhand - 5 half reps )  
( 3 x half your max number you can complete underhand - 5 half reps )

- \* Use cheating principle on 3 & 4 sets.
- \* Bring your legs up in front of you so you don't arch your back.

### UPRIGHT ROW

- \* Stop immediately if shoulder or back pain
- \* 3 x 12



### INCLINE HAMMER CURLS

- \* Use 45 degree seated bench
- \* thumbs should be pointing upwards

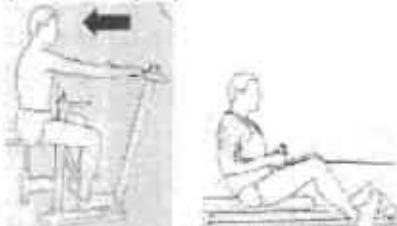
3 x 12 reps

### SEATED

OR

### INCLINE PULLEY ROW

- \* No back movement is permitted, tense lower abdominal muscles prior to pulling
- ( 3 X 12 reps )



### SEATED D / B SHOULDER PRESS

( 4 x 12 reps )

- \* Seat at 90 degrees
- \* Change incline of bench to 45 degrees if shoulders feel uncomfortable

**BACK EXTENSIONS OR ALTERNATE ARM / LEG RAISE** (if no back extension)  
**( 2 x 10 reps)**

- \* Do not come up further than being parallel to the ground
- \* 2 second hold at 45

University of Cape Town

## PRE-SEASON

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- For those who have trained with weights in the gym for a year or longer you will now start to train at a higher intensity (using a heavier weight with less reps eg 5 - 8 rep maximum which is approximately 85% of 1RM) on the core exercises.
- For those who have been training for less than a year, you will continue to use 3 x 12, unless otherwise stated in the program as for push ups or push press.
- Weight Training 3 x a week
- Emphasis on core exercises, **plyometrics** and ballistic resistance training. No cone jumps for props and locks.
- Two hard days and one short day, gym training three times a week
- How long should my rest period between sets be in this phase?  
➔ 1 - 2min for all gym exercises
- For those with a years training experience use the following 4 week cycle when completing core exercises:

WEEK 1-2 ➔ 3 SETS OF 8-10 RM  
WEEK 3-4 ➔ 3 SETS OF 5 RM

Once a cycle is finished it is repeated. All repetitions and sets for the other exercises are shown on the program e.g. 3 x 12 reps.

If you don't have a years experience or if you have never previously trained then keep to 3 x 12 reps, unless otherwise specified as for jump squats and push press (3 x 5)

### PRE-SEASON WEEKLY SCHEDULE : PHASE 1 (1 - 30 January)

	Morning	Afternoon
Monday	Rest	Weight training
Tuesday	Rest	Session 1
Wednesday	5 km (time trial)	Weight training
Thursday	Session 2 (am or pm)	
Friday	Rest	Weight training
Saturday	Rest	Rest
Sunday	40 minute run (am or pm)	

### PRE-SEASON SESSIONS

#### Session 1:

Warm up and stretch

**Week one:**

- \* Mark out 20 meters
- \* Run 10 shuttles in under 52 seconds
- \* Rest for 52 seconds and **repeat** 4 times, adding an extra set each week for 3 weeks

<b>Session 2:</b>
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Warm up and stretch

\* 10 slow 20 m shuttles as a warm up

\* no jumps for props and locks

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**Week one:**

Complete 2 set of six 30cm cone jumps going from side to side (remember soft landing) **No jumps for locks and props**

Sprint 3 x 25m 80% pace

Run 200 meters at 80% of full pace, jog 200m (x2)

Run 300 meters at 80% of full pace, jog 300m (x2)

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**Week two:**

Complete 3 set of six 30cm cone jumps going from side to side (remember soft landing) **No jumps for locks and props**

Sprint 4 x 25m 90% pace

Run 300 meters at 80% of full pace, jog 300m (x2)

Run 200 meters at 80% of full pace, jog 200m (x3)

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**Week three:**

Complete 3 set of six 30cm cone jumps going from side to side (remember soft landing) **No jumps for locks and props**

Sprint 4 x 25m 100% pace

Run 300 meters at 80% of full pace, jog 300m (x3)

Run 200 meters at 80% of full pace, jog 200m (x3)

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**Week Four:**

As for week three

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**PRE-SEASON WEIGHT TRAINING PROGRAMME**

MONDAY
<b>WARM UP AND STRETCH</b>
<b>PUSH UPS ( 2 x 10 reps )</b> * Bum up.
<b>LUNGES (1 x 10)</b> * no weight
<b>POWER CLEAN (3 x 5 reps)</b> * Stop if back pain
<b>SQUATS</b> * Sets x reps - follow guidelines for pre- season * Do not go further down than 90 degrees * Keep back straight, look forward and slightly upwards
<b>BENCH PRESS</b> * Sets x reps - follow guidelines for pre- season * Keep feet on bench * Do not arch back
<b>D / B Flyes</b> <b>OR cable crossovers ( 3 x 12 reps )</b>
<b>LEG CURLS ( 2 x 12 reps)</b> * Keep head down
<b>PULL UPS ( 2 x max overhand + 5 half reps )</b>
<b>SEATED PULLEY OR CHEST SUPPORTED ROW</b> * Sets x reps - follow guidelines for pre- season * Do not pull with the lower back. * Keep the stomach tight throughout the movement.
<b>BACK EXTENSIONS OR ALTERNATE ARM / LEG RAISE (if no back extension) ( 2 x 10 reps)</b> * Do not come up further than being parallel to the ground. * 2 second hold at 45
<b>ISOMETRIC NECK HOLDS ( 2 x 5 sec on each side)</b> <b>OR</b> <b>NECK EXT ON LEG CURL MACHINE ( 2 X 10 REPS)</b> * props & locks
<b>STOMACH CRUNCHES ( 3 x 10 - 15 reps)</b>

WEDNESDAY
<b>NORMAL LUNGES</b> * complete slowly, use as warm up for jump squat (1 X 10 reps on each leg, alternating)
<b>JUMP SQUATS</b> <i>Full recovery between sets (5sec break between reps)</i> Wk 1 (2 x 5 reps - add 20kg bar) Wk 2 (3 x 5 reps - Olympic bar 20kg or equivalent) WK 3- 4 (3 x 5 reps - add 10kg to bar) WK 4-6 (3 x 5 reps - add 15-20kg to bar) * Stop immediately if knee pain * Don't use weight above 30% of body weight * Jump as high as possible, landing as softly as possible
<b>UNDERHAND PULL UPS ( 2 x max)</b>

<b>D/B BICEP CURLS</b> (3 X 12)
<b>SEATED D / B SHOULDER PRESS</b> * Sets x reps - follow guidelines for pre- season
<b>CHAIR TRICEP DIPS</b> ( 2 x 12 reps ) * Upper arm not to go below being parallel with the ground.
<b>SEATED CALF RAISE</b> ( 2 x 12 reps )
<b>BACK EXTENSIONS OR ALTERNATE ARM / LEG RAISE</b> (if no back extension) ( 2 x 10 reps ) * Do not come up further than being parallel to the ground. * 2 second hold at 45
<b>STOMACH CRUNCHES</b> ( 3 x 10 - 15 reps ) * Straight crunches, side to side, touch toes (superset)

#### FRIDAY

<b>WARM UP AND STRETCH</b>
<b>PUSH UPS</b> ( 2 x 10 reps ) * Buttocks up.
<b>POWER CLEAN</b> * Sets x reps - follow guidelines for pre- season * Stop if back pain.
<b>BENCH PRESS</b> * Sets x reps - follow guidelines for pre- season * Keep feet on bench * Do not arch back.
<b>INCLINE D/B OR B/B PRESS</b> ( 3 X 12 reps )
<b>INCLINE HAMMER CURLS</b> * Use 45 degree seated bench * thumbs should be pointing upwards <b>3 x 12 reps</b>
<b>SQUATS</b> * Sets x reps - follow guidelines for pre- season * Do not go further down than 90 * Keep back straight.
<b>LEG CURLS</b> ( 2 x 12 reps ) * Keep head down
<b>PULL UPS</b> ( 3 x half your max overhand)
<b>SEATED OR INCLINE PULLEY ROW</b> * No back movement is permitted, tense lower abdominal muscles prior to pulling ( 3 X 12 reps ) if there are no machines in your gym replace the above exercise with a D/B row
<b>SEATED D / B SHOULDER PRESS</b> * Sets x reps - follow guidelines for pre- season
<b>LATERAL RAISE</b> (3 x 12) * Arms 30 degrees in front of the body keeping arms slightly bent, not going above shoulder level