QUANTIFYING AEROBIC AND ANAEROBIC TRAINING AND ITS IMPACT ON

PHYSICAL ATTRIBUTES AND PERFORMANCE IN RUGBY SEVENS PLAYERS

A thesis presented to the Faculty of Health Sciences, University of Johannesburg, In fulfilment of the requirements for the Master's degree in Sports Science

by

Marcel Trisha Lamont

(Student number: 201103312)

Supervisors: ______________________________ ______

Mr A.J.J. Lombard Date

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Prof. Y. Coopoo Date

- **DEDICATION**

This is dedicated to my parents and siblings, for giving me the opportunities that I have today and for their love, constant support and motivation.

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ABSTRACT

Introduction: The current research was carried out to quantify aerobic and anaerobic training and its impact on physical attributes and performance in rugby seven players.

Methods: This descriptive and interventional study was conducted on 54 male rugby sevens players through convenience sampling. Quantitative data was collected by means of physiological tests, consisting of pre-morphological characteristics, aerobic fitness, anaerobic fitness, muscular strength and muscular endurance.

Collected data were analysed by SPSS-15 software. Descriptive statistics were described by means, standard deviation, percentage of improvement and minimum and maximum scores for all variables measured. Inferential statistics drew conclusions on the population group (backs versus forwards) from the sample measurements.

Results: Rugby sevens players had morphological characteristics (sum of 7 skinfolds 75 ± 33 mm, body fat 14 ± 5 %, fat mass 14 ± 7 kg, lean mass 77 ± 11 kg; mean ± SD) similar to those of backs in international 15-player rugby union. No significant difference was found in the predicted VO_{2max} ($p \geq 0.05$) of the total rugby sevens group as well as positional variance.

Significant difference ($p \leq 0.05$) in anaerobic capacity for the total rugby sevens players was obtained (63 ± 3 s). The results of strength and muscular endurance analysis in this study showed significant differences ($p \leq 0.05$) in the total rugby sevens group as well as in position. The results of this study indicated that forwards were stronger in the bench press, demonstrating a change score of 20,7 % compared to that of the backs (19,0%), as well as in squat measures (15,5%) compared to the backs (14,1%). The total rugby sevens group presented a change score of 18,5% in bench press between the pre- and post-intervention results and 14,3% change score in squats. Acceleration, speed and agility (10-m sprint 1.5 ± 0.3 s, 40-m sprint 5.11 ± 0.15 s, 15.1 ± 0.7 s) and muscle-power (vertical jump 28 ± 0.3 cm) qualities were similar to those of professional backs in 15-a-side players.

Conclusion: Rugby sevens players require highly developed aerobic fitness and anaerobic fitness (repeated sprint ability, speed, power, muscular strength and endurance) to tolerate the demands of competition.

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LIST OF ABBREVIATIONS

BF	Body fat
BM	Body mass
BMI	Body mass index
BP	Blood pressure
cm	Centimetre
ES	Effect size
HR	Heart rate
IRB	International Rugby Board
ISAK	International Society for the Advancement of Kinanthropometry
kg	Kilogram
$kg.m^{-2}$	Kilograms per square metre
LBM	Lean body mass
m	Metre
mm	Millimetre
$m.s^{-1}$	Metres per second
n	Number
RPE	Rating of perceived exertion
Sig	Significance
SPSS	Statistical Package for Social Sciences
STR	Subscapular triceps ratio
UJ	University of Johannesburg
USA	United States of America
$V0_{2Max}$	Maximum oxygen uptake

LIST OF DEFINITIONS

Acceleration — the capability to increase movement velocity in the least amount of time possible (Little & Williams, 2005).

Aerobic fitness — performing exercise in the presence of, requiring, or utilizing oxygen (Plowman & Smith, 2011).

Agility — the skills and abilities to explosively change movement velocities or modes (Baechle & Earle, 2008).

Anaerobic fitness — the ability to perform exercise in the absence of, not requiring, nor utilizing oxygen (Plowman & Smith, 2011).

Anthropometric measurements — are used to quantify the characteristics of athletes (Duthie *et al*., 2006).

Morphological characteristics — the physical makeup of the body, including weight, lean weight, and percentage fat (Marrow, Jackson, Disch & Mood, 2011).

Cardiorespiratory fitness — the ability to deliver and use oxygen under the demands of intensive, prolonged exercise or work (Plowman & Smith, 2011).

Concurrent training — a combination of high levels of resistance and aerobic endurance training done as a part of the same programme, often performed on the same day (Plowman & Smith, 2011).

Maximal oxygen consumption — the highest amount of oxygen an individual can take in and utilize to produce ATP aerobically while breathing air during heavy exercise (Plowman & Smith, 2011).

Maximum power — the maximal amount of work performed in a fixed amount of time (Marrow, Jackson, Disch & Mood, 2011).

Muscular Endurance — the physical ability to perform work (Marrow *et al.,* 2011).

Muscular Strength — the force that can be generated by the musculature that is contracting (Marrow *et al.,* 2011).

One repetition maximum — the maximal weight an individual can lift once during a dynamic resistance exercise. (Plowman & Smith, 2011).

Periodisation — plan for training based on the manipulation of the fitness components with the intent of peaking the athlete for the competitive season (Plowman & Smith, 2011).

Reliability — the degree to which repeated measurements of the same trait are reproducible under the same conditions; consistency (Marrow *et al.*, 2011).

Resistance training — a systematic programme of exercises involving the exertion of force against a load, used to develop the strength, endurance, and/or hypertrophy of the muscular system
(Plowman & Smith, 2011).

Rugby league — a body-contact sport played at amateur, semi-professional, and professional levels (Brewer & Davis, 1995).

Rugby sevens - rugby sevens, also known as seven-a-side or VIIs, is a variant of rugby union in which teams are made up of seven players, instead of the usual 15, with shorter matches (Planet Rugby, 2005).

Rugby union – rugby union, mostly referred to as rugby, is a full contact sport which originated in England in the early 19th century (Planet Rugby, 2005).

Speed — the skills and abilities to achieve high movement velocities (Baechle & Earle, 2008).

Sport-specific physical fitness — that portion of physical fitness directed toward optimizing athletic performance (Plowman & Smith, 2011).

Training principles — fundamental guidelines that form the basis for the development of an exercise training programme (Plowman & Smith, 2011).

Training volume — the quantity of training overload calculated as frequency times duration (Plowman & Smith, 2011).

Validity — the degree of truthfulness in a test (Marrow *et al.*, 2011).

CHAPTER 1: INTRODUCTION AND AIM OF THE STUDY

1.1 INTRODUCTION

Rugby sevens has developed, since its beginnings in Scotland in 1883, from a social pastime into a highly competitive sport with a regular season of international tournaments (Planet Rugby, 2005). The International Rugby Board's (2012) Sevens series runs from December to June each year, with the Sevens World Cup held every four years. Rugby sevens is an outdoor team sport that is defined by regular sessions of high-intensity movement and contact.

Rugby sevens is presently being played in 93 countries (Higham, Pyne, Anson & Eddy, 2012) and has recently become one of the new Olympic summer sport codes, first making its appearance in Rio de Janeiro Olympics in 2016 (Engebretsen & Steffen, 2010; Fuller, Taylor & Molloy, 2010; Higham *et al.*, 2012). The sport is continually expanding (Signes, 1990), with more than 30 nations now taking part in the IRB Sevens Series compared to the original 16 teams (Planet Rugby, 2005) that played in the first tournament during the 1999/2000 season.

Given this increase in popularity of the game, is essential to conduct research into the sport to broaden our understanding of its complexity and bodily demands. For instance, since its beginning in 1883, the global expansion of rugby sevens has led to a more specialised approach to coaching and supervision. Moreover, although rugby sevens uses comparable rules to rugby union, such as the same playing field elements, rugby sevens has a reduced number of players per team (seven rather than 15) and is played for a shorter interval of two seven-minute halves with a one- to two-minute half-time, whereas rugby union has two 40-minute halves (Ross, Gill & Cronin, 2015).

Recent research has also shown that rugby sevens is characterised by excessive running demands along with limited recovery intervals between running attacks during play (Higham *et al.*, 2012). These running demands seem to be higher (when expressed as a function of the time played) than those in both rugby union and rugby league. It is therefore likely that rugby sevens players require highly developed sprinting qualities (Higham, Pyne, Anson & Eddy, 2013) and advanced aerobic and anaerobic fitness to cope with the game's requirements (Higham *et al.*, 2012).

In addition to the described running demands throughout a rugby sevens match, players are open to be a part of physical interactions such as; tackling, scrumming and rucking. Such physical contact has a high bodily cost and includes important sport-specific skills (Duthie, Pyne, Hopkins, Livingstone & Hooper, 2006; Gabbett, 2005; Tong & Mayes, 1995). Moreover, during training, required morphological changes in aerobic fitness, muscular strength and flexibility as well as reduced anthropometrical measurements (skinfold thickness) in male rugby sevens players display significant improvement during preseason during peaked training loads, (Holmyard & Hazeldine, 1993; Duthie *et al*., 2006; Gabbett, 2005; Tong & Mayes, 1995), prior to equalization of baseline data or remaining consistent in the competitive season (Duthie *et al*., 2006; Gabbett, 2005; Tong & Mayes, 1995).

Moreover, players anthropometrical measurements (skinfold viscosity) is sustained during the competitive period during the rugby sevens season as training and match loads are limited, and players are prone to injuries (Duthie *et al*., 2006; Gabbett, 2007).

Gabbett (2005) states that there are reduced aerobic fitness and muscular power accompanied by an increase in anthropometrical measurements near the conclusion of the rugby sevens season. This is a result of lessened work load and amplified match load and injury rates. Gabbett's study (2005), which utilised physical and morphological data to determine any variances among the playing positions in junior rugby league players, also concluded that limited differences exist in relation to height, skinfold thickness, speed and anaerobic power.

Although numerous rugby sevens players also participate in traditional rugby league, constant progress in rugby sevens as well as interest from nationwide rugby unions and Olympic boards will possibly conclude in the advancement of a professional rugby sevens player, in which the players' appearance and dexterity or coordination especially in the execution of learned physical tasks is emphasised (Duthie *et al*., 2006; Gabbett, 2005; Tong & Mayes, 1995). This prediction, together with the studies mentioned above, relates to the aim of the current study, which is to establish the changes in physical parameters related to concurrent resistance and aerobic training in selected provincial rugby sevens players.

1.2 RESEARCH PROBLEM

Rugby sevens is a competitive and specialised sport. However, research in rugby sevens is lacking when compared with other sporting codes, even though scientific-based rugby research can equip strength and conditioning trainers with the precise knowledge to aid the development of individualised conditioning programmes (Mellalieu, 2008).

For instance, rugby union is an area where the players must exhibit not only skill but fitness levels above the norm for the general population. Individual players within a team fulfil the roles of their appointed positions and consequently have different requirements for fitness and training levels (Scott, Roe, Coats & Piepoli, 2003). A similar conditioning guideline for fitness established for club rugby sevens players could help improve their fitness. As Gabbett, Kelly and Pezet (2007) state, ultimate bodily fitness of the players can certainly donate to the achievement of the playing capacity of rugby players.

This study will use the morphological characteristics, aerobic and anaerobic fitness, muscular strength and endurance, power, agility and speed measurements during a 12-week intervention programme to assist in establishing the specific physiological demands in selected provincial rugby unions. The results can provide important feedback to coaches and trainers regarding the training stimulus applied to the players, and be used to develop an effective training programme, which can assist in the success of a team (Brooks, Fuller, Kemp & Reddin, 2008).

1.3 PURPOSE AND AIM OF THE STUDY

The purpose of the study is to establish the changes in physical parameters related to concurrent aerobic and anaerobic training (guideline intervention programme) and to describe the physical and fitness patterns in different rugby sevens positions.

1.4 NULL HYPOTHESIS

Quantified aerobic and anaerobic training (guideline intervention programme) will result in significant changes to the physical attributes of rugby sevens players.

1.5 OBJECTIVES OF THE STUDY

The objectives of this study are twofold: to assess the effects of concurrent aerobic and anaerobic exercises on physical parameters including weight, lean muscle mass, fat mass and percentage (%) body fat, the aerobic variable ($V0_{2max}$) and anaerobic variables (muscular strength and endurance, power, speed and agility); and to determine if there is a different fitness profile for backs and forward players respectively.

1.6 DELIMITATIONS OF THE STUDY

The sample of this study is delimited to male first division rugby sevens players involved with league rugby.

1.7 OUTLINE OF CHAPTER

The understanding of the history of rugby sevens and the physiological needs and fitness parameters, training principles essential to rugby sevens players and the lack of research available when compared to other sporting codes is identified in this chapter.

The introduction and aim to this study will recognize the parameters such as; morphological characteristics, aerobic and anaerobic fitness, muscular strength and endurance, power, agility and speed measurements that will be tested during a 12-week intervention programme to assist in establishing the specific physiological demands.

1.8 SUMMARY

The following chapter will focus on literature, which will reveal numerous aspects of rugby sevens with regards to physiological attributes of rugby sevens' fitness parameters, and, importantly, training programmes and principles of the sport.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

Rugby sevens derived in the Scottish town of Melrose in 1883 (Sports.Know.How, 2015). The admiration and involvement in rugby sevens has grown since those early days, with the primary men's rugby sevens World Cup taking place in Scotland in 1993. The inclusion of the sport in the 1998 Commonwealth Games eventually lead to the International Rugby Board (IRB) World Series in 1999/2000, nowadays identified as World Rugby Sevens Series. The rugby sevens World Cup has persisted to advance and has twice, in 2009 and 2013, had equally men's and women's competitions together, where the Australian women's rugby sevens team winning the first women's Rugby World Cup Sevens in Dubai in 2009 (Sports.Know.How, 2015).

The Sevens Series first consisted of 15 core teams, Argentina, Australia, Canada, England, Fiji, France, Japan, Kenya, New Zealand, Portugal, Samoa, Scotland, South Africa, the USA and Wales, in the 2014/2015 tournaments, with one place at each round filled by an invited team (Sports.Know.How, 2015). The IRB World Rugby Women's Sevens Series was announced in the 2012/2013 season, containing of an invitational tournament in Dubai, in the United Arab Emirates. Both the men's and women's rugby sevens competitions have continued to advance with the introduction of these codes into the 2016 Olympic Games in Rio de Janeiro, Brazil, and the 2018 Commonwealth Games on the Gold Coast, with Australia hosting the first Olympic and Commonwealth Games to include both men's and women's rugby sevens (Sports.Know.How, 2015).

The game itself follows similar rules to that of rugby union, but there are notable differences between rugby sevens and traditional rugby. Rugby sevens takes place on an ordinary rugby field (120m x 70m) where each team is comprised of seven players each: three forwards and four backs. Moreover, although forwards require specific technical skills such as scrums and line-outs, the positional group variances are not as distinct as those in traditional rugby, owing to the high overlap in rugby sevens players' movement patterns as well as technical skills during matches (Higham *et al.*, 2013; Ross *et al.*, 2015).

Rugby sevens matches are also divided into two seven-minute halves (seven-minutes) inclusive of a one to two-minute break between the intervals, apart from finals, where match play is extended to 10-minutes.

The adapted laws related with rugby sevens consist of teams made up of 12 players in total for the full length of the competition, with five substitute players and five interchanges permitted during the match. In contrast, rugby union has eight substitute players and eight interchanges permitted in play (Sports.Know.How, 2015).

The formation of rugby sevens games allows a tournament to take place over two to three uninterrupted days, allowing teams to participate in four to six matches, dependent on team outcomes, with a recovery timeframe of roughly three hours between matches (West, Cook, Stokes, Atkinson, Drawer, Bracken & Kilduff, 2013). International men and women's tournaments comprise a total of 45 and 34 games played respectively. The World Rugby Sevens Series is composed of 16 teams, separated into four pools of four teams, while the Women's Sevens Series consists of 12 teams, with three pools of four teams.

Rugby sevens has grown so much in popularity that it has been considered as one of the fastest developed sports internationally (Suarez-Arrones, Nuñez, Portillo & Mendez-Villanueva, 2012). Higham *et al*. (2012a) state that rugby sevens is recognised as an exhilarating sport that involves regular attacks of high-intensity movement and limited recovery times. As such, it is believed that there is extensive physical strain on players (Higham *et al*., 2012a).

The physical, technical, and strategic stresses are indeed apparent in morphological characteristics and internal work-load of the players, observable through evaluating rated perceived exertion (RPE) and fluctuation of skill regularity and/or performance. Improved physical demands or defensive pressure may compromise the players' skill attainment and/or the implementation of new tactical approaches, resulting in an undesirable rate of recurrence and/or performance of selected skills (Casamichana & Castellano, 2010; Gabbett *et al.*, 2012; Kennett, Kempton & Couttz, 2012, 2012; Rampinini, Impellizzeri, Castagna, Abt, Chamari, Sassi & Marcora., 2007). Moreover, it has been demonstrated that during smaller field games, players have increased consistency of skills, while play in the standard-size rugby field intensifies the physical demands of movement patterns and PRE, with in-play skills observed less often (Casamichana & Castellano, 2010; Gabbett, Abernnethy & Jenkins, 2012; Kennett *et al.*, 2012 and Rampinini *et al*., 2007).

However, studies that focus on the performance and match breakdown in rugby sevens matches are limited (Suárez-Arrones *et al.*, 2012; Higham *et al.*, 2012a; Rienzi, Reilly & Malkin, 1999; van Rooyen, Lombard & Noakes, 2008), taking into account training load monitoring (Elloumi, Makni, Moalla, Bouaziz, Tabka, Lac & Chamari, 2012) and physical profiling (Higham *et al.*, 2013). Furthermore, due to limited number of days of play, preparing a team for optimal team performance while building methodological and strategic skill growth while accounting for physical demands placed on the players may be a challenging task.

Even so, quantifying physical demands in high-performance sport has become routine, with a assortment of internal (heart rate (HR) and RPE) and external (Global Positioning System (GPS)) data that quantifies as well as reproduces the players' movement patterns). These captured measurements are being implemented in a training situation (Casamichana & Castellano, 2010; Gabbett *et al*., 2012; Kennett *et al*., 2012; Rampinini *et al.,* 2007).

The objective of this chapter is to assess the existing literature related to physical and physiological features of rugby sevens players and categorise guidelines for the fitness and conditioning aspects of this sport. This review will begin with the physiological attributes of rugby sevens players followed by morphological characteristics, aerobic fitness, anaerobic fitness, muscular strength, muscular power, muscular endurance, repeated sprint ability, speed and acceleration. The review will conclude by analysing training programmes and the principles for rugby sevens.

2.2 PHYSIOLOGICAL ATTRIBUTES OF RUGBY SEVENS FITNESS PARAMETERS

Various intermittent team sports include multi-functional attributes with methodological, strategic and physical factors, which also contribute to achievement in rugby sevens. Coaches have the perception that their athletes' performance will improve by enhancing physical parameters understood to be related to distinctive rugby sevens skills.

However, the level that physical characteristics could correlate to game skills needs to be considered in order to allow strength and conditioning coaches to design sport-specific exercise programmes to replicate match tasks (Smart, Hopkins, Quarrie & Gill, 2011). Studies within rugby union (Smart *et al*., 2011), Australian Football (Mooney, O'Brien, Cormack, Coutt, Berry & Young, 2011; Young & Pryor, 2007) and rugby league (Gabbett *et al*., 2007) have examined the association between physical appearance and specific game skills.

The association between physical measures (morphological characteristics, acceleration, maximum strength and stamina) with designated match responsibilities were noted by Smart *et al*. (2011), in which reasonable correlations in professional and international players were recorded. However, the absence of strong associations does not propose that morphological measures remain disconnected with match skills, as there is a possibility that morphological measures a side from those incorporated by Smart *et al.* (2011) will have stronger associations with match skills.

Even though anaerobic fitness stresses of rugby sevens players persist to be vague, the high-intensity aerobic fitness and acceleration stresses of the game would imply that these physical measures are expected to play a role in the players' capability to execute match skills. The cumulative effect of exercise loading throughout a rugby sevens tournament is thought to be of high intensity compared to the exercise loading experienced during strenuous anaerobic exercise training (Takahashi, Umeda, Mashiko, Chinda, Oyama, Sugawara & Nakaji, 2007), generating an assumption that rugby sevens players experience higher levels of psychological and physical stress than rugby union players (Takahashi *et al.*, 2007).

Within this framework, rugby sevens training necessitates the development of precise physical fundamentals for competition, which requires a high workload of aerobic and anaerobic conditioning, leading to elevated levels of perceived exhaustion (Argus, Gill, Keogh, Hopkins & Beaven, 2010). Furthermore, experimental findings along with scientific data has revealed that muscular strength, power, speed, agility, fitness and body size are all significant features of the overall presentation of a player (Duthie, Pyne & Hooper, 2003). The physical demands on rugby sevens players are thus multifaceted, and improvement on the previously mentioned performance measurements requires a thoughtfully planned conditioning programme (Gamble, 2004).

Strength and conditioning coaches are thus dedicated to designing pre-planned methodical distinctions in training specificity, intensity and volume structured in phases within a complete programme. The programme strategy is called periodisation (Baechle & Earle, 2008), in which the motive is to encourage long-term training and improvements.

Within this programme strategy, rugby sevens training components are divided into precise areas of importance. As such, aerobic and anaerobic training programmes characteristically allocate a specific focus to each phase of the training year.

2.2.1 Morphological Characteristics

The variance between age, rank (for example, juniors vs seniors) and positional group are commonly determined by morphological measurements. These measurements are used to quantify the physical appearance of players (Duthie *et al*., 2006). For example, research of a large sample (n = 264) of international rugby union players recorded forwards as approximately 12 kg heavier ($p \leq 0.001$) and approximately 7 cm taller ($p \leq 0.001$) than backs (Fuller *et al*., 2010).

Rugby sevens players have similarly captured the attention of researchers with regards to their morphological measurements, with studies focussing on player description, time–motion investigation, supervision of load stress as well as injuries. Even though most investigations that have compared morphological measurements between backs and forwards in traditional rugby have noted discrepancies in physical appearance between positional groups (Duthie *et al*., 2006; Crewther, McGuigan & Gill, 2011; Crewther, Lowe, Weatherby, Gill & Keogh, 2009; Hansen, Cronin, Pickering & Douglas, 2011; Quarrie & Hopkins, 2007; Suárez-Arrones *et al*., 2012; Duthie *et al*., 2006; Argus *et al.*,2011), most research in rugby sevens players (Suárez-Arrones *et al*., 2012; Higham *et al*., 2012b; Elloumi *et al*., 2012; Higham *et al*., 2013; Takahashi *et al*., 2007), but not all (Hughes & Jones, 2005; Fuller *et al*., 2010), have demonstrated that backs and forwards proved comparable data.

Owing to insignificant changes observed in morphological assessments, with the coefficient of variation (CV) fluctuating from approximately 3.3 - 8.4%, Higham *et al.* (2013) suggest that teams are more or less homogenous. However, it may be that the morphological homogeneity within the team studied by Higham *et al*. (2013) could possibly not represent rugby sevens players as a whole. As such, even though that there are limited differences captured in the physical appearance amongst the positional groups in rugby sevens players, reporting the morphological changes that do exist between backs and forwards is vital. When comparing rugby sevens players to traditional rugby union players that have not been placed in various playing positions, rugby sevens players have been seen to weigh significantly less. However, they are comparable in body mass (mean 90 kg) and height (mean 1.83 m) to outside backs in rugby union (89 kg; 1.80 m). Moreover, rugby sevens forwards have recorded parallel body mass to lose forwards in rugby union (mean 98 and 102 kg) (Rienzi *et al*., 1999; Fuller *et al*., 2010; Smart, 2011).

Because rugby sevens require high-intensity output, a lean body mass is thought to be beneficial (Suárez-Arrones *et al*., 2012; Higham *et al.*, 2012b; Rienzi *et al*., 1999). Predicted body fat percentage (11–12%) and the sum of seven skinfolds (mean 52.2– 61.6 mm) has indeed been reported by researchers, which have shown that morphological measurements proved that rugby sevens players are lean (Suárez-Arrones *et al*., 2012; Rienzi *et al*., 1999; Elloumi *et al*., 2012; Higham *et al*., 2013).

According to Smart *et al*. (2011) and Duthie *et al*. (2006), backs are smaller than forwards in rugby union, yet there is uncertainty if these differences are present in morphological measurements between modern-day rugby sevens players, as the exclusive study to report the morphological measurements for backs and forwards investigated players in positional groups in 1996 (Rienzi *et al*., 1999). The trend of rugby union players increasing in body mass over the years (Quarrie & Hopkins, 2007) seems to have played also occurred in rugby sevens players, with international backs (7 kg) and forwards (4 kg) heavier, respectively, than backs and forwards in 1996 (Rienzi *et al*., 1999; Fuller *et al*., 2010). Changes in morphological measurements amongst players of dissimilar competition levels were investigated in the rugby union (Smart, 2011; Argus *et al*., 2012); however, there is no research investigating rugby sevens of different rank. Captured data amongst rugby sevens players of varying playing rank (international or provincial) possibly will have consequences for player growth and talent identification.

2.2.2 Aerobic Fitness

Anaerobic energy pathways may be enhanced by developing a player's aerobic capacity. A player with a well-developed aerobic capacity had increased fatigue resistance and lactate clearance, which eases players to return to normal state between sessions of high-intensity movement (Tomlin & Wenger, 2001). Maximal oxygen uptake (VO_{2max}) has frequently been reported as a key point measure of aerobic fitness in rugby players.

Suarez-Arrones *et al.* (2011) demonstrate that more time is spent in high-intensity activity zones than in other zones during match play in rugby sevens. The alternating profile of the matches places demands on the aerobic and anaerobic energy systems of the players, thus forcing them to use the two energy systems in combination (Atkins, 2006).

Success in intermittent sprint sports requires the cardiorespiratory ($V0_{2\ max}$) energy system, as this system contributes to recovery between sprinting, replacing phosphocreatine between extreme efforts (Tomlin & Wenger, 2001).

Owing to the tournament formation of rugby sevens, players participate in several games in one day and over uninterrupted days, with a limited timeframe three hours to return to normal state between matches. As such, a progressive aerobic energy system is critical to improve regain energy post high-intensity movement (Higham *et al*., 2012b; Tomlin & Wenger, 2001).

The Welsh Rugby Union (WRU) states that well-developed aerobic fitness catalyses the tempo of recuperation during the one to two-minutes break between games and post vigorous training and competitions. According to the WRU, aerobic fitness will help the rugby sevens players by postponing the onset of fatigue and support in preserving attentiveness, focal points and quick decision-making abilities in players. A well-developed aerobic fitness base will allow the body to use large amounts of energy from fat stores before using energy in the form of muscle glycogen (sugar stored in the muscle), assisting in the delay of the onset of fatigue. Scott *et al.* (2003) state that, by using cardiopulmonary exercise testing and body fat measurements, comparison between aerobic fitness levels of backs and forwards can be established.

Additionally, it has been suggested that a well-developed aerobic system assists in the frequent sessions of sprints, accelerating and decelerating (Suárez-Arrones *et al*., 2012; Higham *et al*., 2012b). The aerobic capability of rugby sevens players has been made known in two studies (Elloumi *et al*., 2012; Higham *et al*., 2013). Different Yo-Yo intermittent recovery (YYIR) tests have been conducted to examine the aerobic capacity in rugby players. The test is made up of a sequence of gradually quicker 20-metre shuttles to fatigue (endurance version), with five seconds of rest between the shuttles and 10 seconds active rest for the recovery version. In addition, either models contain two levels, where the second level is made up of quicker shuttle speeds than the first level (Krustrup, Mohr, Amstrup, Rysgaard, Johansen, Steensberg, Pedersen & Bangsbo, 2003; Bangsbo, Iaia & Krustrup, 2008; Ingebrigtsen, Bendiksen, Randers, Castagna, Krustrup & Holtermann, 2012).

Various YYIR assessments are also more reliable measurements of outdoor sport endurance than outdated laboratory-determined maximal oxygen uptake ($V0_{2max}$) (Ingebrigtsen *et al*., 2012).

In a recent study, the YYIR test permitted researchers to find the difference between carefully selected (elite) and sub-elite soccer players when $V0_{2max}$ was captured. In contrast, the maximal treadmill test by no means grants this distinction to be made (Ingebrigtsen *et al*., 2012).

Higham *et al.* (2013) conducted the YYIR test 1 (YYITT1) on worldwide rugby sevens players, where a mean of 2,3 metres was captured. The result recorded is higher than elite rugby league players (average 1,7 metres) comparable body mass (Atkins, 2006) as well as a collective group of elite rugby union backs (average 2,0 metres) (Austin, Gabbett & Jenkins, 2013). It has been reported that elite Australian football (Veale, Pearce & Carlson, 2010), rugby union (Atkins, 2006) and soccer (Ingebrigtsen *et al*., 2012) players covered more ground in periodic shuttle outdoor tests than sub-elite players.

Nevertheless, regardless of the possible impact aerobic fitness has on the performance in rugby sevens, no research displays modifications in aerobic fitness amongst rugby sevens players from different competition levels.

2.2.3 Anaerobic Fitness

Anaerobic capacity and power during intermittent training and competition are vital building blocks for rugby union and rugby sevens players. Plowman and Smith (2011) describe anaerobic fitness as the ability to perform exercise in the absence of – not requiring, nor utilising – oxygen.

Due to the fact that the environment is similar to that in which the players would participate competitively, field assessments are applicable and time-efficient option for coaches. The specific field tests conducted can provide a precise evaluation of the players (Svensson & Drust, 2005; Castagna, Impellizzeri, Chamari, Carlomagno & Rampinini, 2006). Regrettably, there is no graded requirement for the analysis of anaerobic characteristics in rugby players.

In order to administer power-built movements such as tackling, scrumming, explosive speed and vertical jumps as well as the effort to insert force during rucking and mauling in rugby sevens competitions, a highly effective anaerobic energy system is believed to be important (Higham *et al.,* 2013). Aziz and Chuan (2004) suggest conducting the repeated sprint ability test in order to test the players' anaerobic performance, because the test is an imitation of repeated sprints required in numerous sprint sports.

The requirements of anaerobic repeated sprint ability are for players to run eight repetitive sprints of 40 metres, with 30 seconds' rest period between each sprint shuttle. The total duration to complete the sprint shuttle is recorded off a "drop-off index" and is worked out from the period of the index to specify the anaerobic measurements of the player by the rate of ability to recover between repetitive high efforts of explosive sprints.

A three-way 120-metre sprint shuttle assessment was designed by Holloway, Meir, Brooks and Phillips (2008) specifically for the measurement of anaerobic endurance in rugby league players. This test emphasised the importance of dependable, sport-specific assessments. In this study, the Wingate anaerobic, 60-second assessment was implemented by calculating the players' HR and blood-lactate concentrations.

A jumping test was developed by Tinazci and Acikada (2009) to assess anaerobic fitness of periodic-type movements. In order to conduct The Hacettepe intermittent jumping test players had to repeated jump five times for 15-seconds with a recovery timeframe of 1-minute between each set. The players heart rate, resting heart rate and maximal heart rate was recorded during and post the sets to determine the fitness level of each athlete.

The Bath University Rugby Shuttle Test (BURST) was established through rugby union competitions and founded on time-motion analyses of the matches to replicate the physical demands of competition (Roberts, Stokes, Weston & Trewartha, 2010a). Rugby-specific test batteries such as BURST may be used as testing protocols to examine and assess interventions that are likely to affect performance (Roberts, Stokes, Trewartha, Doyle, Hogben & Thompson, 2010b) and could potentially be used for player conditioning. Even though this sport-specific test is conducted under controlled conditions, it has the ability to isolate specific physical abilities that reinforce desired performance.

To explain the anaerobic parameter in this study, several components will be analysed. These components will include: muscular strength, muscular power, muscular endurance, repeated sprint ability, speed and acceleration, and agility.

2.2.3.1 Muscular Strength

Peaked levels of muscular strength are understood to be vital in order to be successful in collision-based sports (Smart *et al*., 2011; Argus, Gill & Keogh, 2012; Crewther *et al*., 2009; Hansen *et al.,* 2011; Argus, Gill, Koegh, Hopkins & Beaven, 2010; Comfort, Graham-Smith, Matthews & Bamber, 2011; Argus *et al*., 2009; Gabbett, King & Kenkins, 2008). The contact environment of rugby union is comparable to that of rugby sevens.

These physical conditions of rugby sevens are inclusive of tackling, carrying the ball into contact and scrumming, entirely of which necessitate muscular strength. However, while several investigations have been administered address the strength of rugby union players (Smart *et al*., 2011; Argus *et al*., 2012; Crewther *et al*., 2011; Crewther *et al*., 2009; Hansen *et al*., 2011; Gill, Beaven & Cook., 2006), a lack of research for such data in rugby sevens players is noticeable. According to research by Smart *et al*. (2011) and Argus *et al*. (2012), rugby union forwards appear to be much stronger and powerful than the backs, whereas more mature players are stronger than younger players (Smart, 2011).

Muscular strength ability is commonly measured over a one- to three-repetition maximum (RM) in bench press, squat, chin-up, and power clean. Most available research does not distinguish strength abilities in rugby players according to positional variance, which is challenging as limited statistics are available to compare, for instance, a 15-a-side prop to a rugby sevens centre.

Smart (2011) administered an assessment to determine the strength abilities of rugby union players accordingly to the various playing positions. Results captured display 1 RM average bench press (109 kg), chin-up (123 kg) and power clean (90 kg), predominantly for outside backs related to the 1 RM average bench press (119 kg), chin-up (132 kg) and power clean (98 kg) for loose forwards. Despite the fact that muscular strength is anticipated to be advantageous due to the physical demands of rugby union players, no studies have described the strength characteristics of rugby sevens players.

2.2.3.2 Muscular Power

A critical fitness component to the success of players in sports that include frequent collision is the capability to produce greatest muscular power in the shortest time period (Cronin & Hansen, 2005; Hori, Newton, Andrews, Kawamori, McGuigan & Nosaka, 2008).

Power is expressed as interconnected skills such as sprinting, jumping (Cronin & Hansen, 2005; Hori *et al*., 2008) and tackling capabilities (Gabbett *et al*., 2011). This fitness component is described to better interpret than strength of playing level between rugby players (Argus *et al*., 2010; Baker & Newton, 2006).

Testing protocols for muscular power is usually measured in the lower extremities of the player by means of the loaded jump squat. However, upper extremities may be measured by completing the loaded bench throws (Baker, 2008; Gabbett, Jenkins & Abernethy, 2011). Nevertheless, due to the numerous explosive movements such as accelerating and decelerating, jumping and tackling motion analysis of lower-body power in rugby sevens players is reported more frequently than upper-body power (Gabbett *et al.*, 2011). Additionally, higher vertical jumps relate to better-quality performance during contact situations (Ross *et al.*, 2015).

Higham *et al*. (2013) illustrate power estimates for rugby sevens players (mean 66.3 cm) counter-movement vertical jump and described equivalent outcomes to elite rugby league players (mean 63.9 cm) (Gabbett *et al*., 2011). Lower-body performance seems significant and most appropriate to game execution in rugby sevens players. Indeed, lower-body power and variety of sprinting abilities are fundamental in the skill required for both attacking and defending, allowing for better work rate as well as implementation of skills under exhaustion.

2.2.3.3 Muscular Endurance

As a result of the tackling and upper-body handling that occurs during tackles, training that determines upper-extremity strength and endurance possibly being advantageous to rugby sevens players (Meir, 1993). The American College of Sports Medicine (2002) has suggested that muscle endurance training or assessments involves a weight load range of 30-80% 1 RM and should include 10-25 or more repetitions (Kraemer, Adams & Caffarelli, 2002).

However, it is a challenge to select a test battery that achieves the prerequisites and is suited for rugby sevens. Meir (1993) and Meir, Newton, Curtis, Fardell and Butler, (2001) were the first investigators to administrate and describe upper-body muscular endurance assessments in rugby players. A push-up test with the repetitions completed within a certain time (for example, 60 seconds) was used as the indicator of muscular endurance.

One-minute push-up tests are used in various other environments, such as the military, to calculate muscle endurance. However, the test has characteristically not been standardised according to each participant's dissimilar body mass (LaChance & Hortobagyi, 1994; Gouvali & Boudolos, 2005). As such, it is possible that heavier participates may complete fewer repetitions due to fatigue, indicating low muscular endurance ability, but when analysed may in fact be performing more absolute work.

2.2.3.4 Repeated Sprint Ability

Repeated sprint ability may be defined as the capability to sustain speed over a sequence/shuttle of sprints with minimal recovery. Repeated sprint ability is understood to be a significant part of victory in high-intensity intermittent sports (Girard, Mendez-Villanueva & Bishop, 2011).

Even though the interaction essentials of rugby sevens players are not recorded, it is predicted that players are likely to undertake sprinting in stages of repetitive high-intensity efforts (RHIE) (Austin *et al*., 2013). Austin *et al*. (2013) state that RHIE interactions transpire more often than repeated sprint ability in rugby matches, signifying training for RHIE interactions possibly will be of better importance compared to repeated sprint ability. Unfortunately, the RHIE essentials for rugby sevens are unidentified.

Repeated sprint ability is determined by means of several evaluations, composed of a sequence of quick sprints (≤ six seconds) with limited recovery time (≤ 30 seconds). Final account numbers are commonly transcribed as average duration of sprints (mean), overall time of sprints (totality of all sprints), exhaustion index (the best sprinting time minus the worst sprinting time reported as a percentage) and sprint decrement (totality of sprinting times divided by the best sprinting times, reported as a percentage) (Bishop *et al.*, 2011).

Average sprint time is usually related ($r = 0.9$) to the quickest sprint (Pyne *et al*., 2008), even though the index of exhaustion and sprint decrement are connected ($r = -0.5$) with lactate threshold (da Silva, Guglielmo & Bishop, 2010). The average time captured is apparent to be a dependable technique, while tests of exhaustion as well as percent decrement are not as consistent (Austin *et al*., 2013). Higham *et al*. (2013) is the only study to date that has tested repeated sprint ability of rugby sevens players. The study captures a total time of 24.8 seconds for international rugby sevens players when executing six 30-metre sprints, starting each sprint every 30.0 seconds.

As this study provides a reference point for investigation of repeated sprint ability in rugby sevens players, additional research should aim to examine the effectiveness of repeated sprint ability as a discriminatory measure between players of different competition levels.

2.2.3.5 Speed and Acceleration

Speed also known as the skill to cover ground rapidly from various initial speeds – an imperative component in field sports such as rugby sevens (Duthie, 2006). The skill to cover ground rapidly is valuable for rugby sevens players as the game is played with limited amount players (n=14) on the identical field dimensions as rugby union. However, limited data is recorded for speed characteristics in elite rugby sevens players, with only two applicable studies.

Higham *et al.* (2013) demonstrate the average 10-metre (1.74 seconds), 30-metre (4.02 seconds), and 40-metre (5.11seconds) sprint times of carefully selected international rugby sevens players and the highest velocity (velocity over 30–40 metres during 40-metre sprint) of 9.2 $m.s^{-1}$. When associated with carefully selected rugby union backs, international rugby sevens players look as if they have slower speeds across 10 metres (average 1.74 seconds) and equivalent speeds over 30 metres (average 4.02 seconds) (Higham *et al*., 2013; Smart, 2011).

However, sprint testing batteries have shown inconsistencies amongst studies (for example, surface area, starting position). Moreover, there is a lack of decisive reports on normative speed standards for rugby sevens players, and such, assessments that have been conducted with rugby union players are questionable. Yet speed remains an important aspect for investigation, as development of talent identification and player growth during various competition levels may be enhanced through additional investigation of speed characteristics of rugby sevens players. Moreover, as a part of testing speed over standardised distances (for example, 10-40 metres), understanding acceleration and maximal speed characteristics of rugby sevens players is imperative (Young, Russell, Burge, Clarke, Cormack & Stewart, 2008; Robbins & Young, 2012).

Investigators studying elite Australian Football players observed the association between dissimilar sprint distances and described a strong connection between the 10- and 20-metre ($r = 0.94$) times, 30-metre ($r = 0.89$) and 40-metre ($r = 0.81$) times, signifying that these times are severely affected by acceleration (Robbins & Young, 2012).

A lack of association (r = 0.50) was captured between 10-metre results and 20-40-metre results, suggesting that the 20-40-metre times are reliant on highest speed rather than acceleration. The data captured for the elite American Football players present similar difference between measures of acceleration and maximal speed, where minor and limited associations were detected between speeds over 0-9.1 metres and 18.3-36.6 metres during a 36.6-metre sprint across all playing positions (Robbins & Young, 2012).

As such, both acceleration and maximal speed are of similar importance for the rugby sevens player and are vital in development of specific training programmes. In conclusion, the fitness components that were described appear to be the important requirements for rugby sevens.

2.3 TRAINING PROGRAMMES AND PRINCIPLES FOR RUGBY SEVENS

The competitive nature and demands of rugby sevens are complex due to a great variety of movement patterns of players on the field (Jougla, Micallef & Mottet, 2009). Therefore, it is imperative that strength and conditioning coaches of rugby sevens teams track the effect of intervention programmes and modify movements of play accordingly to create sport-specific training programmes. Peak fitness levels in players will be obtained when using the specific training programmes as players will have the ability to manage with the modern-day type of rugby (King, Clark & Kellman, 2010).

Strength and conditioning for rugby sevens has become progressively important in order to decrease risk of injuries and improve performance (Faigenbaum, Kraemer, Cahill, Chandler, Dziados, Elfrink, Forman, Gaudiose, Micheli, Nitka & Roberts, 1996). Experimental findings along with recognised scientific research have revealed that strength, power, speed, agility, fitness, and body size are all significant characteristics affecting the overall performance of a rugby sevens player (Duthie *et al*., 2003). The physical demands on rugby sevens players are multifaceted, and the concurrent advances in the performance measures involve a thoughtfully planned conditioning programme (Gamble, 2004).

Strength and conditioning instructors design pre-planned methodical differences in training specificity, intensity and volume organised in periods or cycles within a total programme. The programme strategy is termed periodisation (Baechle & Earle, 2008), and motive is to encourage long-term training and improvements. This methodical and progressively planned training programme prepares the player for high-intensity competition levels. It also considers ideal recovery time and balances training load and recovery.

The idea of periodisation is that exercise loads implemented should be cautiously planned with controlled amounts (Bompa & Carrera, 2005). The plan works as a prototype for the player and strength and conditioning coach as it offers a point of reference for monitoring the workload and recovery required for inducing training adaptations (Bompa & Carrera, 2005). In addition, periodised training creates the foundation to differentiate between high-volume and low-intensity training, which assists with the development of aerobic fitness. Generally, a high-intensity training programme is designed and, as the season progresses, the programme is modified to take into account performance (Hellard, Avalos, Millet, Lacoste, Barale & Chatard, 2005). Manipulation of training workloads during the season achieves the desired adaptations. Most resistance training is performed during the off-season period and consequently has the highest utilisation and manipulation of periodisation (Haff, 2004). This method of training regulates and reduces the risk of over-training, allowing the players to peak at a foreseeable time, usually concurring with vital competitions (Hellard *et al.*, 2005).

The physical capacity and appearance of the rugby sevens players is achieved through a specific strength training (anaerobic fitness) programme. Methods of adapting the body to various training loads can be completed using strength training principles. This principle allows for individualised training programmes to be formulated that will suit the players' specific needs related to the various positions (Bompa & Carrera, 2005). Duthie (2006) notes that significant training principles in rugby sevens should be made up of of specificity, overload, progression and reversibility, all in a periodised manner.

2.3.1 Specificity

Rugby sevens places excessive demands on the players' speed, strength, power and agility capabilities. The principle of specificity states that the player receiving various training workloads will adapt to the load imposed in a very specific manner (Schmidtbleicher, 1992).

The effects of training are narrowed to the specific systems throughout training, permitting adaption at its maximum level (International Rugby Board, 2012). Selective conditioning drills and activities are implemented by the strength and conditioning coaches, allowing players to meet specific requirements during match play. Essentially, the principle places emphasis on the fact that the players' training should be directed by the stresses of the game and their position on the field (International Rugby Board, 2012).

2.3.2 Overload

This principle means that a player must increase workload in order to improve (Plowman & Smith, 2011). The player cannot improve in the absence of overload in exertion or intensity of sessions. If the training stress load is low, it will result in detraining (Izquierdo *et al.,* 2007). Conversely, if the overload is too high and accomplished within a short period of time following the last training unit, the player may not adjust positively, leading to breakdown, fatigue and injury (Bompa & Carrera, 2005).

Rugby sevens-specific training programmes are principally dictated by the demands of the game. Gabbett (2004) proposes that controlling training loads by increasing the strength of training sessions in relation to overall period of training sessions will grow and develop the players. Luger and Pook (2004) state that training factors for instance exercise assortment, frequency, intensity, rest and volume must be manipulated to exhaust muscle, nerves and energy systems to reach super compensation.

To progress and improve the rugby sevens players' fitness, it is imperative to put their bodies under additional stress. A systematic order needs to be followed when manipulating the training load (first increase the frequency, then volume or duration, and lastly an increase in intensity) to progressively develop the rugby sevens players' fitness while preventing the risk of extreme fatigue and injury, promoting long-term adaptations that will lead to advanced performance (Duthie, 2006).

2.3.3 Frequency

Enhancement of aerobic fitness in the rugby sevens players can be observed by increasing the amount of training sessions held in a week (Powers & Howley, 2012), limiting fatigue and aiding lactate clearance while facilitating recovery between sessions of high-intensity activity (Tomlin & Wenger, 2001).

2.3.4 Intensity

Intensity is the overload on the cardiovascular system that is required to bring about a training effect, where higher-intensity exercises are for the improvement of $V0_{2\ max}$ (Powers & Howley, 2012).

It has been demonstrated that more time is spent in high-intensity activity zones when compared to the other zones during match-play in rugby sevens (Suarez-Arrones *et al.*, 2012).

2.3.5 Time/duration

The time/duration must be viewed together with intensity, as the total work accomplished per session is an important variable associated with the development of fitness in rugby sevens players (Powers & Howley, 2012).

2.3.6 Adaptation

Adaptation may be defined as the procedure of changing to a physical, environmental or psychological stress. General adaptation syndrome is defined by Selye (1956) as a phenomenon where the work input is the source of a provisional decrease in performance or function of a player, which is to be consistent with the adaptation that advances the players' performance. This enhanced reaction is termed the "supercompensation" theory of training (International Rugby Board, 2012).

According to the International Rugby Board (2012), adaptation is always at a cost – all systems are skilled to assist this adaptation. For example, a long-distance athlete who advances a high-endurance volume may see an effect on his speed, power, and response capabilities. Adaptation invests all energies interested in improving the system of primarily importance Training for rugby sevens is challenging due to the requirement of developing numerous fitness components. Nevertheless, it can be achieved by means of a periodised approach to training ensuring, in which key components required to participate in rugby sevens are equally developed by the International Rugby Board. (2012).

2.3.7 Reversibility

According to Izquierdo *et al*. (2007), improvements achieved through training sessions are negatively affected when training concludes. In other words, should a player fail to sustain the training workload, adaptations will be lost. The detraining effect is generally slower than the initial increase in fitness levels of the player. For example, if rugby sevens players encountered a limited pre-season period of preparation (six weeks) and on no account may strength training take place during in-season, then the gains made during pre-season may be slowly lost to such an extent that the player returns to baseline fitness at an early point during the in-season period.

In contrast, investigations have demonstrated that if strength training is sustained at a limited frequency during the in-season, then gains in strength can persist (Kraemer, Hakkinen, Triplett-Mcbride, Fry, 2003; Izquierdo *et al.*, 2007; Weiss, 1988).

2.3.8 Individualisation

Rugby sevens players achieve greater enhancements in fitness and performance when individualised training programmes are implemented (Rhea, Kenn & Dermody, 2009), as each individual player is required to perform different tasks in various positions. Modifications are based on the players' unique and distinctive morphological make-up (Higham *et al.*, 2013).

Hennessy (2011) gives an example that certain players are genetically strong, or fast, whereas others can have exceptional distinctive endurance levels. Individualisation allows changes to be apparent in different age groups amongst players. Where mature players display a more enlarged training background resulting in advanced fitness levels compared to younger players. In addition, the ability to return to a normal state (recovery) may also be evident. For instance, it has been reported that 80% of players who completed strength training during preseason demonstrated a greater recovery rate whereas 20% of players failed to fully recover (Bishop, Jones & Wood, 2008).

To advance the specificity (or individualisation) of strength and conditioning programmes, further research needs to identity the correlation amongst physical characteristics and specific match performance in rugby sevens (Ross *et al*., 2015).

2.4 SUMMARY

The literature review illustrated an understanding of the history of rugby sevens and the physiological needs and fitness parameters, training programmes and training principles essential to rugby sevens players. When associated with traditional rugby union, rugby sevens players experience comparatively similar bodily and practical strains throughout a competition, permitting comparable training amongst the various positional groups.

The literature review intended to make available suitable background material pertaining to rugby sevens and research models of aerobic and anaerobic training and their impact on physical attributes and performance in rugby sevens. In Chapter 3, the methods of the study will be described.

CHAPTER 3: METHODOLOGY

3.1 INTRODUCTION

The purpose of this chapter is to discuss the methodology of the study and the conceptual framework. Morphological characteristics, cardiorespiratory fitness, anaerobic fitness, muscular strength and endurance, agility, maximum power, and acceleration and speed will be discussed, and explanations of the sample selection, procedure used in designing the instrument and collecting the data, the statistical procedures used to analyse the data, and the 12-week intervention programme will be provided.

3.2 RESEARCH DESIGN

The study design was a descriptive, interventional study. Critical problems and expansion of knowledge in various aspects of exercise science and sports science may be derived through descriptive research (Thomas & Nelson, 2005). On the other hand, interventional research evaluates the direct impacts using prospective and specifically tailored measures (Thiese, 2014).

Permission to approach these players was obtained by the Ethics Committee of the Faculty of Health Sciences at the University of Johannesburg (NHREC No: REC-241112-035) (Appendix C). Thereafter, permission was obtained from the managers, conditioning coaches and players of the various teams (Appendix D). These subjects were required to read the information sheet (Appendix A) and sign an informed consent form (Appendix B) before participating in the study.

3.3 SAMPLING

The subjects were invited to participate from three separate rugby unions. Fifty-four (n=54) rugby sevens players from the Golden Lions, Naka Bulls Pretoria Rugby Academy, and the University of Johannesburg between the ages 18 and 25 years participated in the research. Subjects had to comply with the following inclusion and exclusion criteria:

Inclusion Criteria

- Male rugby sevens players between the ages of 18 and 25 years;
- Played more than three or more provincial rugby sevens matches;
- Injury-free for three months;
- Participated in aerobic and anaerobic training; and
- Completed the informed consent form (Appendix B).

Exclusion Criteria

- Non-rugby sevens players not between the ages of 18 and 25 years;
- Played fewer than three provincial matches;
- Injured within three months;
- Players that did not participate in aerobic and anaerobic training and;
- Informed consent form (Appendix B) was not completed.

3.4 DATA COLLECTION PROCEDURES

Quantitative data was collected by means of the physiological tests. Each participant underwent pre-morphological characteristics, cardiorespiratory, muscular strength and muscular endurance testing. A 12-week intervention training programme adapted from Agha-Alinejad, Kohanpour, Sanavi, Behrouzi and Mirsepasi (2013), Jones (2003) and Brandon (2003) was implemented.

At the end of the 12-week intervention, a post-test battery similar to the pre-test battery was conducted.

Table 1: 2.1- Measuring tools

	TEST	PROTOCOL	EQUIPMENT	REFERENCE
1	Morphological characteristics	▪ Weight ▪ Height ▪ Seven site Skinfold	▪ Seca 813 Robusta digital floor scale (Canada) ▪ Harpenden skinfold calliper (Rosscraft Industries Canada) ▪ Seca 213 portable stadiometer (Canada)	Heyward (2014)
2	Aerobic fitness	▪ YYIR test	▪ 30 metre flat surface ▪ Marking cones ▪ Measuring tape ▪ Audio and CD player	Bangsbo, Iania & Krustrup (2008)
3	Anaerobic fitness	▪ 250m shuttle run	▪ Marking cones ▪ Measuring tape ▪ Stopwatch	Coopoo & Govender (2002)
4	Muscular strength	▪ 1 RM bench Press ▪ 1 RM squat	▪ Standard flat bench with barbell stand or rack ▪ Standard squat rack ▪ Olympic barbell ▪ Olympic weight plates	Baechle & Earle (2016)
5	Muscular endurance	▪ 1-minute push-up test ▪ 1-minute bent knee sit-up test	▪ Stopwatch ▪ Flat, non-slippery surface ▪ Gym mat	Wood (2008)
6	Agility	▪ Illinois agility test	▪ Electronic light sensor timing gates(Fusion Sport International, 2010) ▪ Measuring tape ▪ Marking cones	Getchell (1979)
7	Maximum power	▪ Vertical jump	▪ Measuring tape ▪ Chalk or marker ▪ Swift yardstick	Baechle & Earle (2016)
8	Acceleration & speed	▪ 10m sprint ▪ 40m sprint	▪ Electronic light sensor timing gates (Fusion Sport International, 2010) ▪ Measuring tape ▪ Measuring cones	Mackenzie (2008)

Each of the tests administrated in this study will be described briefly below.

3.4.1 Morphological Characteristics

Purpose

Measurements of height, weight, circumferences and skinfolds are used to estimate morphological characteristics. Although skinfold measurements are more difficult that other anthropometric procedures, they provide a better estimate of body fatness than those based only on height, weight, and circumferences (Lohman, Houtkooper & Going, 1997).

Required Equipment

- Seca 813 Robusta digital floor scale (Canada)
- Harpenden skinfold calliper (Rosscraft Industries Canada)
- Seca 213 portable stadiometer (Canada)

Test Procedure

Morphological characteristics were conducted according to the protocol of the International Society for the Advancement of Kinanthropometry (ISAK) (Norton & Olds, 1996).

Body mass was measured in kilograms to the 0.1 kg on a calibrated scale (Trojan, BSA16056v, Duteck Industrial Co. Ltd, Taiwan) and stature was measured to the nearest 0.01 centimetre (cm) using a standard wall-mounted stadiometer (Seca Stadiometer, 216, Seca, USA) with the subjects wearing minimal clothing and no shoes.

Skinfolds of the triceps, subscapular, iliac crest, supraspinale, abdominal, front thigh, and medial calf was measured to the closest 0.2 mm using a Harpenden skinfold calliper (Rosscraft Industries, Canada). The skinfolds were calculated as the sum of triceps, biceps, subscapular, iliac crest, supraspinale, abdominal, front thigh, and medial calf skinfolds.

Percentage body fat was calculated using the equations provided by Heyward (2014) and body mass index (BMI) by dividing body mass by stature squared (weight/height^2) and expressed as kilograms per square metre (kg.m^{-2}) (Plowman & Smith, 2011).

$$\text{BMI} = \frac{\text{mass(kg)}}{(\text{height(m)})^2}$$

Fat mass (FM) was calculated by multiplying body mass measure in kilograms (kg) by fat percentage (%), which was divided by 100 [body mass x (fat percentage/100)]. Lean mass (LM) measured in kilograms (kg) was calculated by subtracting the subject's body mass (BM) by fat mass (FM) [body mass (kilograms) – fat mass (kilograms)] (Shaw, Shaw & Mamen, 2010).

$$\text{Fat mass (kg)} = \frac{\text{Body weight (kg)} \times \%\text{BF}}{100}$$

3.4.2 Aerobic Fitness

Purpose

The YYIRT1 test was developed to measure an athlete's ability to repeatedly perform high-intensity aerobic work (Bangsbo *et al.*, 2008). Since then, it has established itself as one of the most commonly used aerobic field tests for youth and recreational athletes. It has been shown to be a valid and reliable predictor of high-intensity aerobic capacity and $VO_{2\,max}$ among athletes from various sports and competition levels (Bangsbo *et al.,* 2008).

Required Equipment

- Facility – flat and non-slippery (minimum length of 30m)
- Cones
- Measuring tape (> 30m)
- YYIR test audio CD or MP3
- CD or MP3 player with loud speaker (volume of speaker is particularly important)
- Performance recording sheet

Test Procedure

The YYIR test was used to assess the role of concurrent resistance and aerobic training in improving cardiorespiratory fitness (VO_{2max}) using cones marked out two lines of 20 metres apart (Bangsbo *et al.,* 2008). The cones are used to mark out three lines, 20 metres and 5 metres (recovery test) apart.

The subject starts on or behind the middle line and begins running 20 metres when instructed by the CD. The subject turns and returns to the starting point when signalled by the recorded beep.

There is an active recovery period (5 and 10 seconds respectively for the endurance and recovery versions of the test) interjected between every 20 metres (out and back) shuttle, during which the subject must walk or jog around the other cone and return to the starting point.

A warning is given when the subject does not complete a successful out and back shuttle in the allocated time; the subject is removed the next time they do not complete a successful shuttle (Bangsbo *et al.,* 2008).

Scoring System

Aerobic fitness was calculated using the formula (Bangsbo *et al.,* 2008):

$$V0_{2max}\ (\text{mL/min/kg}) = \text{YYIR final distance (m)} \times 0.0084 + 36.4$$

3.4.3 Anaerobic Fitness

Purpose

The purpose here was to measure resistance to fatigue after repeated bouts of short-duration, high-intensity activity (Coopoo & Govender, 2002).

Required Equipment

- Facility – flat and non-slippery (minimum length of 30 metres)
- Cones
- Measuring tape (>30 metre)
- Performance recording sheet

Test Procedure

The test was set up on a grass surface of 10 x 1 metres. The subject stands behind one of the lines in a chosen starting position. The subject starts to run on the command "Go!" which is preceded by the word "Ready". The subject runs 10 metres to the second line at the opposite end, bends over it and touches the ground on the other side with both hands.

The subject then turns around and returns to the starting line to repeat the procedure, until 250 metres are completed in 25 runs.

On the last lap, the subject runs across the finishing line – in other words, the line opposite end of the starting line. The subject is advised to maintain an even pace (Coopoo & Govender, 2002).

Scoring System

The score is the time it takes the subject to complete the 25 runs to the nearest 1/10th of a second.

3.4.4 Muscular Strength

3.4.4.1 One Repetition Maximum Bench Press

Purpose

This 1 RM test is defined as the maximal weight an individual can lift for only one repetition with correct technique. It is most commonly used by strength and conditioning coaches to assess strength capacities and strength imbalances, and to evaluate the effectiveness of training programmes (Baechle & Earle, 2016).

Required Equipment

- Standard flat bench with barbell stand or rack
- Olympic barbell
- Olympic weight plates

Test Procedure

This exercise required the subject to lie in a supine position on a bench with his feet flat on the floor and his hips and shoulders in contact with the bench. Hand spacing was usually 1.5 times the player's bi-acromial width.

The subject started the lift by lowering the bar, in a controlled manner, to the centre of the chest, touching the chest lightly (no bouncing the bar on the chest) and then extending upwards until the arms were in a fully locked position. The subject was advised to inhale when lowering the bar and to exhale when pressing it.

The exercise was performed until momentary muscular failure. The subjects did not complete a maximum lift without a spotter (Dooman & Vanderburgh, 2000).

There were several reasons for disqualifying a lift, and these included:

- Lifting the buttocks off the bench during the movement
- Bouncing the bar off the chest
- Uneven extension of the arms
- Touching of the bar by the spotter

Scoring System

1 RM = The greatest amount of weight that can be lifted with the proper technique for only one repetition.

3.4.4.2 One-Repetition Maximum Squat

Purpose

The purpose of this test was to assess the maximum muscular strength of the leg musculature (Baechle & Earle, 2016).

Required Equipment

- Standard squat rack
- Olympic barbell
- Olympic weight plates

Test Procedure

The subject stood erect with feet placed 5-10 cm wider than shoulder width and toes pointing slightly outwards. The bar could rest on the middle of the trapezius muscle of the upper back, while the subject gripped the bar with both hands positioned 10-15 cm from the shoulders. The subject then performed a controlled squat until an angle of 90 degrees was reached at the knee joints. The subject then extended the knees to fully return to the starting position.

Subjects were instructed to keep their heads up in the neutral position throughout the entire movement (Dooman & Vanderburgh, 2000). The subject was prohibited to complete a lift without a spotter.

There are several reasons for disqualification of a lift:

- More than one recovery attempt
- Touching of the bar by the spotter
- Shifting or movement of the feet or hands during the lift

Scoring System

1 RM = The greatest amount of weight that can be lifted with the proper technique for only one repetition.

3.4.5 Muscular Endurance

3.4.5.1 One-Minute Maximum Push-Up Test

Purpose

The push-up test was used to assess endurance of the upper-body musculature (Baechle & Earle, 2016).

Required Equipment

- Stopwatch
- Flat non-slippery surface
- Gym mat

Test Procedure

The subjects had to lay prone on the ground by fully extending the elbows and using the toes as the pivot point. The upper body had to be kept in a straight line and the head kept up. The subjects could return to the down position, touching the chin to the mat or ground.

The stomach and thighs could not reach the mat. The subjects had to perform as many consecutive repetitions as possible in one minute (Baechle & Earle, 2016).

Scoring System

Record the number of correctly completed push-ups in one minute.

3.4.5.2 One-Minute Maximum Sit-Up Test

Purpose

The bent-knee sit-up test was used to assess muscle endurance of the abdominal musculature (Baechle & Earle, 2016).

Required Equipment

- Stopwatch
- Flat non-slippery surface
- Gym mat

Test Procedure

The subjects were required to lie in a supine position on the floor. Subjects then flexed the knees to bring the heels close to the buttocks, folding the arms across the chest or abdomen. The subjects were required to flex the neck to move the chin toward the chest, keeping the feet, buttocks, and lower back flat and stationary on the floor, curling the torso towards the thighs until the upper body was off the floor. In completion of the movement, the subjects then uncurled the torso back to its starting position while keeping the feet, lower back, and arms in the same position (Baechle & Earle, 2016).

Scoring System

Record the number of correctly completed sit-ups in one minute.

3.4.6 Illinois Agility Test

Purpose

This test measured the player's ability to accelerate, decelerate, and change direction (Getchell, 1979).

Required Equipment

- Electronic light sensor timing gates (Fusion Sport International, 2010)
- Measuring tape
- Cones

Test Procedure

The test started with the player in prone position on the starting line with his chin touching the floor. The first light sensor was placed at the start line, 50 centimetres above the ground.

The light sensor was activated as the subject moved from the prone position. The second light sensor was placed at the finish line.

Subjects set off, accelerating towards and around the opposite cone. He then ran towards the starting line's middle cone, zig-zagged through the cones downward and again upwards, sprinted to the last cone on the far side and finished at the finish line. The subject was tested on a grass surface; therefore, boots were used. No starting blocks were allowed. The player had two attempts with the minimum rest period of four minutes between the tests.

Scoring System

The fastest time was recorded in seconds (Getchell, 1979).

3.4.7 Maximum Power

Purpose

The design of this test was to measure the take-off velocity and power output of the athlete (Baechle & Earle, 2016).

Required Equipment

- Vertec device (Questtec Corp, Northridge, California)
- Non-slippery surface

Test Procedure

The subject stood side-on to the Vertec jumping device. Keeping heels on the floor, the subject reached upward as high as possible, fully elevating the shoulder to displace the zero-reference vane. The take-off had to be from both feet, with no preliminary steps or shuffling.

Scoring System

The difference in distance between the standing reach height and the jump height is the score.

3.4.8 Acceleration and Speed

Purpose

The purpose of this test was to determine the subject's maximum sprint speed and the ability to accelerate from a stationary position (Baechle & Earle, 2016).

Required Equipment

- Electronic light sensor timing gates (Fusion Sport International, 2010)
- Measuring tape
- Marking cones

Test Procedure

Subjects had to warm up thoroughly before this test, as they were required to produce an all-out effort. It was strongly recommended that each subject performed a minimum of 10 minutes of sub-maximal running, followed by an appropriate stretching regimen, and some acceleration sprints, building up to full pace.

For this test, an electronic sprint timer, with photo-electric sensors, was set at chest height and placed at 10-metre and 40-metre intervals from the start line. The subject was instructed to position himself, in a crouched start position, 30 centimetres from the start line (this line was clearly marked). The first set of light sensors were placed at the start line, the second at 10 metres and the third at 40 metres.

The subject had to sprint maximally for 40-metres through the sensors. The subject was required to complete three maximal effort runs separated by a minimum of five minutes' recovery period (Mackenzie, 2008).

Scoring System

The fastest time was recorded in seconds (Baechle & Earle, 2016).

3.5 INTERVENTION PROTOCOL

Table 2: 3.1 - Guideline intervention programme

WEEK	WARM-UP	ANAEROBIC TRAINING	AEROBIC TRAINING	COOL DOWN
1 **2** **3**	10-minute jog 8-12-minute stretching	Nine exercise Protocols: 1 Chest press 2 Leg press 3 Shoulder press 4 Seated rows 5 Leg extension 6 Triceps extension 7 Leg curl 8 Bicep curl 9 Sit ups	Run around a 400-metre track until 2.4km is completed (*RPE = 12-14*)	5-minute jog 5-minute Stretching
4 **5** **6**	10-minute jog 8-12-minute stretching		Fartlek or continuous running, every 1.5 minutes introducing a harder run of 30, 60, or 90 seconds. (*RPE = 14-15*)	5-minute jog 5-minute stretching
7 **8** **9**	10-minute jog 8-12-minute stretching		Run around a 400-metre track until 2.4km is completed (*RPE = 15-17*)	5-minute jog 5-minute Stretching
10 **11** **12**	10-minute jog 8-12-minute stretching		Fartlek or continuous running, every 1.5 minutes introducing a harder run of 30, 60, or 90 seconds. (*RPE= 17-19*)	5-minute jog 5-minute Stretching

Table 2 provides a summary of the intervention programme, comprising a 5-day week training over a 12-week period. The subjects started with a standardized 10-minute jog followed by eight to 12 minutes of dynamic stretching. Anaerobic training was initiated with eight repetitions at 85% of the subject's 1 RM; the repetition increased by two every third week.

In conjunction with the anaerobic training, aerobic training was implemented, where every third week the running intensity (RPE) increased. After every training session, a standardized cool- down of five-minute jog followed by static stretching for five minutes was advised.

3.6 ETHICAL CONSIDERATIONS

A letter requesting permission to conduct the study was sent to the selected rugby sevens teams, a presentation on what the study entailed was delivered to the management and thereafter permission was granted. Ethical clearance for the study was obtained from the University of Johannesburg Health Sciences Faculty's Ethics Committee (Ethics Committee -241112-035) (Appendix C).

An informed consent form (Appendix B) fully explaining the purpose and process of the study was given to each player.

According to the Belmont Report, there are three foundational ethical principles relevant to the ethics of human subjects that a researcher should consider when conducting research. These are: beneficence, respect for human dignity, and justice (Houser, 2012; Schmidt & Brown, 2009; Polit & Beck, 2008). The ethical principles of autonomy, beneficence, no-maleficence, and justice (Dhai & McQoid-Mason, 2011) will be adhered to throughout the research process.

The assurance that confidentiality and anonymity as well as privacy would be honoured was offered to each rugby sevens player and was adhered to throughout data collection. Each participant was treated courteously, respectfully, and in an impartial manner. Players were informed that the assessment results would be communicated or made available to the subjects after the conclusion of the study. The researcher respected that participation was on a voluntarily basis and that subjects were free to withdraw at any stage.

3.6.1 Principle of Respect for Autonomy

The right to self-determination and the right to full disclosure are key elements of the principle of respect for autonomy. Participants were given a letter about the study that provided full disclosure about the research, allowing them an opportunity to make an informed decision of whether to participate in the study (Appendix A). An informed consent form was signed by willing participants (Appendix B) (Dhai & McQoid-Mason, 2011).

Results and additional information have been stored in a confidential and undisclosed site. Participation in this study was purely voluntary.

3.6.2 Principle of Non-maleficence

The researcher ensured participants' confidentiality of information and privacy. Anonymity within data-sharing is confidential and all participants consented to such. Only the researcher, statistician and supervisors have access to the participant data. All data will be destroyed after two years of publication of the research (Dhai & McQoid-Mason, 2011).

3.6.3 Principle of Beneficence

The researcher has an obligation to avoid, prevent, or minimise harm (i.e. maleficence), by refraining from subjecting the participants to unnecessary discomfort during the study. The researcher thus exercised sensitivity and vigilance during in-depth probing. The possible benefits for the participants and respondents were that they would be part of the development of strategies to facilitate scientific rugby sevens training guidelines (Appendix C) (Dhai and McQoid-Mason, 2011).

3.6.4 Principle of Justice

This principle included the right to fair treatment. The researcher has honoured all agreements; those that withdrew from the study were respected and not judged. The participants were treated fairly. The study used the supervisors' expert knowledge in qualitative research and theory to ensure rigour of the research process. The study was conducted with the utmost honesty and integrity (Dhai & McQoid-Mason, 2011).

3.6.5 Delimitations of the Study

The study found it necessary to institute the subsequent boundaries within the study; (1) subjects needed to be male, (2) subjects had to be selected as a part of the provincial rugby union in South Africa, (3) subjects needed to be between the ages of 18 and 25 years, (4) subjects had to be free from absolute and relative contraindications to exercise.

3.6.6 Limitations of the Study

The limitations of the present study were found to be that field testing was challenged by players' level of motivation; however, the researcher motivated all participants.

3.7 DATA ANALYSIS PROCEDURES

Statistical analysis of the data was completed using the Statistical Package for Social Sciences (SPSS) for Windows version 15.0 (SPSS Inc., Chicago, IL, USA). Descriptive and inferential statistical methods have been applied in the data analysis. All the data was analysed to determine the mean and standard deviation, which will show variance in the scores. Correlations and t-tests have been computed to determine test significance of differences. The p-value set at the 5% level ($p \leq 0.05$).

3.7.1 Descriptive Statistics

Descriptive statistics were used to describe data. The means, standard deviations, percentage improvement, and minimum and maximum scores for all variables measured were captured to determine variance among data. An indication of the physiological demands placed on the rugby players could be captured through descriptive data.

3.7.2 Inferential Statistics

Inferential statistics sample data was used to draw conclusions on the population group or groups from which sample measurements were obtained (Sheskin, 2000).

3.7.3 Dependent T-Test (Paired T-Test)

When was collected twice on the same subjects, an analysis was done with a dependent sample t-test to test whether a significant difference exists between the mean of two sets of scores (Thomas & Nelson, 2005). In this study this test was used to determine the significant differences between pre- and post-variables after the 12-week intervention programme.

3.8 SUMMARY

The purpose of this chapter was to describe the research methodology of this study, the sample selection, the procedure used in designing the instrument and collecting the data, and the statistical procedures used to analyse the data. The following chapter will present the data captured.

CHAPTER 4: PRESENTATION OF RESULTS

4.1 INTRODUCTION

The purpose of this chapter is to present the data collected as well as the statistical analysis thereof. The aim of the study was to establish the changes in physical parameters related to concurrent anaerobic and aerobic intervention training in selected provincial rugby sevens players. The subjects (n=54) aged between 18 and 25 years were invited from Gauteng male rugby sevens clubs to participate in the study. The pre- and post-test scores were computed for every subject. Significant differences were determined by the dependant-t test with significant differences set at a p-value of ≤ 0.05.

4.2 CLUB REPRESENTATION

The largest group represented in the total sample (Table 4.1) is Club A (51%), followed by Club B (33%) and Club C (17%).

Table 3: 4.1 - Representation of players

Number	Club	Player Representation (%)	Player Representation (n)
1.	Club A	50	27
2.	Club B	33	9
3.	Club C	17	18
Total (n)		**100**	**54**

4.3 DISTRIBUTION OF PLAYER POSITION

The player position distribution within this study is demonstrated in Table 4.2. The sample size for backs is significantly higher (n= 39) than the forwards (n= 15).

Table 4: 4.2 - Distribution of player position (n=54)

Number	Club	Backs	Forwards
1.	Club A	20	8
2.	Club B	6	3
3.	Club C	13	4
Total (n)		**39**	**15**

4.4 MORPHOLOGICAL CHARACTERISTIC VARIABLES

The baseline data for descriptive statistics of the provincial rugby sevens players that were invited volunteered to participated in pre- and post- fitness tests and a 12-week guideline intervention programme is presented in Table 4.3.

Table 5: 4.3 - Morphological characteristic results for the <u>total group</u> of rugby sevens players (n= 54) ($p \leq 0.05$)

Physical Measurement	Pre-Test Mean ± SD	Post-Test Mean ± SD	% Change	Sig. (p-value)
Sum of seven skinfolds (mm)	83 ± 38	75 ± 33	9,6	.0008
Body fat (%)	15 ± 6	14 ± 5	6,7	.0009
Fat mass (kg)	15 ± 8	14 ± 7	6,7	.0003
Lean mass (kg)	76 ± 9	77 ± 11	1,3	.14

Statistical differences were found between the mean sum of seven skinfolds (mm), body fat (%) and fat mass (kg).

The participants' sum of seven skinfolds was between 35 mm and 149 mm with a pre- and post- test mean of 83 ± 38 mm and 75 ± 33 mm respectively, indicating a 9,6% change after the 12-week intervention. These results were significant at the 5% level.

The participants' fat mass results reduced from 15 ± 8 kg to 14 ± 7 kg, resulting in a 6,7% pre- to post-test change. This result coincides with the pre-test lean body mass (76 ± 9 kg) compared to the post-test lean body mass (77 ± 11 kg). Although this was not significant, a mean score difference of 1.0 kg and 1,3% change was recorded between the pre- and post-test results, which was statistically significant for the post-intervention test.

There were significant statistical differences ($p \leq 0.05$) found in the sum of seven skinfolds (mm), body fat (kg) and fat mass (kg) when analysing the pre- and post-intervention test results after the 12-week intervention.

Table 6: 4.4- Morphological characteristic results between backs (n=39) and forwards (n=15) ($p \leq 0.05$)

Physical Measurement	Backs (n=39)				Forwards (n=15)				
	Pre-Test Mean ± SD	Post-Test Mean ± SD	% Change	Sig. (p-value)	Pre-Test Mean ± SD	Post-Test Mean ± SD	% Change	Sig. (p-value)	% Change between Backs and Forwards (Post-Test)
Sum of seven skinfolds (mm)	84±38	75±32	10,7	.0007	86±38	79±34	8,1	.004	5,1
Body fat (%)	16±6	14±5	12,5	.0007	16±6	15±5	6,3	.004	6,7
Fat mass (kg)	15±8	14±7	6,7	.0005	15±7	14±6	6,7	.007	0
Lean mass (kg)	77±9	79±12	2,5	.11	77±7	77±7	0	.94	2,5

The difference in morphological characteristic results between the backs (n=39) and the forwards (n=15) are presented in Table 4.4. The backs recorded 10,7% and forwards 8,1% improvement in the sum of seven skinfolds respectively.

The forwards recorded a drop of 6,3% in body fat and 6,7% in fat mass compared to the backs, who had 12,5% body fat and 6,6% fat mass reduction. The backs recorded better gain in lean mass (2,6%) compared to the no gain in the forwards.

The percentage changes (from post- to post-intervention) between backs versus forwards were 5,1% for the sum of seven skinfolds, 6,7% for decreased body fat and 2,5% for increased lean mass. However, no percentage change was recorded between post- and post-intervention results for backs versus forwards in fat mass.

4.5 AEROBIC AND ANAEROBIC VARIABLES

Table 7: 4.5 - Aerobic and anaerobic results for the total group of rugby sevens players (n=54) ($p \leq 0.05$)

Physical Measurement	Pre-Test Mean ± SD	Post-Test Mean ± SD	% Change	Sig. (p-value)
Predicted VO_{2max} ($ml.kg^{-1}.min^{-1}$) (Aerobic)	53 ± 0.7	54 ± 0.6	1,9	.01
250 m shuttle run (sec) (Anaerobic)	65 ± 3	63 ± 3	3,1	.0006

Table 4.5 reflects the aerobic and anaerobic performance of the total rugby sevens group. No mean difference was captured in the aerobic results; therefore, no significant statistical differences were recorded between pre- and post-intervention results.

The anaerobic 250 metre shuttle run results indicated a two second mean improved difference between the pre- and post-intervention scores, resulting in an improvement of 3,1%. There were significant statistical differences ($p \leq 0.05$) found for anaerobic values between the pre- and post-intervention results.

Table 8: 4.6 - Aerobic and anaerobic results between the <u>backs (n=39) and forwards (n=15)</u> ($p \leq 0.05$)

Physical Measurement	Backs				Forwards				
	Pre-Test Mean ± SD	Post-Test Mean ± SD	% Change	Sig. (p-value)	Pre-Test Mean ± SD	Post-Test Mean ± SD	% Change	Sig. (p-value)	% Change between Backs and Forwards (Post-Test)
Predicted VO_{2max} ($ml.kg^{-1}.min^{-1}$) (Aerobic)	53±0.8	54±0.7	1,9	.06	54±0.6	54±0.5	0	.05	0
250 m shuttle run (secs) (Anaerobic)	54±3	53±3	3,1	.0006	65±4	64±3	1,5	.06	1,6

A comparison of aerobic fitness components between the backs and forwards indicated a 1,9% improvement in the backs and 0% change in the forwards. Therefore, no significant differences ($p \geq 0.05$) were captured for backs versus forward in the aerobic fitness component.

However, the anaerobic scores for the backs showed a decrease of 3,1% in time compared to a 1,5% decrease in the forwards. The percentage change (post- to post-intervention) between backs and forwards for the aerobic component showed no improvement when compared to the 1,6% change in the anaerobic component. Therefore, significant differences ($p \leq 0.05$) are only captured in the anaerobic fitness component for backs.

4.6 STRENGTH AND MUSCLE ENDURANCE VARIABLES

Table 9: 4.7 - Strength and muscle endurance results for the total group rugby sevens group (n=54) ($p \leq 0.05$)

Physical Measurement	Pre-Test Mean ± SD	Post-Test Mean ± SD	% Change	Sig. (p-value)
Squats (kg)	160 ± 31	183 ± 24	14,3	.0002
Bench press (kg)	113 ± 16	134 ± 17	18,5	.0002
One-minute push- up (no.)	46 ± 11	77 ± 17	67,3	.0001
One-minute sit-up (no.)	65 ± 18	77 ± 17	18,5	.0002

Table 4.7 reflects changes in the strength and muscle endurance variables of the total group. Statistical differences were recorded between the pre- (160 ± 31 kg) and post-intervention (183 ± 24 kg) 1 RM squat test, with a 14,3% improvement.

The 1 RM bench press also recorded statistically significant differences ($p \leq 0.05$) between the pre- (113 ± 16kg) and post-intervention (134 ± 17kg) test scores, with a 18,5% improvement.

The one-minute push-up score improved statistically ($p \leq 0.05$) with 67,3% from pre- (46 ± 11) to post-intervention (77 ± 17). The one-minute sit-up test also recorded statistically significant differences ($p \leq 0.05$) between the pre- (65 ± 18) and post-intervention (77 ± 17) test scores with a 18,5% improvement.

Table 10 4.8 - Strength and muscle endurance results between backs (n=39) and forwards (n=15) (p ≤ 0.05)

Physical Measurement	Backs				Forwards				
	Pre-Test Mean ± SD	Post-Test Mean ± SD	% Change	Sig. (p-value)	Pre-Test Mean ± SD	Post-Test Mean ± SD	% Change	Sig. (p-value)	% Change between Backs and Forwards (Post-Test)
Squats (kg)	163±30	186±24	14,1	.0002	161±33	186±27	15,5	.0001	0
Bench press (kg)	116±17	138±18	19,0	.0002	111±14	134±13	20,7	.0004	2,9
One-minute push up (no.)	67±20	78±18	16,4	.0003	64±14	77±16	20,3	.001	1,3
One-minute sit up (no.)	46±11	55±11	20,0	.0008	50±10	58±11	16	.0007	5,2

Table 4.8 depicts the muscle strength and endurance results between the backs (n=39) and forwards (n=15). The backs recorded a 14,1% and 19,0% improvement in the squat and bench press respectively. The forwards recorded an improvement of 15,5% in the squat and 20,7% in the bench press. Muscle strength components recorded statistically significant differences ($p \leq 0.05$). The forwards recorded a greater improvement (20,3%) compared to that of the backs (16,4%) in the 1-minute push up test. The backs, however recorded better muscle endurance post intervention (20%) than forwards (16%) for the 1-minute sit-up test. Muscle endurance components recorded statistically significant differences ($p \leq 0.05$).

In a (post- and post-intervention) comparison, no change was recorded in the 1 RM squat results. However, the 1 RM bench press resulted in 2,9% improvement (strength component). Muscle endurance results improved by 1,3% (1-minute push up) and 5,5% (1-minute sit-up) respectively.

4.7 EXPLOSIVE POWER, SPEED AND AGILITY VARIABLES

Table 11: 4.9 - Explosive power and speed results for <u>total rugby sevens group (n=54)</u> ($p \leq 0.05$)

Physical Measurement	Pre-Test Mean ± SD	Post-Test Mean ± SD	% Change	Sig. (p-value)
Vertical jump (cm)	27 ± 0.3	28 ± 0.3	3,6	.0004
10 m sprint (secs)	1.9 ± 0.4	1.5 ± 0.3	21,1	.0008
40 m sprint (secs)	5.5 ± 0.4	5.2 ± 0.3	5,5	.0004
Agility (secs)	15.6 ± 0.8	15.1 ± 0.7	3,2	.0001

Table 4.9 indicates a mean difference of 1.0 cm and a 3,6% improvement between the pre- and post-intervention explosive power tests for the total group. A mean difference of 0.4 seconds and 0.3 seconds for the 10-metre and 40-metre sprints were recorded. The results recorded demonstrate a greater improvement in the 10-metre sprint (21,1%) when compared to the 40-metre sprint (5,5%).

Agility recorded statistically significant differences ($p \leq 0.05$) between the pre- (15.6 ± 0.8) and post-intervention (15.1 ± 0.7) test scores, demonstrating a 3,2% improvement.

Significant statistical differences ($p \leq 0.05$) were recorded for explosive power, 10-metre and 40-metre sprints as well as for agility.

Table 12: 4.10 - Explosive power and speed results between the backs (n=39) and forwards (n=15) ($p \leq 0.05$)

Physical Measurement	Backs				Forwards				
	Pre-Test Mean ± SD	Post-Test Mean ± SD	% Change	Sig. (p-value)	Pre-Test Mean ± SD	Post-Test Mean ± SD	% Change	Sig. (p-value)	% Change between Backs and Forwards (Post-Test)
Vertical jump (cm)	27±0.3	28±0.3	3,5	.0009	26±0.4	27±0.4	3,7	.0008	3,6
10 m sprint (secs)	1,9±0.4	1,6±0.3	15,8	.0002	1,9±0.4	1,8±0.3	5,2	.001	11,1
40 m sprint (secs)	6±0.4	5±0.3	16,7	.0004	6±0.4	5±0.3	16,7	.008	0
Agility (secs)	16±0.7	15±0.6	6,3	.0001	16±1	15±0.8	6,3	.005	0

Table 4.10 depicts the explosive power and speed results between the backs (n=39) and forwards (n=15). The backs recorded a 3,5% improvement in explosive power compared to the forwards (3,7%), resulting in a 3,6% change between the positional groups, therefore there was significant statistical differences ($p \leq 0.05$) in these results.

In the post- and post-intervention comparison, an 11,1% change between the backs and forwards was captured for the 10-metre sprint. Significant statistical differences ($p \leq 0.05$) were captured from pre- to post-invention in the 40-metre (16,7%) and agility (6,3%) for backs and forwards.

Thus, in a (pre- to post-intervention) comparison no change was recorded between backs versus forwards for the 10- and 40-metre sprint as well as agility results.

4.8 CORRELATIONS BETWEEN PHYSICAL ATTRIBUTES AND PERFORMANCE INDICATORS VERSUS AEROBIC AND ANAEROBIC FITNESS IMPROVEMENTS

Table 4.11 demonstrates that the correlation coefficients (r) are close to zero, indicating that there is a weak correlation. Values closer to one suggest stronger correlations with negative values indicating a downward sloping relationship.

Table 13: 4.11 - Correlations (degrees of freedom =52) (r – correlation coefficient, p) between physical parameters and aerobic and anaerobic fitness improvement

Physical Parameter	Aerobic Fitness Improvement		Anaerobic Fitness Improvement	
	Significance (Pre to Post)	Correlation (r)	Significance (Pre to Post)	Correlation (r)
Sum of seven skinfolds (mm)	$p \geq 0.05$	0,05	$p \leq 0.05$*	0,01
Body fat (%)	$p \leq 0.05$*	0,03	$p \leq 0.05$*	0,01
Fat mass (kg)	$p \geq 0.05$	0,25	$p \leq 0.05$*	0,00
Lean mass (kg)	$p \geq 0.05$	0,26	$p \leq 0.05$*	0,01

*The non-parametric Spearman's correlation (p-value = 0.04) shows that there is a strong correlation between aerobic fitness and a drop in body fat (kg).

Conversely, there is a strong correlation between anaerobic fitness and a decrease in the sum of seven skinfolds (mm), drop in body fat (%) and fat mass (kg), and gain in lean mass (kg) after the 12-week intervention.

Table 14: 4.12 - Correlations (degrees of freedom=52) (r – correlation coefficient, p) between performance indicators and aerobic and anaerobic fitness improvement

Performance Indicator	Aerobic fitness		Anaerobic fitness	
	Significance (Pre to Post)	Correlation (r)	Significance (Pre to Post)	Correlation (r)
Squat (kg)	$p \geq 0.05$	0,05	$p \geq 0.05$	0,11
Bench press (kg)	$p \geq 0.05$	0,07	$p \geq 0.05$	0,24
Push up (no.)	$p \geq 0.05$	0,24	$p \leq 0.05$*	0,02
Sit up (no.)	$p \geq 0.05$	0,12	$p \geq 0.05$	0,08
Vertical jump (cm)	$p \geq 0.05$	0,12	$p \leq 0.05$*	0,03
Ten metre sprint (secs)	$p \geq 0.05$	0,06	$p \geq 0.05$	0,12
Forty metre sprint (secs)	$p \geq 0.05$	0,05	$p \geq 0.05$	0,12
Agility (secs)	$p \geq 0.05$	0,06	$p \leq 0.05$*	0,04

*The non-parametric Spearman's correlation (p-value = 0.04). A strong correlation was recorded between the performance indicators (push-ups, explosive power and agility) and anaerobic fitness.

Table 4.12 reflects the correlation between the performance indicators and aerobic and anaerobic training improvements in physical parameters or performance indicators ($p \leq 0.04$). Strong correlations were recorded between performance indicators (push-ups, explosive power and agility) and anaerobic fitness training.

No correlation was found in performance indicators and aerobic fitness training. This could be as a result of the percentage change in these variables being slight and one might therefore need to assess improvement on multiple occasions, over a longer period, to detect if any correlations do indeed exist.

4.9 SUMMARY

In this chapter all results were presented according to players' positions. To meet the demands of competition, rugby sevens players require highly developed aerobic, anaerobic, speed, power, and endurance qualities.

The small inter-athlete variability of characteristics in rugby sevens players highlights the need for relatively uniform physical attributes and performance. The following chapter will focus on a discussion of the results.

CHAPTER 5: DISCUSSION AND CONCLUSION

5.1 INTRODUCTION

The aim of the study was to establish whether any changes occurred in the assessed physical parameters related to concurrent aerobic and anaerobic training in selected provincial rugby sevens players. This chapter interprets and discusses the identified physical fitness patterns in different rugby sevens positions (i.e. backs and forwards).

5.2 MORPHOLOGICAL CHARACTERISTIC VARIABLES

Morphological characteristics assessments are used in various sports to describe the characteristics of athletes to distinguish between age and positional variations (e.g. backs versus forwards) (Duthie *et al*., 2006).

Higham *et al.* (2013) suggest that there traditionally has been variation between the positional roles and physical requirements of backs and forwards in rugby union. Given the reduced number of players on the field in rugby sevens, there is a greater requirement for all players to develop rugby sevens physical performance indicators and associated physiological characteristics to meet the demands of play.

The aim of this study was to compare the morphological characteristic variables of rugby sevens players as well as to compare backs and forwards. The results of this study illustrate the change in morphological characteristics variables from pre- to post-intervention for rugby sevens players. Substantial differences ($p \leq 0.05$) were found in the total rugby sevens group (n=54) in the sum of seven skinfolds (mm), body fat (%) and fat mass (kg) after the 12-week intervention programme. Although the pre-intervention lean body mass of the total rugby sevens group compared to that of the post-intervention results is not significant, a mean score difference of 1.0 kg and 1,3% improvement is recorded.

Rugby sevens backs present greater improvement in morphological characteristics when compared to that of the forwards. The sum of seven skinfolds for the backs decreased by 9mm from pre- to post-assessment, generating a 2,6% improvement when compared to forwards. Desirable changes in morphological characteristics (here a decrease in skinfold thickness) have been demonstrated in pre-season when the training volume is high (Holmyard & Hazeldine, 1993; Duthie *et al*., 2006; Gabbett, 2005 and Tong & Mayes, 1995), explaining the 5,1% change for backs versus forwards.

Some disparity in morphological characteristics between backs and forwards is demonstrated by both the sum of seven skinfold measurements and lean mass. It thus appears that the homogeneity of morphological characteristic variables within the team investigated by Higham *et al*. (2013) may not apply to rugby sevens players. Nevertheless, players with low body fat percentage, regardless of position, would be advantageous given the high intensity running demands of rugby sevens (Higham *et al*., 2012b; Suarez-Arrones *et al*., 2012).

The results obtained in this study present a significant difference ($p \leq 0.05$) in the pre- and post-intervention body fat (%) results of backs and forwards. The study found that when compared with forwards, backs deceased only 1% more body fat than forwards but enhanced a percentage change of 6,7 between pre- and post-intervention assessment results. In contrast to these findings, backs and forwards sustained an equal decrease in fat mass (kg), which in this case reflects the assertion by Higham *et al*. (2013) that players in rugby sevens are more homogenous in terms of morphological characteristics measurements in all positions compared to a 15-a-side rugby union. These authors found small variance in morphological characteristics measurements with a coefficient variance (CV) ranging from 3.3-8.4%.

Research data on morphological characteristics have shown that rugby sevens players have greater lean mass, as indicated by estimated body fat percentage (11% -12%) and the sum of seven skinfolds (52.2mm – 61.6mm) (Rienzi *et al*., 1999; Suarez-Arrones *et al*., 2012; Higham *et al*., 2013). Results show that there are limited differences between the backs and forwards in rugby sevens. This may be due to the fact that all players are conditioned with the same programme as coaches may believe that all players in the sevens team must be equally fit and be utility players. However, coaches do need to distinguish between backs and forwards, and different fitness demands are required.

5.3 AEROBIC VARIABLES

5.3.1 Aerobic Fitness

Field tests such as the YYIR evaluate the endurance qualities of players under more team-sport-specific conditions, incorporating acceleration, deceleration, and change of direction (Bangsbo *et al.*, 2008).

An assessment of the rugby sevens players' aerobic fitness after the 12-week intervention programme (which included high-intensity interval running), showed a slight increase in the number of shuttles successfully in the post-intervention test. However, no significant difference was found in the predicted $V0_{2max}$ of the total rugby sevens group as well as positional variance. This may due to the fact that the training time spent in aerobic activities were considerably lower than time spent on anaerobic activities.

Alternatively, the low estimated $V0_{2max}$ in this study suggests that the volume and intensity of training may have been too low. However, in comparing the correlations between physical attributes and performance indicators versus aerobic and anaerobic fitness improvement results, there is a strong correlation between aerobic fitness and a drop-in body fat (kg). In addition, the intervention time period may have been too short to see significant aerobic results.

Scott *et al.* (2003) state that, by using cardiopulmonary exercise testing and body fat measurements, comparison between aerobic fitness levels of backs and forwards can be established. Studies of other sports demonstrate the YYIR test is a more accurate predictor of on-field performance than $V0_{2max}$ and offers greater sensitivity in discriminating between athletes of various levels and in evaluating training interventions (Bangsbo *et al.,* 2008). Similarly, in rugby union, more mature players tend to outperform junior players and backs outperform forwards in the YYIR (Higham *et al*., 2012b). In this study, there is some support of this statement, as backs displayed an improved percentage of 1,9 compared to forwards, who showed no percentage improvement.

International rugby sevens players typically cover a mean of 1650 meters per 14-minute match, of which 9% is covered at speeds ≥ 5 $m.s^{-1}$, in conjunction with frequent bouts of sprinting, accelerating, and decelerating (Higham *et al*., 2012b; Suarez-Arrones *et al.,* 2012), suggesting a need for a well-developed aerobic energy system. As such, conditioning programmes need to be specific for the physiological characteristics stated above. The aerobic variable is a very specific component to performance, hence longer time periods must be spent for improvement to be captured during the pre-season training.

Two studies have reported the aerobic ability of rugby sevens players (Higham *et al.,* 2013; Elloumi *et al*., 2012). Both studies used variations of the YYIR test to assess aerobic fitness, using a series of progressively faster 20-meter shuttles to exhaustion with five-second rest between shuttles for the endurance version and 10 seconds active rest for the recovery version.

Both versions have two levels with level two, consisting of faster shuttle speeds than level one (Krustrup *et al.,* 2003; Bangsbo *et al*., 2008). Ross *et al*. (2015) agree with the aerobic results of this study as research into the aerobic endurance characteristics of rugby sevens players has not distinguished between backs and forwards and, as such, it is unclear whether differences exist between the position groups.

In the current study, in investigating physical attributes and performance indicators versus aerobic and anaerobic fitness (resistance training) improvement results, a strong correlation between aerobic fitness and a drop-in body fat (kg) was observed.

5.4 ANAEROBIC VARIABLES

5.4.1 Anaerobic Fitness

This research study demonstrated significant difference ($p \leq 0.05$) in anaerobic capacity for the total rugby sevens players. The first major finding of this research is there were significant differences captured in the pre- to post-intervention assessment results. A change score of 1,6% was observed between the two positional groups, with the backs (3,1%) show a greater percentage improvement than forwards (1,5%).

The anaerobic results in this study tend to agree with those of Barnard & Coetzee (2012), in which no significant difference was found between the backs versus forwards for the 23-meter sprint or the Margaria test. As the Margaria test results were similar in both groups, the difference in power scores were caused by the differences in body weight. Despite their greater weight, the forwards were able to run as fast as the backs, which demonstrates their leg power. This most likely reflects the influence of positional requirements and future starters.

In contrast to these results, given the limited ecological validity of laboratory-based measures, such as cycle ergometry, anaerobic metabolic properties are rarely tested in isolation (Baker & Davies, 2004; Lombard, 2003; Thomas & Baker 2005).

The relevance of laboratory-based testing to rugby competition and the lack of its translation has led to the development of more sport-specific tests, such as repeated-sprint ability tests. These tests evaluate players under conditions that more closely replicate the demands of competition (Higham *et al.,* 2012b; Maso, Cazorla, Godemet, Lac & Robert 2002; Nirmalendran & Ingle, 2010; Smart *et al.,* 2011).

Research into the anaerobic characteristics of rugby sevens players has not distinguished between backs and forwards and, as such, it is unclear whether differences exist between the position groups. However, rugby sevens is a high-intensity sport that requires players to repeatedly sprint, change direction, and contest for tackles, interspersed with periods of low and moderate-intensity running (Higham *et al*., 2013; Ross *et al*., 2015; Suarez-Arrones *et al*., 2012). High levels of both aerobic power and repeated sprint ability suggest the ability to maintain speed and skill execution under fatigue.

Only one study to date has investigated the repeated sprint ability of rugby sevens players (Higham *et al.,* 2013). Higham *et al*. (2013) reported a total time of 24.8 seconds for international players when completing six 30 meters sprints, starting each sprint every 30 seconds. While this study provided a starting point in the analysis of repeated sprint ability in rugby sevens players, further investigation should seek to examine the utility of repeated sprint ability as a discriminatory measure between players of different competition levels.

Future research should also seek to investigate differences in other physical measures between players from different competition levels as well as between positional groups, which may aid in identifying the relative importance of physical traits. Once identified, the relationship between physical characteristics and on-field success factors can be investigated.

5.4.2 Strength and Muscle Endurance Variables

Muscular strength and endurance are critical components for success during attack and defence in both rugby formats (Higham *et al.,* 2012b). Abernethy, Wilson & Logan (1995) define strength as the peak force (in newtons, N) or torque (in newton-meters, Nm) developed during a maximal voluntary muscle contraction(s) under a given set of conditions (with conditions influenced by posture, pattern, and velocity of movement).

The results of strength and muscular endurance analysis in this study showed significant differences ($p \leq 0.05$) in the total rugby sevens group as well as in position. The results of this study indicated that forwards were stronger in the bench press, demonstrating a change score of 20,7 % compared to that of the backs (19,0%), as well as in squat measures (15,5%) compared to the backs (14,1%). The total rugby sevens group presented a change score of 18,5% in bench press between the pre- and post-intervention results and 14,3% change score in squats.

In comparison with Australian Rugby Union players, the relative strength results from this study indicate that forwards were similar to the international and senior levels of competition for the bench and squat respectively, whereas the backs were more consistent with the senior and intermediate levels respectively (Tanner & Gore, 2013).

In agreement with previous research, forwards were shown to be stronger than backs (Bradley, Cavanagh, Douglas, Donovan, Morton & Close, 2015). This is likely related to the greater contact (e.g., rucking, mauling, and scrummaging) observed in forwards during competition than among backs (Deutsch, Kearney & Rehrer, 2007; Duthie, Pyne & Hooper, 2003).

Clear percentage differences (67,3% and 18,5%) are observed in the total rugby sevens group for muscular endurance one-minute push-up and one-minute sit-up results. The forwards recorded a 3,9% greater improvement than the backs in the one-minute push-up post-test. By contrast, the backs recorded 4% improvement over that of forwards in the one-minute sit-up post-test. The value of strength in sevens rugby is related to speed, jumping, rucking, mauling, and tacking.

5.4.3 Explosive Power, Speed, and Agility Variables

The importance of lower-body power has been shown in Gabbett *et al.* (2010), in their study on tackling ability, with lower-body power being the second highest correlate of tackling ability ($r = 0.38$, $p \leq 0.01$) behind acceleration ($r = 0.60$, $p \leq 0.001$). Most of the studies on lower-body power have used a yardstick device to measure jump height (Gabbett, 2000, 2002, 2005, 2006, 2007; Gabbett *et al*., 2008; Gabbett, Kelly, Ralph & Driscoll, 2009; Gabbett *et al.*, 2010).
Higher vertical jumps were shown to relate to improved performance during contact situations specifically during attacking and defensive rucks (Ross *et al.*, 2015). Equivalent to other attributes of rugby sevens players, lower-body performance seems to be important and be the most applicable to match performance. In this study, although the vertical jump measurements are low, significant difference ($p \leq 0.05$) is captured in the total rugby sevens group as well as in positional difference. A change of 3,6 % is captured between the pre- and post-intervention vertical jump test for the total group, where forwards display 0,2 % greater improvement than backs.

Previous research (Gabbett *et al*., 2007) in the rugby league identified a strong (r = 0.42) relationship between vertical jump performance and the ability to evade tacklers. In comparison, Comfort, Graham-Smith, Matthews and Bamber (2011) demonstrate that backs have a greater mean vertical jump height (40.3 ± 6.4 cm) compared to forwards (37.3 ± 4.4 cm), which may be because the backs exhibit a greater relative power output (20.71 ± 5.15 W•kg^{-1}) compared to the forwards (19.91 ± 3.91 W•kg $^{-1}$).

Speed is also an essential physical fitness component for high-level rugby players (Smart *et al*., 2011). Speed is typically separated into two related phases: acceleration and maximal velocity. Accelerations in rugby union and rugby sevens are often associated with principal facets of the match, such as the ability to move into a position to receive the ball or move toward or away from an opponent to make or evade a tackle (Smart *et al*., 2011).

The results in this study indicate a greater percentage change between pre- and post-intervention results of players' 10-metre sprinting abilities (21%) when compared to that of the 40-metre (5,5%) of the total group tested. The ability to move quickly over various distances, starting from a variety of positions and speeds, is a key component in all players' performances (Duthie *et al.*, 2006).

When the results were divided and analysed by positional groups, a 10,6% difference in the 10-metre sprinting abilities between the backs and forwards was noted. The difference in sprinting performance may not be large due to the similarity in training regimes between the two positional groups. However, Gabbett *et al*. (2012) suggest that the importance of large body size in dominating the ruck and tolerating the heavy tackles and collisions associated with forward positions was the reason for lack of consistent significant differences between backs and forwards in sevens rugby. In other field-based testing, Super 12 rugby union backs (9.4 ± 0.4 m·s^{-1}) achieved a significantly higher (0.9 ± 0.4 m·s^{-1}) speed results than forwards (8.5 ± 0.4 m·s^{-1}) during a 60-metre sprint (Higham, 2013). Rugby forwards typically perform short distance (10–20-metre) sprints during a game, therefore, the initial acceleration over the first 10-metre of a sprint may be a critical factor in their performance (Duthie *et al.*, 2006). Thus, the ability to attain maximum speed quickly following a break from the opposition is an important performance requirement for rugby sevens players. The value of high-intensity training must be emphasised in the strength and conditioning programmes for rugby sevens players.

5.6 CONCLUSION

The findings of this study have provided information on quantifying aerobic and anaerobic training and the relevant impact on physical attributes and performance in rugby sevens players. Furthermore, the study indicated that an increase in a player's lean body mass resulted in a decrease in fat mass and body mass, possibly improving the performance of the players.

After the intervention, the morphological characteristics measurements improved, showing increased lean body mass of the players and decreased fat mass and body mass. These improvements would be advantageous and impact positively on performance.

The anaerobic fitness results display significant difference in the total rugby sevens group. When comparing backs versus forwards, observations can be made that backs displayed a better improvement in anaerobic fitness values than forwards. No significant difference was captured for aerobic fitness, which could be due to the fact that more focus was placed on resistance training, or perhaps more intervention time is required.

Positive results were found when comparing the muscle strength and endurance parameters of the sevens rugby players after the intervention programme. Forwards had a greater percentage improvement in strength, because strength and power are essential to apply high forces rapidly in contact situations and during scrummaging. These measurements demonstrate the necessity of position and task-specific strength development. In contrast, backs had a higher percentage improvement in muscular endurance (one-minute sit-ups) when compared to forwards.

The results for power and speed tests indicate that forwards showed a slightly greater 0,2% greater improvement than backs in the explosive power results. However, data indicates that backs were faster than forwards in the 10-metre though there is no difference between backs and forwards in the 40-metre sprinting ability. It appears that more time is required to see improvements in these components.

Backs are seen to have a good explosive starting speed when compared to forward players. It would seem of value to normalise strength and power to individual body mass, particularly in rugby sevens where players are likely to possess a lean morphological characteristic.

Comprehensive investigations of the characteristics of players, fitness requirements, and movement patterns during competition which are available on rugby union players do not currently exist for rugby sevens players. This information is required to guide the development of effective evidence-based physical preparation programmes. Given the increased worldwide popularity of rugby sevens and the corresponding interest in the contribution of sports science to training and competition performance, three main priority areas emerge for future applied research in the sport.

Research is required to establish the technical, tactical, and physical demands of the sport. Investigations in this area will determine the key differences between rugby union and rugby sevens and quantify the effects of changes to the game format, such as the reduced number of players on the field and the tournament style of competition.

Once the requirements of rugby sevens competition and priorities for physical and physiological development are established, future research should investigate methods of training that maximise adaptations to benefit performance while minimising the risk of injury. Findings from research into these areas can be used to update strategies designed to improve specific components of rugby sevens performance.

The similarity in results between the backs and forwards show the similar training of sevens rugby players based on the need to make utility positional groups.

5.7 LIMITATIONS TO THE STUDY

The limitations of the present study were found to be that field testing continuously has a challenge with players' motivation. However, the researcher attempted to motivate all participants.

5.8 RECOMMENDATIONS

- Coaches need to specifically condition players based on the needs of the game.
- Backs and forwards may be conditioned together, however, specific fitness needs for positional variance need to be addressed separately during training.

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APPENDICES

APPENDIX A: INFORMATION LETTER

DEPARTMENT OF SPORT AND MOVEMENT STUDIES
FACULTY OF HEALTH SCIENCES

INFORMATION LETTER

Dear Participant

You are invited to participate in a research study that forms part of my/our formal MPhil Sports Science. This information leaflet will help you to decide if you would like to participate. Before you agree to partake, you should fully understand what is involved. You should not agree to partake unless you are completely satisfied with all aspects of the study.

PROJECT TITLE:

Quantifying aerobic and anaerobic training and its impact on physical attributes and performance in rugby sevens players.

PRIMARY INVESTIGATOR(S):

Ms. M.T Lamont (MPhil Sport Science).

STUDY LEADER(S):

Mr AJJ, Lombard, PhD, Department of Sport and Movement Studies, Faculty of Health Sciences, University of Johannesburg, Republic of South Africa;
Prof. Y. Coopoo, PhD, Department of Sport and Movement Studies, Faculty of Health Sciences, University of Johannesburg, Republic of South Africa.

WHAT IS THE STUDY ALL ABOUT?

Rugby sevens has developed since its beginnings in Scotland in 1883, from a social pastime into a very competitive sport with a regular season of international tournaments. Rugby Union is a contact team sport that is made up of 15-a-side or 7-a-side formats (hereafter referred to as rugby sevens) where players require high levels of physical fitness, composite of aerobic fitness and anaerobic endurance, muscle strength and power, speed, agility and body composition.

Combining aerobic exercise and resistance training in the same workout session, is a technique referred to as concurrent training, this is considered to be a time-efficient training method. The resistance training programmes typically assign a specific focus to each phase of the training year. Physical conditioning programmes have been designed to increase physical capacities of players in addition an effective way to reduce the incidence of injuries. A high maximal aerobic power is necessary for adequate recovery during bouts of play.

The relevance of this study will be to apply the anthropometric, cardiorespiratory (VO_{2max}) and muscular strength and endurance data to identify specific physiological markers in selected provincial rugby sevens players. This can provide important feedback to coaches and conditioning trainers regarding the training stimuli to be applied to enhance performance on the field of play. Finally, this gives us an opportunity to investigate quantifying aerobic and anaerobic training and its impact on physical attributes and performance in rugby sevens players.

WHAT WILL I BE REQUIRED TO DO IN THE STUDY?

I do understand that I will undergo an independent medical clearance before any participation in the study will take place. After medical clearance I will be required to undergo pre-testing and post-testing and possibly participate in a 6-week concurrent resistance and aerobic training programme. I also understand that on days of testing I will be required to wear light clothes only.

1.1 Anthropometry

- I understand that my height and weight will be measured.
- I understand that it will be required of me to wear minimal clothing and no shoes
- I understand that my body composition will be assessed using various skinfold measurements. Skinfold measurements will be taken at a number of anatomical landmarks (e.g abdominal muscle, front thigh muscle, medial calf, triceps muscle, subscapular muscle, suprailiac muscle) using a skinfold caliper. The technique employed to measure these skinfold sites requires that the researcher 'pinch' the subcutaneous fat at the aforementioned anatomical landmarks.
- I understand that my waist and gluteal (hips) girths will be measured using a tape measure. For measurement of the waist, I will be required to assume a relaxed standing position with my arms folded across my chest. The measuring tape will be placed

around the narrowest part of my waist and the measurement will be recorded. For measurement of the gluteal (hips), I will be required to assume a relaxed standing position with my feet together and my arms folded across my chest.

- My gluteal (hip) muscles must remain in a relaxed position. The measuring tape will also be placed around the largest part of my gluteal (hips) and the measurement will be recorded.
- I understand that my subscapular triceps ratio (STR) will be measured by calculating the subscapular skinfold divided by triceps skinfold.
- I understand that my BMI will be calculated by dividing the body mass (kg) from the height (m2), also my body percentage fat will be calculated using Heyward equation 2010. Fat Mass will be calculated by multiplying body mass (kg) to body percentage fat and divide by 100. Lean body Mass will be measured by subtracting the participating body mass (BM) from fat mass (FM).

1.2 Functional fitness testing

I understand that I will be required to undergo a series of fitness tests. These tests include:

1. Strength and Endurance – For upper body strength and endurance I will be required to perform a push-up-test for one minute as well as to perform a bent-knee-sit-up-test for one minute and it will be used to assess the strength of the abdominal musculature.
2. Cardio respiratory Fitness – I will be required to complete the YoYo Intermittent test $V0_{2max}$ will calculated by using: $V0_{2max}$ = (22351x km)-11,288.

EXCLUSIONS

I will not be able to participate in the study if I am currently suffering from any of the following conditions: Asthma, depression, muscle injuries, chronic diseases, muscular-skeletal injuries, cardiovascular defects or any conditions that preclude me from exercise.

WHAT ARE THE RISKS INVOLVED IN THIS STUDY? <u>OR</u> CAN ANY OF THE STUDY PROCEDURES RESULT IN PERSONAL DISCOMFORT OR INCONVENIENCE?

Cardio-respiratory Fitness: As this requires me to walk or run for around an athletics track, I can suffer from related injuries, muscle cramps, muscle injuries.

Functional testing: Tightness in the muscles might produce mild tension. Individuals might also experience some fatigue in the muscles and increased respiratory and heart rate which can lead to some discomfort.

Discomfort of the concurrent resistance and aerobic training programme:

- Muscle injuries
- DOMS (Delayed onset muscle soreness) is most possible to occur after initial exercising.
- Fatigue in the muscles might be experienced during exercising and therefore resulting in a reduced ability to persist with the exercise session.
- Some discomfort might be felt during the progression from standing to sitting and visa-versa.
- May suffer fatigue during training
- I also understand that it is my responsibility to inform the tester of any discomfort and pain that I may experience during and after the test.

WHAT SHOULD I DO IF I EXPERIENCE ANY UNEASINESS OR PAIN?

If any pain, uneasiness or undesirable motion occurs during the testing and/or programme, you can report to any of the primary investigator(s) or study leaders. If any complaint needs to be addressed feel free to contact me/us (primary investigator(s)) personally on our contact details as given below.

BENEFITS OF PARTICIPATION

My participation will make a contribution to the broadening of academic knowledge and understanding of Anthropometric and cardiopulmonary Reponses to concurrent resistance and aerobic training in overweight males.

I will receive information on my blood pressure, heart rate, weight, height and percentage body fat, muscular strength, muscular endurance and cardio respiratory endurance and how to conduct my own training programme. Prevent the possible increase in overweight males in the future.

WHAT WILL HAPPEN AFTER THE STUDY?

- Each subject will be given a feedback report on both their pre- and post-testing results that might indicate possible improvements.
- If any difficulty in understanding or interpreting the results, it will be explained in detail on request.
- On request further exercise programmes and/or guidelines on exercising will be supplied.
- If needed, based on results further medical referrals will also be made.

FINANCIAL COMPENSATION OR INCENTIVE

Please note that you **will not** be paid to participate in the study.

VOLUNTARY PARTICIPATION

The nature and purposes of the procedures, and the known risks involved have been explained to me. I understand that participation in this study is voluntary and refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled. I understand that I may withdraw from participation at any point in the study with no penalty.

CONFIDENTIALITY

I understand that the information provided by this study may be used for research purposes, including publications in research journals. All individual information will be coded and at no time will my personal identity be revealed without my permission. The data will be destroyed two (2) years after publication or six (6) from the time of the study.

TERMINATION OF PARTICIPATION

My participation in this research may be terminated without my consent if the investigators believe that any portion of the study will put me at undue risk. My participation may also be terminated if I do not adhere to the study protocol.

IS THE RESEARCHER/PRIMARY INVESTIGATOR QUALIFIED TO CARRY OUT THE STUDY?

The primary investigator(s) currently hold(s) B.A degrees in B.A Sports Communication and B.A Hons in Sports Science Ms. M Lamont. Also, she/he/they has/have received special training in exercise studies from the University of Johannesburg in South Africa.

ETHICAL APPROVAL

The Faculty of Health Sciences' Academic Ethics Committee has approved the formal study proposal. All parts of the study will be conducted according to nationally and internationally accepted ethical principles.

QUESTIONS

We have used some technical terms in this form. Please feel free to ask about anything you don't understand and to consider participation and the consent form carefully – as long as you feel it is necessary – before you make a decision.

PERSONS TO CONTACT WITH QUESTIONS

The primary investigator(s) can be contacted during office hours on her/his/their cellular phone(s): Ms M.T Lamont (076 759 9369) ***lamont.marcel@gmail.com*.** The study leaders, Mr AJJ, Lombard can also be contacted during office hours on (011) 559-6965 or Prof Y, Coopoo can be contacted during office hours on (011) 559-4292. Should you have any questions regarding the ethical aspects of the study, you can contact the Chairperson of the Faculty of Health Sciences' Academic Ethics Committee, Prof M. Poggenpoel, during office hours on (011) 559-6686.

DECLARATION: CONFLICT OF INTEREST

There is not any conflict of interest that may influence the study procedures, data collection, data analysis and publication of results.

A FINAL WORD

Your co-operation and participation in the study will be greatly appreciated. Please sign the informed consent if you agree to participate in the study. In such a case, you will receive a copy of the signed informed consent form from the primary investigator(s).

APPENDIX B: INFORMED CONSENT FORM

DEPARTMENT OF SPORT AND MOVEMENT STUDIES
FACULTY OF HEALTH SCIENCES

CONSENT FORM TO PARTCIPATE IN STUDY

PROJECT TITLE: Quantifying aerobic and anaerobic training and its impact on physical attributes and performance in rugby sevens players

I hereby give consent to M.T Lamont, to conduct the study procedures indicated in the Information Letter above on me for the purposes of research toward his/her/their Masters Degree in Sports Science. I understand that all my personal details and identifying information will be altered to protect my identity.

I understand that my name will not appear in any data records. The data will be destroyed two (2) years after publication or six (6) from the time of the study.

______________________________ ______________________

Participant's Name (print) Date

____

Participant's Signature

APPENDIX C: ETHICAL CLEARNACE

UNIVERSITY OF JOHANNESBURG

FACULTY OF HEALTH SCIENCES

RESEARCH ETHICS COMMITTEE

NHREC Registration no: REC-241112-035

REC-01-13-2016

07 April 2016

TO WHOM IT MAY CONCERN:

STUDENT: LAMONT, M
STUDENT NUMBER: 201103312

TITLE OF RESEARCH PROJECT: Quantifying Aerobic and Anaerobic Training and its Impact on Physical Attributes and Performance in Rugby Sevens Players

DEPARTMENT OR PROGRAMME: SPORT AND MOVEMENT STUDIES

SUPERVISOR: Mr AJJ Lombard CO-SUPERVISOR: Prof Y Coopoo

The Faculty Academic Ethics Committee has scrutinised your research proposal and confirm that it complies with the approved ethical standards of the Faculty of Health Sciences; University of Johannesburg.
The REC would like to extend their best wishes to you with your postgraduate studies.

Yours sincerely,

Prof M Poggenpoel
Chair : Faculty of Health Sciences REC
Tel: 011 559 6689
Email: mariep@uj.ac.za

APPENDIX D: CLUB PERMISSION LETTER

LETTER OF PERMISSION

Coaches Permission

I ______________________________ (coach) give my athletes _____________________ (rugby sevens team) permission to be a part of the scientific research: ***Quantifying aerobic and anaerobic training and its impact on physical attributes and performance in rugby sevens players***. I agree to assist the team in being at scheduled practices and games.

Coaches Signature: ___________________________