

The relationship between training/match load and injuries in academy players during a provincial under 19 rugby union season

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Signed by candidate

(Signature)

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(Date)

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Abstract

Background

The influence of professionalism has filtered down to junior levels in rugby union. The increased demands on junior professional rugby players has an impact on their fitness characteristics, training load, match load and injury profiles. Although many studies have been conducted on senior rugby union players, not much is known about junior players as they make the transition into the senior ranks. The aim of this study was to describe the training/match load during the pre-season and competitive in-season in a squad of under 19 academy rugby players and then to relate this to the injuries (contact and non-contact) sustained during the different phases of the season. A secondary aim was to measure the physical ability of the players through the season.

Methods

Injury and training data from players in the Western Province under 19 Currie Cup squad (n=34) were recorded on a daily basis throughout the rugby season (42 weeks). The training load was represented by the time (minutes) spend in each activity associated with training, conditioning and match play. The players also underwent measurements of body mass, stature, body fat percentage, upper body muscular endurance (pull ups), and muscular strength (1RM bench press), sprint times (10m and 40m) and anaerobic capacity (5 meter shuttle run). All tests were conducted in January and June, which coincided with the beginning of pre-season and the beginning of the competition phase respectively.

Results

Over the season 71 injuries were recorded, comprising 17 pre-season injuries, 18 pre-competition injuries and 36 competition phase injuries. There was no difference between the occurrence of contact and non-contact injuries during the different phases of the season. Although there was no significant difference between the injury rates during the different phases of the season, there was a significant difference between the injury rates in training (4.4/1000 player hours) and matches (74.1/1000 player hours). The most common body parts injured were thighs, hip/groin, ankles and shoulders, with injuries to the hand/finger and knee being the most severe. Muscles and ligaments were the structures that got injured the most. The average duration of days to return-to-play after an injury was 17 days. There were significant changes in the physical characteristics of the players in the six months between the test batteries. In addition to getting taller, players generally improved their fitness characteristics with significant improvements occurring in the bench press (8%), pull ups (113%), vertical jump (13%) and the 5 meter shuttle run (6%).

Conclusion

The training load of the junior professional rugby players is similar to the load of senior professional rugby players. This represents a sudden increase compared to the previous year when the players were at school. A long-term research project with a database of rugby schools will assist in bridging the gap between the demands of junior rugby and junior professional rugby. Players joining a professional academy system after school need physical, emotional and tactical fast tracking as they are competing in a highly competitive environment for senior professional

contracts. This accounts for the relatively high rate of injury throughout the season. Players need to be carefully monitored and managed during the season to detect symptoms reflecting poor adaptation to the training load.

CHAPTER 1:

Introduction and Scope of Thesis

Introduction

Rugby union (or rugby) is a sport characterized by intermittent, short duration bouts of high intensity exercise with collisions between players (Garraway *et al.*, 2000). During a match the forwards are involved in more contact events than the backline players. These contact events can be quantified as contact with the ground, contact during scrums, contact during lineouts or contact in the tackle situation (van Rooyen *et al.*, 2008). Rugby provides athletes of different shapes and sizes an opportunity to participate in the same team because the various playing positions require widely different skills and physical attributes (Quarrie *et al.*, 2013). There is a high risk of injury as a result of the collisions between players, particularly when the players are running fast before the collision (Brooks *et al.*, 2005; Hendricks *et al.*, 2014).

Rugby union became a professional game in 1995, and since then teams have sought to gain a competitive edge by conditioning players to increase their lean body mass and to develop greater strength, speed and stamina (Garraway *et al.*, 2000). As a consequence the body mass of senior players has increased progressively (Fuller *et al.*, 2013). Increases in body mass, power and strength of players relates to increased impact forces during contact, which is a risk factor for injury (Fuller *et al.*, 2007; Fuller *et al.*, 2010). Higher level rugby league players produce greater absolute and relative strength and power outputs than lower level players (Baker, 2002). The same has been found in rugby union players (Durandt *et al.*, 2008). Therefore younger or lower level rugby players have to strive to attain greater levels of strength and power to be physically prepared for the next level of competition (Argus *et al.*, 2012).

The chances of getting injured in rugby increases with increasing age until the senior playing level is reached (Fuller *et al.*, 2011). The reason for this is that the volume and intensity of training and

game related activities is higher at senior levels than at junior levels (Hartwig *et al.*, 2008). From a safety perspective, rules have focused on reducing the risk of serious injuries. Rules are constantly modified to reduce the risk of injury. For example, the high tackle and spear tackle have been outlawed because they are associated with a high risk of injury (Brooks and Kemp, 2008). Also the scrum laws changed to have a more controlled engage and pushing phase of the scrum (Hendricks *et al.*, 2014). There are also separate scrum laws for under 19 players that prevent excessive wheeling and pushing during the scrum (Brooks and Kemp, 2008).

The impact of professional rugby has filtered through to amateur and junior rugby with professional age group (academy level) competitions. The academy system has evolved into a professional age group competition where the best players in the country compete against each other. The standard of the competition is high. Also the intensity of training and matches is high which increases the training load. The academy player (16 to 19 years old) is still developing on a physical, motor and cognitive level (Gluckman and Hanson, 2006; Parsonage *et al.*, 2014). These characteristics need to be fully developed before the players are able to handle the demands of professional rugby. This problem is compounded because the demands of the game and player characteristics are changing. For example, during the last 13 years the South African U20 national age group players have become heavier (20%), stronger (40%), and taller (3%) and improved their upper body muscular endurance (40%) (Lombard *et al.*, 2015). The volume and intensity of training and games of players at academy level are increasing and need to be monitored (Palmer-Green *et al.*, 2013). This is particularly important because this is the phase during which junior rugby players make the transition into senior rugby. Failure to manage this phase appropriately may result in a high dropout rate (Lambert and Durandt, 2011).

The volume of work that players must focus on during their academy year(s) is high and includes a combination of technical, physical, tactical, social and personal development. Gymnasium and field based conditioning are an essential part of this development stage and high load work time

is spent mastering basic movements such as: squatting, lifting, running, sprinting, landing and jumping (Parsonage *et al.*, 2014; Smart *et al.*, 2011). A broad goal of the academy system is to focus on the development of basic techniques and movements to ensure a well-balanced, physically mature player. Proper movement and technique will most likely result in a lower risk of injury (Lehance *et al.*, 2009).

Another goal of the academy system is to develop rugby players that can perform under pressure, as these are the requirements of a successful senior professional player. Therefore, the load relating to training and matches must be monitored so that the volume can be increased in a systematic way (Gabbett *et al.*, 2014).

The intensity of the game increases with the level of play (Austin *et al.*, 2011) and the risk of injuries also increases with an increase in the intensity of the game (Haseler *et al.*, 2010). For example, as the level of play increases the players are obliged to spend more time on strength and conditioning (Sedeaud *et al.*, 2012). This training develops the players' speed, strength and endurance (Garraway *et al.*, 2000), and as a consequence the intensity of the game increases. Also, body mass, power and strength are risk factors for injury at a professional level as they increase the impact forces during collisions (Fuller *et al.*, 2013; Hendricks *et al.*, 2014).

There is a relationship between tests of physical abilities, match performance and team selection (Gabbett *et al.*, 2013). For example, in a sport such as rugby, where sprinting and change of direction is important, a long term resistance program can improve the change of direction performance of a younger or professional athlete (Burgess and Naughton, 2010; Gabbett *et al.*, 2008; Keiner *et al.*, 2014). Also, the development of a good strength base through specific resistance programs for developing players can be an effective strategy to reduce sport related injuries in adolescents (Gabbett, 2006).

In summary, rugby union is a sport which is growing at the amateur and professional level. In South Africa the most talented players at school level are recruited and fast tracked into a professional academy environment characterized by an high training volume and increased game time the year after leaving school (Durandt *et al.*, 2011). These players have not reached full maturity, therefore the acceleration into a professional environment poses unique challenges. In particular, the management regarding their training load, match load and injuries needs to be understood so that the players can be managed better to facilitate their transition into senior rugby.

Aim of the study

The aim of this study was to describe the training/match load during the pre-season and competitive in-season in a squad of under 19 academy rugby union players and then to relate this to the injuries (contact and non-contact) sustained during the different phases of the season. A secondary aim was to measure the physical ability of players pre-season (at the end of the off-season) and at the start of the season (6 months later).

Objectives

- To measure the characteristics of the players associated with conditioning through the pre-season and at the start of the season.
- To measure the type, site and primary cause of injuries during the different phases of the season.
- To measure all aspects of training and match load (time spent in match, field, gymnasium, recovery and extra conditioning) during the different phases of the season.

- To determine whether any of these measurements (training and match loads) are associated with the risk of injury.

The next chapter will discuss the research aligned to the aims of the dissertation. This will provide a context for the experimental phase of the dissertation (chapter 3), which is designed to answer the questions associated with the aims of this dissertation. Finally the data will be contextualized and the practical application of the data will be discussed (chapter 4).

CHAPTER TWO

LITERATURE REVIEW: TRAINING/MATCH LOAD AND INJURIES IN RUGBY UNION

Background

Rugby union (rugby) is a team sport involving short duration, intermittent, high intensity work. There is contact and collisions between players moving at high velocity. Therefore there is always a risk of injury during training and matches (Fuller *et al.*,2007; Garraway *et al.*,2000). After rugby became a professional sport in 1995 there were opportunities for players to spend more time training. As a result, more emphasis was placed on conditioning and rugby related skills in preparation for competition (Garraway *et al.*, 2000). The physical characteristics of players associated with success in rugby also changed as the game evolved, particularly as a consequence of the faster pace of the game and the greater impact forces arising from collisions (Cunniffe *et al.*,2009). Also the rugby season became longer with more games being played. Consider for example that in 1995 players started with pre-season training in January; while now high level players start playing matches in January after finishing the preceding season about six weeks earlier. As a result of the longer seasons, the training load of players has increased, and the time for recovery between seasons has decreased (Brooks *et al.*, 2008). It is not possible for the players to maintain a physiological peak for the duration of the season and therefore they have to be managed carefully to ensure that the training load and recovery from training and competition are carefully balanced. Players could become over trained (non-functional over-reaching) , with symptoms of fatigue and an increased risk of injury, if the work load increased without due consideration for adequate rest and recovery (Brooks *et al.*, 2008; Gabbett, 2004; Gabbett & Domrow, 2007). It is inevitable that fatigue and overuse injuries are a consequence of high volume training and have to be managed through the season to reduce the risk of this happening (Coutts *et al.*, 2007; Gabbett and Domrow, 2007; Nederhof *et al.*, 2006).

To cater for the risk of non-functional over-reaching, teams performing at a high level have a management team consisting of a range of sports medicine, health and conditioning specialists who look after the well-being of the players. The communication and integration of the management team needs to be well structured, to cater for both the needs of the player and the goals of the team. For example, the main interest of the coach is to have the player ready to compete on the field, while the doctor is responsible for ensuring that the player is healthy with a low risk of injury; sometimes these respective objectives are at odds. Also the strength and conditioning trainers have to prepare the players physically to be able to implement the game plan of the coach. The challenge for all members of the management team is to have healthy players in top condition at the end of the season when the play-offs occur.

The management of young elite rugby players has further challenges because the stresses of training have to be balanced against the fact that the players are still developing physically and psychologically (Hartwig *et al.*, 2009; Malina *et al.*, 2000). The professional environment in rugby is adapting to cater for the younger talented player. This observation is supported by the numerous rugby academies and institutes that form part of the professional unions and clubs around the world. Talented players are offered contracts which require them to embark on full time rugby programs with the goal of professional contracts if they are successful. The junior player has the same mental and physical problems to overcome as the senior player. However, an additional problem the junior players have to overcome is that they start the year after leaving school. At this stage they have a relatively low training base, which is inadequate to prepare them for the physical demands of professional rugby (Durandt *et al.*, 2008). Therefore the young player must be “fast-tracked” towards a high performance environment in six months. This increases the physiological stress because exposure to a high intensity environment, without a sufficient base of conditioning has the potential to increase the risk of fatigue and injury, particularly after the introduction of the start of a high intensity, high load training program (Hartwig *et al.*, 2008). Acute

increases in the training load of athletes that are not prepared appropriately can tip the training stress balance negatively and increase the injury risk (Hulin *et al.*, 2014).

At present there are limited data that can guide the support staff in preparing the young players. Although the interaction between conditioning, injuries and training load associated with rugby are well researched in the senior environment, these data cannot be translated directly to younger players who are physically immature. The next section discusses the literature pertaining to rugby and adolescents, injuries and conditioning and performance.

The sections within this theme will be discussed under the following headings: 1) Injuries in rugby; 2) Junior rugby players and injuries in rugby; 3) Training load/match load and rugby injuries; 4) Physical characteristics of junior rugby players and relationships to injuries; and 5) the physiological difference between adolescents and adults.

The literature will be summarized and main points relevant to the broad aim of the thesis will be highlighted.

Injuries in rugby

Definitions:

The variety of definitions and methodologies used in studies of injuries in rugby union caused inconsistencies in reported data (Fuller *et al.*, 2007). For example, the following examples are different definitions for an 'injury' that have been used in research: '*An event that forced the player to either leave the field or miss a subsequent game*' (Bathgate *et al.*, 2002); and

'Any injury that prevents a player from taking a full part in all training activities typically planned for that day and match play for more than 24 hours from midnight at the end of the day the injury was sustained' (Brooks *et al.*, 2005).

The International Rugby Board established a Rugby Injury Consensus Group which was tasked to reach an agreement on appropriate definitions and methodologies. The aim of this group was to standardise the recording of injuries and reporting of studies in rugby union (Fuller *et al.*, 2007).

The following definition of "injury" was accepted:

'Any physical complaint, which was caused by a transfer of energy that exceeded the body's ability to maintain its structural and/or functional integrity, that was sustained by a player during a rugby match or rugby training, irrespective of the need for medical attention or time-loss from rugby activities. An injury that results in a player receiving medical attention is referred to as a 'medical - attention' injury and an injury that results in a player being unable to take full part in future rugby training or match play as a 'time-loss' injury' (Fuller *et al.*, 2007). The requirements of injury classification include the location of injury, type of injury, body-side and injury event (Fuller *et al.*, 2007).

A third subgroup was added which included non-fatal catastrophic injuries. The definition is the following:

'A brain or spinal cord injury that results in permanent (>12 months) severe functional disability.' (Fuller *et al.*, 2007). Another definition of catastrophic injuries in rugby used by BokSmart (www.boksmart.co.za); can be defined as *'Any head, neck, spine or brain injury that is life-threatening, or has the potential to be permanently debilitating and results in the emergency admission of a rugby player to a hospital or medical care centre'* (BokSmart).

The emphasis on preventing, diagnosing and treating concussion in rugby union is of major importance and protocols around this has been established (McCrory *et al.*, 2013). Concussion

can be defined as: *'Concussion is a brain injury and is defined as a complex pathophysiological process affecting the brain, induced by biomechanical forces. Several common features that incorporate clinical, pathologic and biomechanical injury constructs that may be utilised in defining the nature of a concussive head injury include:*

- 1. Concussion may be caused either by a direct blow to the head, neck or elsewhere on the body with an "impulsive" force transmitting to the head.*
- 2. Concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously. However, in some cases, symptoms and signs may evolve over a number of minutes to hours.*
- 3. Concussion may result in neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury and, as such, no abnormality is seen on standard structural neuroimaging studies.*
- 4. Concussion results in a graded set of clinical symptoms that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course. However, it is important to note that in some cases symptoms may be prolonged ' (McCrory et al., 2013).*

The consensus definition enables research to be standardized which improves comparison across studies.

Overview of injuries:

The factors that have to be considered when discussing injuries in sport are diverse. The introduction of professionalism in rugby coincided with an increase in injuries to both professional and amateur players (Brooks and Kemp, 2008; Garraway et al., 2000). The increased demands of the game filtered down to the amateur level of rugby (Garraway et al., 2000). The common

types of injuries that occur in rugby are fractures, joint, muscle and tendon, lacerations and central/peripheral nervous injuries (Brooks and Kemp, 2011; Williams *et al.*, 2013)). These injuries can differ in severity and location on the body. For example, injuries to the lumbar spine, thigh and ankle are have the highest incidence per 1000 player hours; while the injury severity (days absent after injury) are highest in the shoulder, arm and knee. An important point is that recurrent injuries are often more severe than new injuries and this highlights the fact that complete and effective rehabilitation must be done with an injured player (Brooks *et al.*, 2005; Devlin, 2000). The incidence of catastrophic injuries is higher for senior players than junior players (Brown *et al.*, 2013). This finding is not unexpected as the consistent finding is that all injury incidence rates are higher at senior level than junior level (Brown *et al.*, 2013; Gabbett, 2004). The scrum and tackle were the major events where catastrophic injuries happened, with a higher proportion scrum related catastrophic injuries. Other factors that are related to the scrum are that the hooker position has the highest incidence of catastrophic injuries and 56% of injuries during scrums happens during the engagement sequence (Brown *et al.*, 2013). During 2013 and the beginning of 2014 the IRB (now known as World Rugby) changed the ruling of the engagement sequence to make this aspect of the game safer. It is too early to reach a conclusion on the effect of the new scrum engagement rules.

The tackle is the main event associated with injury in rugby union (Fuller *et al.*, 2010), as this is the main contact event of the game. Collisions and scrums are less common but carry a greater risk for an injury (Williams *et al.*, 2013). Running is also associated with injury, but this is predominantly during training when the incidence of contact injuries are low (Brooks *et al.*, 2005). In rugby league it was pointed out that players with a low speed and maximal aerobic power have an increased risk of injury. This highlights the importance of speed and endurance training to prevent injuries (Gabbett and Domrow, 2005). Previous injury is a major risk factor for re-injury, although the incidence of new injuries is higher than recurrent injuries (Williams *et al.*, 2013).

Players with low body mass have a higher risk of sustaining severe injuries, while the heavier players have a greater risk of lower limb injuries (Williams *et al.*, 2013). Studies have shown the lower limb was the region with the highest injury incidence, with the tackle situation being the most common injury incident. Prevention strategies are therefore important, with particular emphasis being placed on lower limb injury prevention strategies and techniques during contact (Williams *et al.*, 2013).

The incidence of injury during training is significantly lower than during matches (Brooks *et al.*, 2008; Viljoen *et al.*, 2009). Exposure time during training is an important predictor of injury incidence (Quarrie and Chalmers, 2001), with high volume training during the week before a match carrying a significantly high risk of injury (Brooks *et al.*, 2008). The exposure time (training volume) does not include warm ups, cool downs or recovery times. By monitoring training loads during the week, the data can be used to determine which players are at increased risk of injury (Killen *et al.*, 2010).

Injury rates increase as the standard of play increases (Garraway *et al.*, 2000). Reasons for this can be explained by differences in body composition, levels of player fitness and strength, time of ball-in-play and the more competitive nature of matches at higher standards (Quarrie and Chalmers, 2001). The players' position is also associated with varying risk factors (Brooks and Kemp, 2011 ; Gabbett and Domrow, 2005). Earlier research showed that the incidence of injury for forwards was higher during a match (Brooks *et al.*, 2005), however this was contradicted by a more recent meta-analysis which showed there is a trivial difference between the incidence in injury between forwards and backs during a game (Williams *et al.*, 2013). The lowest incidence of injury occurs in the first quarter of the match and the highest incidence of injury occurs in the final quarter of a match (Brooks *et al.*, 2008; Williams *et al.*, 2013). These results suggest that fatigue may be a risk factor for injury (Brooks *et al.*, 2005). When comparing semi-professional with amateur players, the semi-professional group have almost 40% less injuries in the second

half. This highlights the importance of fitness to prevent fatigue related injuries (Alsop *et al.*, 2000; Haseler *et al.*, 2010).

Injuries to the lower limb are the most common injury location during a match (Brooks *et al.*, 2008; Brooks and Kemp, 2008). Knee injuries result in the most days absent for forwards and backs, while shoulder dislocations/instability are responsible for the second highest number of days absent (Brooks *et al.*, 2005).

Injury rate during training increases as the standard of play increases (Garraway *et al.*, 2000; Quarrie and Chalmers, 2001). Hamstring muscle injuries sustained while running are the most common injuries for forwards and backs (Brooks *et al.*, 2005). There is a significantly higher incidence of injury during the pre-season period than the in-season period. This may be attributed to low fitness levels or lack of strength during the pre-season, or poor training progressions during the in-season (Brooks *et al.*, 2008; Brooks and Kemp, 2008).

The incidence of injury during the season can be interpreted in two ways. Firstly, the incidence of injury is high in the pre-season from where it declines toward the end of the year (Alsop *et al.*, 2000). Secondly, the severity of injury is low in the pre-season and increases in the early stages of the in-season. Towards the end of the season there is another increase in the severity of injuries (Brooks and Kemp, 2008). Management of players became more professional as the professional era in rugby evolved. For example, the pre-season phase has become an important stage of the season to prepare the player and ensure he enters the competition phase in optimal condition. High volume training can cause overuse injuries, while the increase in contact intensity during competition phase might increase the severity of injuries (Brooks and Kemp, 2008).

Acute infections are common in athletes and can impair the player's ability to train and compete. In professional sport with high pressure on players and staff due to public interest, competition

and financial constraints, the return-to-play protocol is of utmost significance for the player's health (Scharhag and Meyer, 2014; Schweltnus *et al.*, 2012).

In summary, the contact and high intensity nature of the game cause a variety of possible injuries ranging from minor to severe. Management staff must be able to identify factors that have the potential to reduce the risk of injuries so that the squad remains healthy and fit.

Junior rugby players and injuries in rugby

As previously mentioned, the impact of professionalism in senior rugby has filtered through to amateur and junior rugby, with all levels of the game having an increase in the intensity of the game (Garraway *et al.*, 2000). Injuries are a major concern for everyone involved in rugby, and the question is whether one can draw parallels between injuries at senior level and injuries at the junior level where the demands of the game are different. Although the nature of the game at the junior level remains similar to the games at the senior level, junior players are smaller, slower and weaker than senior players (Durandt *et al.*, 2006). This translates into a slower pace of the game and a lower impact of the collisions. Both factors lower the risk of injury in youth rugby (Haseler *et al.*, 2010).

As player's mature they get bigger and stronger (Malina *et al.*, 2000), which has a direct effect on the load, intensity and collisions in the game (Gabbett, 2013). There is limited research on injuries in youth rugby. However, the existing research suggests that the incidence and severity of injuries increase from the under 13 age group to the under 16 and the under 18 age groups (Brown *et al.*, 2013; Haseler *et al.*, 2010). The risk of injury in the under 20 age group is lower than in senior players (Fuller *et al.*, 2011). Therefore the chances of getting injured in rugby union increases with age until the senior playing level is reached (Fuller *et al.*, 2011). However, there is another

interpretation of the injury data in junior and senior players. Using identical injury definitions and methodology, the incidence between junior and senior rugby players was similar (Gabbett, 2008). The reporting of injuries at the junior level might not be as good as reporting at senior or professional levels.

The majority of injuries in junior rugby players are shoulder sprains which occur in the tackle situation (Gabbett, 2008). The range of injuries, caused by contact and non-contact events, were from relatively minor injuries such as lacerations, abrasions and contusions to more severe injuries like ligament, tendon, muscle tears and bone (contusion, fracture) injuries. An important finding of this study was that there are similarities between the incidence of injuries of junior and senior rugby players. Concussion and systemic problems (sick players) also added to missed training days (Cunniffe *et al.*, 2011).

Well-constructed resistance conditioning programs under appropriate supervision reduces the likelihood of overuse injuries (Lloyd *et al.*, 2013). At this stage of the player's development the major risk factors associated with youth sport injuries, such as low fitness levels (cardiorespiratory and musculoskeletal) and muscle imbalances, must be addressed to help them reduce the risk of injury when they enter the professional environment (Lloyd *et al.*, 2013; Baker, 2013; Ford *et al.*, 2011).

The incidence and severity of injuries at the professional age group level (academy level) has not been studied extensively. This is an important group to study because the players are still developing from a physical perspective, while the volume and intensity of play at this level are ever increasing (Palmer-Green *et al.*, 2013).

Training load/match load and rugby injuries

There are long competitions in rugby union (i.e. Super 15, Heineken Cup, Premiership, and the international games). For example, in the Super 15 tournament, which has 15 regional rugby teams from South Africa, Australia, and New Zealand, there are 125 matches. The tournament starts in February (in World Cup years the tournament starts earlier) and ends in July. The Super 15 ends in July and is followed with international matches between the national teams of South Africa, New Zealand, Argentina and Australia. Therefore, a Super 15 rugby team must prepare for 14-17 matches during the competition. To accommodate these demands the players must be well conditioned and talented. The playing squads must have sufficient depth to cover for injured players and also for players that lose their form during the tournament. Players as young as 18 years are contracted by the teams to provide depth and cover for certain positions. This means that the young players must be able to compete with senior players in these competitions and the young players must also be able to handle the higher training loads and intensities (du Toit *et al.*, 2012). After the Super 15, the Currie Cup competition starts (August to end October). This competition consists of seven teams playing in a double round robin with a semi-final and final. The regular players of the national team are rested from this competition as they have an end year tour to the Northern hemisphere where they play to play four test matches. The academy players have a longer pre-season and play non-competition games during the pre-competition stage. Where the senior players have two major competitions in a season, the junior professional player have only one competition, the under 19 Currie Cup. The junior competition follows the same format as the senior Currie Cup; i.e. seven teams with a double round robin ending with a semi-final and final.

It has been well documented that high pre-season training loads and existing injuries from the previous season contribute to the high injury rate during training in rugby (Gabbett, 2004; Killen *et al.*, 2010; Lee *et al.*, 2001). Therefore medical screening to identify existing injuries and players at risk is part of the management of the players' well-being. Another way to manage players' well-being is to plan the training loads in accordance with the changing demands of the season (Gabbett and Domrow, 2007). For example, a reduction of the training load in the early competition phase reduces the chance of injury without compromising agility performance in the rugby player (Gabbett and Domrow, 2007). Although high pre-season loads correlate with high injury risk, appropriate pre-season preparation is necessary to provide rugby players with adequate physiological capacity to get through the season (Brooks *et al.*, 2005).

The injury rate reduces during competition (Alsop *et al.*, 2000). An explanation for this is that coaches probably reduce high volume and high intensity contact sessions during the competition (Gabbett and Domrow, 2007). However, it has also been shown that the severity of the match injuries increases with increased training volumes. Training loads greater than 9.1 hours per week were associated with increases in severe injuries during matches (Brooks *et al.*, 2008). Intermediate training volumes, 6.2 – 9.1 hours per week were associated with the least days lost due to injury (Brooks *et al.*, 2008). The stress recovery profiles of adolescent rugby players decreased from pre-season towards the intensive competition phase where the participation demands were higher. The stress of the intensity of rugby matches (physically and psychologically) has a negative impact on the recovery of adolescent rugby players (Hartwig *et al.*, 2009). Stress/Recovery was measured with Stress-Recovery Questionnaires (RESTQ-Sport) and training diaries. It was suggested that these markers (e.g. fatigue, lack of energy, emotional stress, sleep and self-regulation) could be a warning sign for increased risk of injury, a decrease in performance or overtraining (Hartwig *et al.*, 2009).

In summary, research of adolescent injuries in sport is under explored, so further study is warranted in this area (Hartwig *et al.*, 2009).

Physical characteristics of junior rugby players and relationships to injuries

The physical characteristics of rugby players are usually defined by anthropometry (height, body mass and sum of skinfolds), speed (10 meter and 40 meter sprints), agility, estimated lower body power (vertical jump), upper body strength (bench press), upper body strength endurance (pull ups), repeated sprint capabilities and maximal aerobic power (multi stage fitness tests) (Baker and Newton, 2008; Durandt *et al.*, 2006).

The growth and maturation of boys to men has been well researched and boys become bigger, stronger and faster as they get older (Malina *et al.*, 2000). Some players develop faster than others with the 'fast developers' having a physical advantage over the 'slow developers' (Gluckman and Hanson, 2006; Malina *et al.*, 2000). The aspects of maturity in children with increasing age can be considered at the levels of physical, motor and cognitive functions. Chronological age refers simply to the age in years, whereas biological age refers to the age at a cellular level or level of development (physical, motor and cognitive). Chronological age and biological age are not completely synchronised (Gluckman and Hanson, 2006). Players of a similar chronological age but with a higher biological age usually have an advantage in sports such as rugby where physical size provides an advantage (Durandt *et al.*, 2008).

Physical development: Up to puberty the increase in height and mass of boys is consistent and the differences in height and mass are not that significant. During the pre-pubertal, pubertal and post-pubertal period (14-19 years) these differences vary the most as some players mature

(reach puberty) earlier than others (Malina *et al.*, 2000). The adolescent growth spurt is also known as Peak Height Velocity (PHV) and is defined as the age when maximal gains in height and body mass occur. The onset of PHV is the best determinant of when to increase the training focus on aerobic and strength development. The importance of resistance training for youth and adolescents is supported by scientific evidence, providing there is supervision from qualified professionals. The focus of youth resistance training should be on mastering the technical skill of the exercise in a safe environment. Resistance programs must be based according to training age, motor skill, competency, technical proficiency and existing strength levels (Lloyd *et al.*, 2013).

Motor development: There is an increase in all motor abilities from late childhood into late adolescence. The increase in physical ability is partly due to the development of fine motor skills and large muscle activities which improve as muscles become bigger and stronger. This development allows the player to run faster and to be more powerful. Eye-hand coordination and reaction times also improves with increasing age (Lefevre *et al.*, 1990).

Cognitive development: All children go through four stages of cognitive development as they get older (Lefevre *et al.*, 1990). The first stage is the sensory-motor stage (birth to two years). The second stage is the pre-operational stage (years two to seven). The third stage is the concrete-operational stage (years seven to eleven). The formal operational stage follows stage three and this is where the skill is acquired to think hypothetically and creatively. Studies have shown that cognitive ability improves with age and that the brain continues to develop through adolescence and into adulthood (Gluckman and Hanson, 2006). This point emphasizes that cognitive maturity is an important factor to consider in the maturity of adolescent and junior rugby players.

Several studies have shown that the physical qualities, in particular maximal aerobic power, of elite junior rugby players are superior to sub-elite senior rugby players (Gabbett *et al.*, 2009; Veale *et al.*, 2008). These studies emphasized that team selection appeared to be related to better

physical qualities in players who were starters versus non-starters (Gabbett *et al.*, 2013; Veale *et al.*, 2008).

There is a relationship between tests of physical qualities, team selection, and physical match performance (Gabbett *et al.*, 2013). It is important to integrate the physical qualities of players into the rugby environment and the specific skills required for the various aspects for the game. For example, tackling is a technical skill, and it has been shown that by improving acceleration and lower body power, the tackling ability of junior rugby players will also improve (Gabbett *et al.*, 2010).

Therefore physical development is important for junior players who are talented and competing for a place in a professional team. As explained above, physical development happens over years and with a long term development plan and age appropriate guidelines the risk of injury is lowered. Children and adolescents can significantly increase their strength, above and beyond growth and maturation, providing the resistance training program is of sufficient intensity, volume, duration and is performed with qualified supervision (Lloyd *et al.*, 2013). Comprehensive conditioning programs which include resistance training, plyometric training or both can be an effective strategy for reducing sports related injuries in adolescent players. Specificity of the training programs is important as junior players adapt differently to a given training stimulus than senior players. Therefore training programs must be modified to accommodate the differences in training ages (Gabbett, 2006). In sports, such as rugby, where change-of-direction sprint performance is important, a long-term resistance training program can improve change-of-direction performance for young and professional athletes (Keiner *et al.*, 2014). Greater levels of strength and power relate to higher levels of play (Baker, 2002), therefore younger or lower level rugby players must train to increase their levels of strength and power to be physically prepared for the next level of competition (Argus *et al.*, 2012).

The physical ability of senior rugby players declines towards the end of the competition phase (Gabbett *et al.*, 2004). This can be explained because as the season progresses, training loads decrease as match loads and injuries increase. However, this pattern was not observed in junior rugby players, possibly because they played fewer matches towards the end of the season, allowing players to maintain a higher level of fitness (Gabbett, 2005; Gabbett *et al.*, 2008). However this pattern may change as the professionalism in junior rugby increases and the junior players also have to play more matches.

The physiological differences between adolescents and adults

Adolescence is the period of transition between childhood to adulthood, encompassing not only reproductive maturation, but also cognitive, emotional and social maturation (Lloyd *et al.*, 2013). The important factor is that adolescence is a dynamic phase of growth and development in contrast to the adult phase where these aspects are more static. For example, during the development phase there is an increase in height and muscle development, which results in an increase of body mass. The long bones of the body grow with the epiphyses closing at the end of the maturation phase. There is an increase of the secretion of hormones (testosterone, growth hormone and insulin-like growth factor) (Lloyd *et al.*, 2013) which help with development of the body structures. The development stage leads to increases in muscular power, agility, speed and VO₂ max (Gabbett, 2005; Gabbett *et al.*, 2009).

As the adolescent matures into a young adult the maturation phase slows down. The neuromuscular system keeps on developing but at a much slower rate. Hormone secretion (gonadal steroid hormones) stabilizes and the young adult's coordination improves with

maturation as their motor ability improves (Lefevre *et al.*, 1990; Lin *et al.*, 1994). While the physical maturation is almost complete the cognitive and emotional development of the young adult still has years of development to complete (Gluckman and Hanson, 2006). Increases in biological maturity has a positive effect on functional running fitness and running performance in both the training and competition environment. During the developmental years players mature at different rates. It is important to realize that more mature players in an age group, either chronologically, biologically or a combination of both, are at a performance advantage to less mature players (Gastin *et al.*, 2013).

In summary, research of younger players emphasizes that the incidence of injuries increases as the playing level increases (Gabbett, 2004; Gabbett, 2013). The junior player adapts differently to conditioning programs than the senior player (Gabbett, 2006) and the importance of monitoring match loads for integration with training loads is important for optimal management of the players (Gabbett and Domrow, 2005). The elite young rugby player must be treated as a professional in the transition to adult professional rugby. However, it is important to consider younger players are still developing in several areas (physical, emotional and tactical) (Gluckman and Hanson, 2006). To refine the management structures catering for the demands of young players entering a professional environment, the association between the training/match load and fitness and injuries needs to be established.

Summary of practical points

The main points from the literature which can be translated into management of younger players are summarized in point form.

- Professionalism in rugby union has increased the training load and match load on players (Garraway *et al.*, 2000).

- Injuries have increased with the introduction of professionalism in rugby union (Garraway *et al.*, 2000).
- The demands of professionalism has filtered through to junior rugby (Garraway *et al.*, 2000).
- Injury rates increase as players get older and the intensity of the game increases (Fuller *et al.*, 2011).
- The highest rate of injuries occur pre-season (Gabbett, 2004; Killen *et al.*, 2010).
- The severity of injuries increase during the competition phase of the season (Brooks and Kemp, 2008).
- Junior players with superior physical qualities have a better chance of team selection when they enter the adult level (Argus *et al.*, 2012).
- Well-constructed conditioning programs can reduce sport related injury in adolescent players (Lloyd *et al.*, 2013).
- Research investigating the integration of the adolescent players into professional rugby union needs to be conducted.

The next chapter describes the experimental part of this dissertation which examines the training/match load and injuries of under 19 academy players during a season.

CHAPTER 3:

The relationship between training/match load and injuries in academy players during a provincial under 19 rugby union season.

Introduction

Following the onset of professionalism in rugby union in October 1995 players had more time to spend on conditioning to accommodate the changing demands of the sport (Brooks *et al.*, 2005). In particular, training was designed to prepare the players for contact, collisions and intermittent, short duration high intensity bouts of exercise. This type of training, coupled to training for rugby related skills, resulted in stronger, fitter, faster and larger players with enhanced rugby skills (Argus *et al.*, 2012). This had an impact on the demands of the game that evolved to be played at a faster pace with greater impact forces (Quarrie and Hopkins, 2007). The contact situations between players during training or matches results in structural damage to the soft tissue of players (Takarada, 2003). Forwards are involved in more contact situations than backline players, which leads to the conclusion that forwards experience higher loads of physiological stress and need to be managed accordingly (Takarada, 2003).

The fact that the rugby season has become longer and more games are played means there is a significant increase in training load of players (Brooks *et al.*, 2008). It is not possible for the players to maintain a physical peak for the duration of the season and therefore they have to be managed carefully to ensure that the training load and recovery from training and competition are carefully balanced (Borresen and Lambert, 2009). It is inevitable that fatigue and overuse injuries are a consequence of an imbalance in training load and recovery and have to be managed through the season (Meeusen *et al.*, 2013). The multiplicity of factors that contribute to injury in rugby union makes it difficult to identify causality (Quarrie *et al.*, 2001). To adequately look after the well-being of the players, teams performing at a high level have a management team consisting of a range of sports medicine, health and conditioning specialists who condition players, reduce their risk of

injury, and treat and rehabilitate rugby injuries appropriately. Furthermore, as part of the program to manage injuries it is important to gain a better understanding of the nature and causes of rugby injuries, in particular their association with training (Brooks *et al.*, 2005).

As a consequence of professionalism in rugby union, the younger players are targeted for early talent identification. This results in them being exposed to a high intensity, high load training environment after school (Nutton *et al.*, 2012). The junior players have to overcome the problem of a rather sudden increase in load when they move from a school environment with a relatively low training base to the professional environment with a much higher load, coupled with higher expectations from the management team. This increases the risk of training-induced fatigue and injury (Killen *et al.*, 2010).

Rugby union at the senior professional level has been the target of much research since the sport turned professional. The physical demands of the game have been described, and it is known that body mass, strength, power, speed and anaerobic fitness are important attributes that players have to compete at the highest level of rugby union (Smart *et al.*, 2011). There has also been much research conducted on the injury profiles of players in different positions within the professional game. For example, forwards tend to have shoulder, knee and ankle injuries while the backs most frequently have shoulder, hamstring and knee injuries (Brooks and Kemp, 2011).

The same research vigor needs to be applied to the junior professional rugby union environment. The demands of these players are different as the mental and physical characteristics of the junior players are still developing (Gluckman and Hanson, 2006; Hartwig *et al.*, 2008; Hartwig *et al.*, 2009; Hartwig *et al.*, 2011). It is not always appropriate to transfer knowledge gained from research conducted at the senior level directly to the junior level. In particular elite schoolboy rugby (under 18) and professional rugby played at the under 19 to under 21 levels cannot be compared as the load and intensity of training is much higher when the game is played at a senior level (Brooks *et al.*, 2008; Hartwig *et al.*, 2008; Hartwig *et al.*, 2011). The aim of the management

team for professional junior players is to create a professional player that can compete at the senior level. Therefore, physical characteristics and physical capabilities important for rugby need to be developed, while also adapting the players so that they can accommodate the high training loads and high intensity training methods they will be exposed to at the senior level (Duthie *et al.*, 2003).

As previously mentioned, with rugby being a professional sport there are increased competition demands, which requires a greater pool of players. It is these young talented professional players that are being selected to fill the void (Fuller *et al.*, 2013). The structured training environment provided by professional academies provides the players with the opportunity to get fast tracked towards the physical capabilities they need to perform in the senior professional levels. The majority of the physical adaptation appears to be attained in the first two years in a structured environment. After this period the adaptation still continues but at a slower pace. (Argus *et al.*, 2012). This highlights the importance of having appropriate development pathways for young talented players.

The aim of this dissertation was to investigate the relationship between training and match load during an under 19 pre-season, and competitive in-season. The specific objectives of the dissertation have been described in chapter 1, page 15.

Methodology

Study design

The study has a retrospective, descriptive design.

Ethical Considerations

This study was performed in accordance with the principles of the Declaration of Helsinki (Fortaleza, Brazil, 2013). Ethical clearance was obtained from the Human Research Ethics Committee of the Faculty of Health Sciences at the University of Cape Town (HREC REF 002/2011). The study was explained to each player after which he signed an informed consent form. The participants had the right to withdraw from the research at any time. All data were kept confidential.

Selection of participants

The participants were under 19 rugby union players (n = 34) of the Western Province Rugby Institute who were promoted in the second half of the year to the under 19 Western Province Currie Cup squad. The under 19 Currie Cup is the national rugby union competition in South Africa for under 19 rugby players. Participants were included in the study if they were in the under 19 age group for the year, played at least one match for the under 19 Currie Cup side and gave consent for their data to be used.

Although all players had already signed a consent form provided by the BokSmart program (www.boksmart.co.za) they were asked to sign an additional consent form for this study. Prior to signing the form a description of the study was read to each player. This described all the information collected throughout the rugby year that was going to be analyzed for the study. The form also explained that their information would be kept confidential and that their participation was voluntary. Furthermore it stated that they could withdraw their consent at any stage.

This was a convenience sample, therefore there was no randomization of participants and the sample size was defined by the number of players chosen to play for the team during the under 19 Currie Cup season. The sample size was 34.

Testing procedure

Players were monitored for 10 months of the season (January to October). All fitness testing, injuries and training and match loads were recorded during this time. The outline of the rugby year is shown in Table 1.

Table1: *Outline of the rugby year with the timing of the testing sessions.*

JANUARY	<ul style="list-style-type: none"> • Pre-season start (block of 10 weeks). • 1st battery of fitness tests is completed. • Medical screenings are done.
FEBRUARY	<ul style="list-style-type: none"> • Pre-season continues.
MARCH	<ul style="list-style-type: none"> • Pre-season ends middle March. • Players break for ten day leave.
APRIL	<ul style="list-style-type: none"> • 8 Week block of friendly games and trials for team selection start.
MAY	<ul style="list-style-type: none"> • Friendly games and trials continue.
JUNE	<ul style="list-style-type: none"> • Players break for three week leave (off feet conditioning program). • Players go into three week pre competition block (field and conditioning block). • 2nd Battery of fitness tests is completed.
JULY	<ul style="list-style-type: none"> • Provincial competition starts middle July.
AUGUST	<ul style="list-style-type: none"> • Provincial competition continues.
SEPTEMBER	<ul style="list-style-type: none"> • Provincial competition continues.
OCTOBER	<ul style="list-style-type: none"> • Provincial competition finish end October. • Medical screening and referrals to specialists if necessary.

Players underwent a battery of fitness tests in the first week of the year and again in June at the start of the pre competition block. All players had a consultation with the doctor, fitness trainer and physiotherapist prior to testing. This served to inform the player of the testing protocol and also to identify injuries that may be aggravated by the testing.

The order of testing on both occasions was as follows:

- Monday – anthropometry and wide grip pull ups.
- Tuesday morning – sprinting speed (10 meter and 40 meter).
- Tuesday afternoon – vertical jump and 1 RM bench press
- Wednesday – repeated sprint test
- Flexibility testing was incorporated in the musculoskeletal screening conducted by the physiotherapist. No lower body strength tests were completed as they were regarded as being associated with a high risk of injury. A description of the tests follows.

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

Anthropometry

The measurements were performed by the same person at each testing session to ensure repeatability. Body mass was recorded on a calibrated scale (Adam Equipment Co, Ltd, Milton Keynes, UK). Players were weighed in underpants and without shoes. (TEM = 0.48kg, CI 0.33 – 0.83kg; TEM as % CV = 0.6%, CI 0.4 -0.7%) For the measurement of height, each player stood barefoot with his arms at his sides and with his head, upper back, buttocks, and heels in contact with the wall. Height was recorded from the floor to the highest point on the skull using a stadiometer. (TEM = 0.33cm, CI 0.26 – 0.44cm; TEM as % CV = 0.2%, CI 0.2 -0.3%)

As an estimate of adiposity, skinfold thickness was measured as the sum of four skinfolds (abdomen, supra- iliac, triceps and thigh) using a Harpenden skinfold caliper (Baty International, West Sussex, UK). The exact positioning of each skinfold measurement was as follows:

Abdomen – The vertical fold taken at the lateral distance of approximately 2 cm from the umbilicus.

Suprailiac – A diagonal fold above the crest of the ilium at the spot where an imaginary line would come down from the anterior auxiliary line just above the hip bone and 2-3 cm forward.

Triceps – A vertical fold on the posterior midline of the upper arm, over the triceps muscle, halfway between the acromion process and olecranon process. The elbow was extended and the arm relaxed.

Thigh – A vertical fold on the anterior aspect of the thigh, midway between the hip and knee joints. The leg was straight and relaxed.

1 Repetition max (RM) Bench Press

The 1 repetition max (RM) bench press test represents the maximum muscle strength of the upper body. There were always three 'spotters' with this test to reduce the risk of injury. The warm up consisted of three times ten repetitions of push-ups and five repetitions on the bench press with a submaximal weight.

The player was supine on a bench, feet flat on the floor with the hips and shoulders in contact with the bench. Hand spacing on the Olympic bar was 1.5 times the player's biacromial width. The 'spotters' helped to lift the bar and when the player was ready to take control of the weight, stepped away. The bar was lowered in a controlled manner until it touched the player's chest. The player then pushed up until both of his arms were in a locked position. Lifts were disqualified when the player's buttocks lifted off the bench, the bar was bounced off his chest or the 'spotters' touched the bar because the player was about to fail. Players started the test lifting a weight that they rated as "comfortable". After the initial press the weight was increased by 5 kg. The players had two chances to fail at the same weight before being disqualified. The last successful lift was recorded. The 1RM bench press test is reliable (ICC, $R = 0.99$; $CV = 1.4\%$) and valid (McCurdy *et al.*, 2001)

Wide grip pull ups

The purpose of the pull up test was to measure the upper body strength endurance. An overhand grip was used with hands shoulder width apart. The player started from a hanging position (arms fully extended). The player's chin had to reach above the bar on the ascent and the arm had to fully extend on the descent. Repetitions that did not fulfill these requirements were not counted. This test was a maximal effort test and players were asked to continue until failure. No rest was

allowed between pull ups. *Gabbett et al* (2008) showed a TEM for pull ups to be 6.4% and the ICC being $R=0.98$.

Vertical jump

The purpose of the vertical jump test was to measure leg power (*Quagliarella et al.*, 2011). A tape measure was attached to a wall. The player's standing height was measured with his dominant side to the wall. The player reached up with the dominant arm, and the stretched standing height was measured at the finger tips. No run up or shuffle step was allowed before the jump. The players were allowed to bend their knees and swing their arms in preparation for the jump. The players had a 10 minute warm up, which consisted of 4 times 30 second rope skipping and dynamic stretches of the calves, hamstrings and quads. The warm up ended with five submaximal vertical jumps. Two maximal jumping efforts followed the warm up. The player had chalk dust on his fingers and made a mark on the wall at the highest point of his jump. The vertical jump score was measured as the distance (cm) between the stretched standing height and the jump height. The highest jump height was recorded.

5 Meter shuttle test

The 5 meter shuttle run measures the player's repeat sprint ability, local muscle endurance of the legs and lower back, as well as agility (*Durandt et al.*, 2006). The test area was prepared on an athletic track (non-slip) using all eight lanes. Six cones were placed at five meter intervals. The players started the test at point 0 at the sound of a whistle, sprinting to cone one (5 m), touching the line and then sprinting back to cone 0 (10 m) touching the line, turn around and sprint to cone 2 (20 m). The players continued in this manner, sprinting to cones 3, 4, 5 and returning to cone 0 between each outward shuttle sprint, with each repetition consisting of 30 seconds. The players

had a 30- second rest before the next repetition. The distance measured was that of the last cone fully reached. If a player turned short of a cone it was an immediate 5 meter subtraction of the finished distance. The players had to complete six repetitions and the main outcome measure was the distance covered by the player during any single repetition, and the total distance (m) in six repetitions.

Sprint Speed: 10 meter and 40 meter

The purpose of the test was to determine the player's maximum sprint speed and the ability to accelerate from a stationary position. A Newtest timing device (NewtestOy, Finland) was used to measure the time for the sprints. Players warmed up for 15 minutes supervised by a conditioning coach. The key points for the warm up included progression in strides building up to full speed and dynamic stretches. The players were instructed to exert a maximal effort on the test runs. The player positioned himself in a crouched start position 30 centimeters from the start line. The first set of light sensors was placed at the start line, the second at 10 meters and the third at 40 meters. Players had two maximal effort runs with a minimum of 3 minutes between runs. The faster of the two runs were recorded. *Gabbett et al*, showed test-retest reliability of the 10m and 40m sprint to be $R= 0.95$ and 0.97 respectively, with a TEM of 1.8% and 1.2% respectively.

Injuries

Players had a musculoskeletal screening test at the start of the pre-season. The screening test was the standardized protocol from the BokSmart programme of SA Rugby (www.sarugby.co.za/boksmart/). The main focus areas were current and previous injuries, joint integrity and range of motion tests, muscle strength and flexibility and proprioception.

Injuries were defined as conditions that caused a loss of rugby training. All injuries during the 10 months were recorded and managed appropriately. Injuries were classified by location, type, body side, injury event and whether it was a contact or non-contact mechanism according to the definitions provided by Fuller *et al.*, (2007). Injuries were monitored through the year on a daily basis by injury report sessions at eight o'clock in the mornings before training sessions started. Time lost from the rugby environment was defined as follows: “*the number of days that have elapsed from the date of injury to the date of the player’s return to full participation in team training and available for match selection*”. This definition allowed the injuries to be grouped as follows: slight (0-1 day), minimal (2-3 days), mild (4-7 days), moderate (8-28 days), severe (> 28 days, “career ending” and “non-fatal catastrophic injuries” (Fuller *et al.*, 2007). Injured players were screened and referrals were made to the physiotherapist, or if necessary to the sport clinician. The referral for special investigations or for examination by a specialist was the sport clinician’s responsibility. The ultimate goal was to have fast, correct diagnoses to prevent wasting time on treatment without a confident correct diagnosis.

Training and Match time

The players’ training time was monitored and recorded daily by the strength and conditioning coaches. Training times were subdivided into rugby sessions and conditioning sessions for fit players. Injured players had additional training times recorded for their rehabilitation, and any extra conditioning to compensate for lost time on the field. The data were double checked by the medical department to ensure injured players were credited with off field rehabilitation and conditioning sessions and not on field rugby sessions. Training time was used as a measure of training load. This has a potential limitation as it does not account for training intensity. However “duration” was considered the best alternative in the absence of perceived exertion from each player throughout the year.’

Each player's game time during the year was monitored by the conditioning coach and recorded as minutes. Injuries, red and yellow cards and substitutions during the games were incorporated and accounted for in the monitoring system.

Statistical Analysis

The differences between fitness levels (January vs. July) were analyzed using a paired t test. The magnitude of these differences (i.e. whether the changes were positive or trivial) were determined using the spreadsheet downloaded from www.sportsci.org, as described in Batterham and Hopkins, (2006).

A Chi² test determined the occurrence of injuries during the different phases of the season. The incidence of injury was calculated expressing the number of injuries per 1000 player hours, as described by Brooks & Fuller, (2006) and Knowles *et al.*, (2006). The calculation of the 95% confidence intervals was done according to Knowles *et al.*, (2006). Between the incidence of injury in the different phases of the season was determined by comparing the overlap of the 95% confidence intervals. Incidences were considered significantly different if the 95% CIs did not overlap as previously described (Brown *et al.*, 2013).

Differences in the number of days to return-to-play after contact or non-contact injuries in the different phases of the season were determined using an analysis of variance, after confirming homogeneity of variance using the Levene's test.

Data are expressed as the mean \pm standard deviation. Statistical analysis were performed using Statistica software (Statsoft, Inc. 2004) STATISICA (Data analysis software system, version 8) (www.statsoft.com).

Results

Structure of the season

A total of 34 players met the selection criteria. The players were monitored over a period of 42 weeks. The season was divided into pre- season, pre- competition and competition phases (Figure 1). There were two holiday breaks, the first one after week 10 and the second one after week 22. Their general characteristics at the start of the season are shown in Table 2 (January).

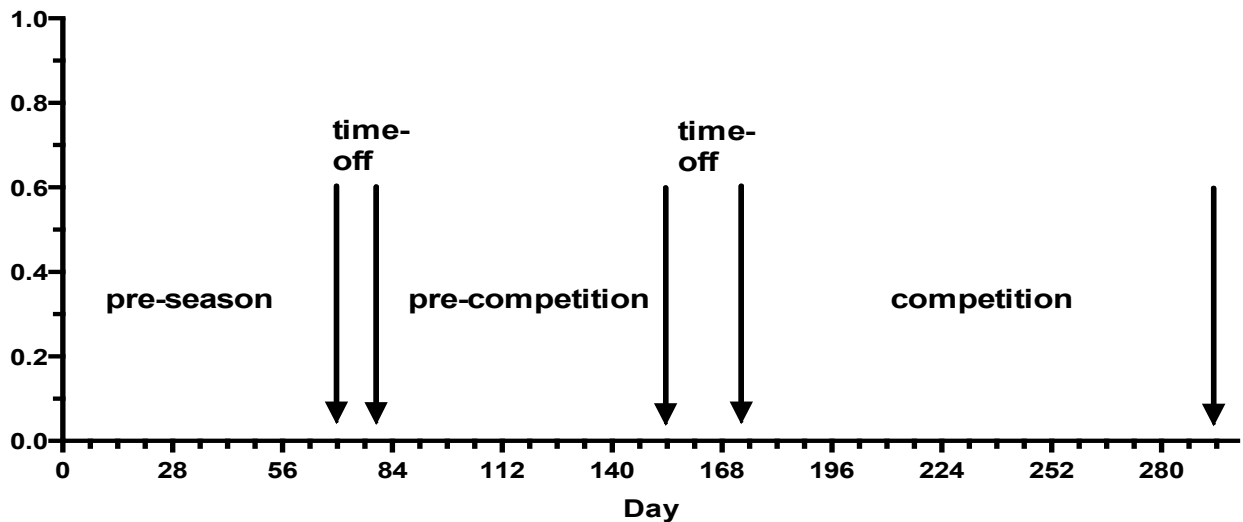


Figure 1: *The breakdown of the season including the days when the players were given time off.*

The main objective during the pre-season phase were conditioning and rugby integration. Playing matches was not a priority but two trial matches were played at the end of the pre-season phase as part of the preparation. During the pre-competition phase, conditioning was still a main focus but the rugby training sessions became more of a priority. Matches were introduced and during the pre-competition phase, 11 matches were played. During the competition phase the training volume decreased, but the intensity of training remained high. The 16 matches played during the competition phase were the main focus during this period.

Physical changes

The physical characteristics of the players in January (week 1) and June (week 26) are shown in Table 2. The first battery of tests were at the beginning of the pre-season and the second in the beginning of the competition phase. All the test scores improved significantly ($p < 0.0001$). In other words, the players got taller and heavier and their skinfolds decreased. The number of pull ups they did increased, as did the weight lifted in the bench press. Their vertical jump height increased and their repeat sprint ability improved. They also became faster at 10 m and 40 m sprints. When the magnitude of these changes were analyzed using the procedure described by Batterham and Hopkins (2006), the changes were 100% positive for skinfolds, pull-ups, bench press, vertical jump and repeat sprint, whereas they were only 14% positive for body mass. The changes were smaller (trivial) for stature, and sprint times (10 m and 40 m) (Table 2).

Table 2: *Measurements of fitness characteristics in January and July. Sample size varies because only the players that were tested on both occasions are included in the analysis. Values are expressed as means \pm standard deviation. All the changes are significant at $p < 0.0001$.*

Variable	January	June	n	Positive effect (%)*	Trivial effect (%)*
Stature (m)	1.81 \pm 0.09	1.81 \pm 0.09	34	0	100
Body mass (kg)	93.2 \pm 17.3	94.0 \pm 15.3	34	14	86
Skinfolds (mm)	41.7 \pm 20.1	36.2 \pm 15.0	34	100	0
Pull-ups (number)	8 \pm 7	17 \pm 9	33	100	0
Bench press (kg)	102 \pm 16	110 \pm 14	31	100	0
Vertical jump (cm)	51.6 \pm 8.2	58.2 \pm 9.1	34	100	0
Repeat sprint	710 \pm 48	753 \pm 28	32	100	0
Sprint 10 m	1.77 \pm 0.08	1.72 \pm 0.08	33	0	100
Sprint 40 m	5.39 \pm 0.24	5.23 \pm 0.25	33	0	100

*Batterham, A., & Hopkins, W. (2006). Making meaningful inferences about magnitudes.

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The individual data for each variable are shown in Figure 2. It is evident from these graphs that there was individual variation, with players changing at different rates.

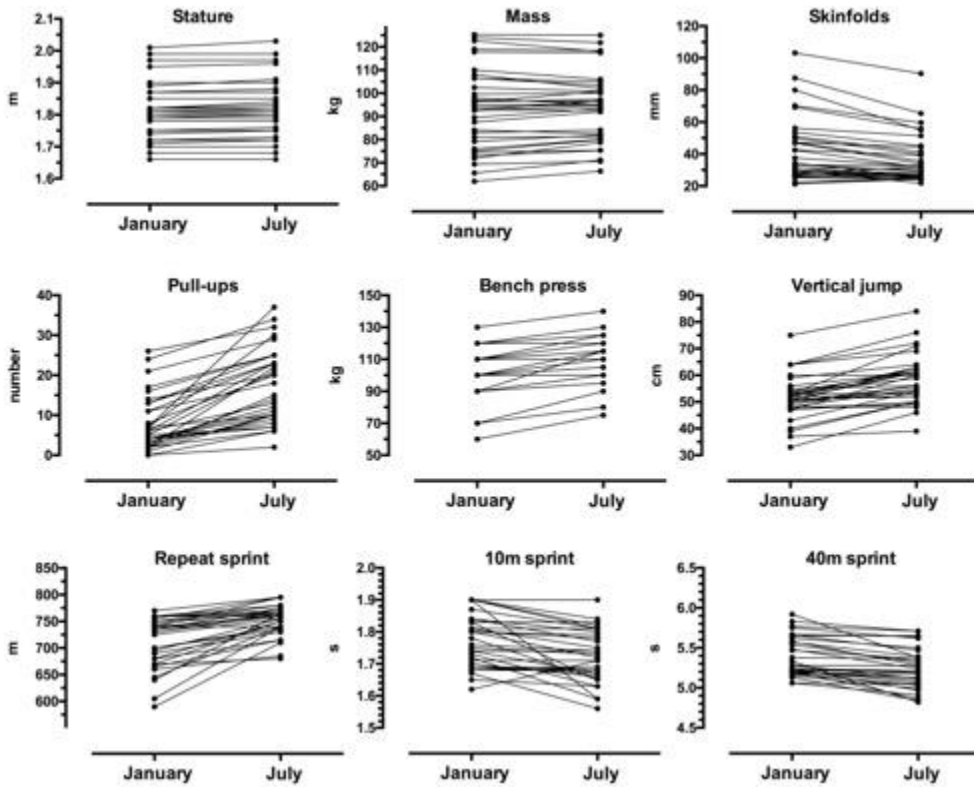


Figure 2: The measurements associated with fitness in January and July. The sample size and statistics for each variable are shown in Table 1.

Quantification of exposure type

Rugby specific training sessions were supervised by the rugby coaches, while the conditioning related training sessions (strength, rehabilitation, and fitness) were supervised by the conditioning coach and physiotherapist. Rehabilitation was done after hard training sessions and matches. The average time per day for training, strength and conditioning, recovery and extra fitness are shown in Figure 3. The stages of the season where the matches were played are also shown in Figure 3. The average training time per week was 5 hours 52 minutes.

Most of the time during the year was spent on the training field. This was followed by strength and conditioning training, matches, extra fitness and rehabilitation training and recovery after training.

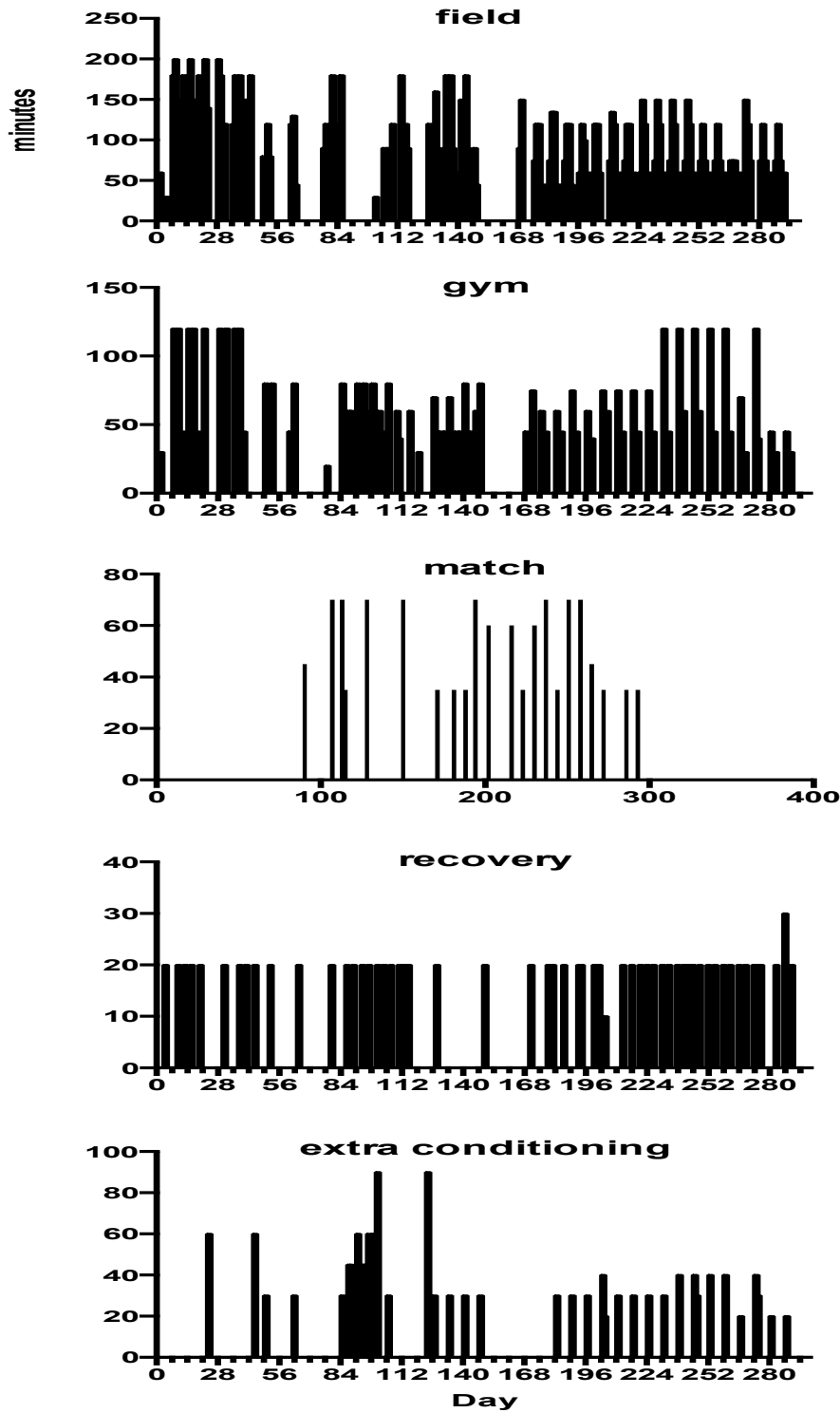


Figure 3: Average time (minutes) for field training, conditioning, matches, recovery and extra conditioning and rehabilitation sessions.

Injuries

Over the entire season the players sustained 71 injuries. These were divided into 17 pre-season injuries, 18 pre-competition injuries and 36 injuries during the competition phase. Injuries were also divided in contact and non-contact injuries (Table 3). There was no difference in the occurrence of injury during the different phases of the season ($\chi^2 = 3.03$, $df = 2$, $p = 0.22$).

Table 3: *A breakdown of the injury events during the different phases of the season (n = 71)*

	<u>Phase of season</u>			Total
	Pre-season	Pre-competition	Competition	
Non-contact	10	6	13	29
Contact	7	12	23	42
Total	17	18	36	71

The distribution of the injuries in the season are shown in Figure 4a, (contact vs. non-contact), Figure 4b (body part) and 4c (type of injury).

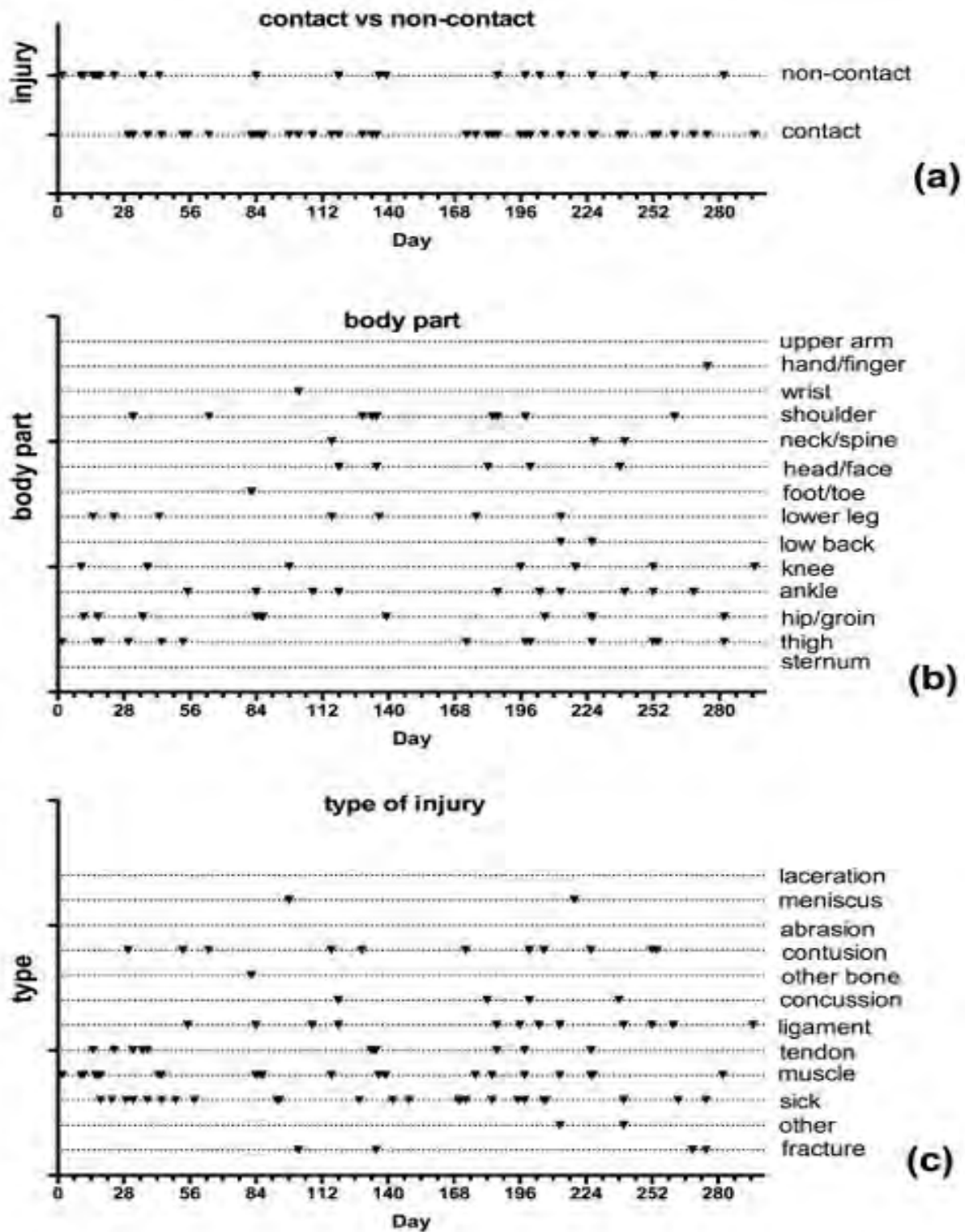


Figure 4: The distribution of the 71 injuries during the season according to contact and non-contact injuries, (Figure 4a), body part (Figure 4b) and type of injury (Figure 4c).

The incidence of injury was also expressed considering the exposure time for the different phases of the season (Brookes *et al.*, 2006 and Knowles *et al.*, 2006). The breakdown and details of the calculations are shown in Tables 3, 4 and 5. The overall rate of injury between the phases of the season was 6.3/1000 player hours (pre-season), 7.6/1000 player hours (pre-competition) and 10.3/1000 player hours (competition). These were not significantly different (Table 4). There was however a significant difference between the injury rate in training (4.4/1000 player hours) and matches (74.1/1000 player hours) (Tables 4 and 5).

Table 4: Incidence of total injuries which are subdivided into contact and non-contact injuries during the different phases of the season.

	Phases of the season		
	Pre-season	Pre-competition	Competition
Player exposure (h)	2710	2355	3510
Number of injuries	17	18	36
• contact	7	12	23
• non-contact	10	6	13
Incidence of total injuries (per 1000 player h) (95% CI)	6.3 (3.3 – 9.3)	7.6 (4.1 – 11.2)	10.3 (6.9 – 13.6)
• Incidence of contact injuries (per 1000 player h) (95% CI)	2.6 (0.7 – 4.5)	5.1 (2.2 – 8.0)	6.6 (3.9 – 6.6)
• Incidence of non-contact injuries (per 1000 player h) (95% CI)	1.4 (3.7 – 6.0)	2.5 (0.5 - 4.6)	3.7 (1.7 – 5.7)

Table 5: Incidence of injury during training during the different phases of the season.

	Phases of the season			
	Pre-season	Pre-competition	Competition	Total
Player exposure (h)	2655	2132	3208	7995
Number of injuries (training)	15	6	14	35
Incidence of injury (training) (per 1000 player h) (95% CI)	5.6 (2.8 – 8.5)	2.8 (0.6 – 5.1)	4.4 (2.1 – 6.7)	4.4 (2.9 – 5.8)

Table 6: Incidence of injury during matches during the different phases of the season

	Phases of the season			
	Pre-season	Pre-competition	Competition	Total
Player exposure (h)	55	224	302	580
Number of injuries (matches)	2	12	22	36
Incidence of injuries (matches) (per 1000 player h) (95% CI)	36.4 (-14.0 – 86.8)	53.6 (23.3 – 83.9)	98.2 (57.2 – 139.3)	74.1 (53.8 – 94.4)

The nature of the injuries were varied, while the most common body parts injured included the thighs (n=13), hip/groin (n=10), ankles (n=10) and shoulders (n=9). The sample size, after considering the various body parts was too small to do any meaningful statistics.

The body parts injured and type of injury are shown in Tables 7 and 8 respectively.

Table 7: *The body parts injured during the different phases of the season.*

	Phase of season			Total
	Pre-season	Pre-competition	Competition	
thigh	6	0	7	13
hip/groin	3	4	5	10
ankle	1	3	6	10
shoulder	2	3	4	9
knee	2	1	4	7
lower leg	3	2	2	7
head/face	0	2	3	5
neck/spine	0	1	2	3
low back	0	0	2	2
foot/toe	0	1	0	1
wrist	0	1	0	1
hand/finger	0	0	1	1
Total	17	18	36	71

Muscles (n=24) and ligaments (n=14) were the structures that were most frequently injured.

Illness episodes (n=36) also added to the total days missed by the players on the training events. Once again the number were too small for meaningful comparisons.

Table 8: *The type of injury during the different phases of the season.*

	Phase of season			Total
	Pre-season	Pre-competition	Competition	
illness	10	5	21	36
muscle	7	6	11	24
ligament	1	3	10	14
contusion	3	2	7	12
tendon	6	2	1	9
fracture	0	2	2	4
concussion	0	1	3	4
meniscus	0	1	1	2
other bone	0	1	0	1
other	0	0	1	1
Total	27	23	57	107

The total injuries due to contact events were 42, while the total injuries due to non – contact events were 29. Muscles injuries (n= 19) were the reason for the highest non-contact injury count, while contusions (n=12) were the reason for the highest contact injury count. The hip/ groin area (n=11) was the area mostly affected by non-contact events, and the shoulder (n=8) and thigh (n=9) were mostly injured during contact events.

A breakdown of the body parts injured as a result of contact or non-contact is shown in Table 9, and the type of injury (contact vs non-contact) is shown in Table 10.

Table 9: *The body parts injured as a result of either non-contact or contact situations.*

	Cause of injury		Total
	Non-contact	Contact	
thigh	5	8	13
hip/groin	11	1	12
ankle	6	4	10
shoulder	0	9	9
knee	1	6	7
lower leg	4	3	7
head/face	0	5	5
neck/spine	0	3	3
low back	2	0	2
foot/toe	0	1	1
wrist	0	1	1
hand/finger	0	1	1
Total	29	42	71

Table 10: *The type of injury as a result of either non-contact or contact situations.*

	Cause of injury		Total
	Non-contact	Contact	
sick	-	-	-
muscle	19	5	24
ligament	6	8	14
contusion	0	12	12
tendon	4	5	9
fracture	0	4	4
concussion	0	4	4
meniscus	0	2	2
other bone	0	1	1
other	0	1	1
Total	29	42	71

Tables 9 and 10 indicate that the hip/ groin injuries are mostly caused by non- contact events and that the structures injured were mostly muscles.

The average duration of days to return-to-play after an injury for the season was 17 days. For contact injuries it was 19 days and for non-contact injuries the return-to-play duration was 16 days (Table 11). The number of days to return-to-play were not different between phases of the season ($F = 0.79$, $p = 0.46$). Also, there was no difference in return-to-play duration whether the injuries were caused by contact or non-contact situations. ($F = 0.37$, $p = 0.54$) (Table 11).

Table 11: *The number of days to return-to-play following non-contact and contact injuries during the different phases of the season (n = 71). Values are expressed as mean ± SD.*

	Pre-season	Phase of season		Total
		Pre-competition	competition	
Non-contact	23 ± 29	19 ± 11	8 ± 7	16 ± 19
Contact	24 ± 28	15 ± 11	19 ± 28	19 ± 22
Total	24 ± 28	16 ± 11	15 ± 23	17 ± 22

The injuries to the hand/finger and knee were the most severe, in terms of time to-return-to-play (Table 12). There was only one hand/finger injury in the study, so this should be interpreted with caution. Injuries to the thigh were the most common ($n = 13$), with the average time to return to play being eight days. There was much variation around each mean, so a bigger sample size is needed before these data can be interpreted properly and applied to the management of injured players.

Table 12: *The number of days to return-to-play for the various body parts injured during the season. Values are expressed as mean ± SD.*

	Days	n
thigh	8 ± 6	13
hip/groin	21 ± 27	12
ankle	22 ± 24	10
shoulder	19 ± 25	9
knee	31 ± 38	7
lower leg	14 ± 13	7
head/face	17 ± 11	5
neck/spine	8 ± 6	3
low back	2 ± 1	2
hand/finger	50	1
wrist	20	1
foot/toe	8	1
Total	17 ± 22	71

The structures involved with the more severe injuries were bone (fractures), meniscus, ligament and tendons (Table 13). These injuries were associated with the most training days lost by the players. Injuries to the thigh and lower back was less severe and included contusions and muscles strains. The average number of days to return-to-play was 17 days.

Table 13: *The number of days to return-to-play for the various types of injury during the season.*

Values are expressed as mean \pm SD.

	Days	n
sick	5 \pm 6	36
muscle	12 \pm 6	24
ligament	20 \pm 28	14
contusion	6 \pm 4	12
tendon	33 \pm 35	9
fracture	47 \pm 27	4
concussion	12 \pm 3	4
meniscus	26 \pm 22	2
other bone	8	1
other	14	1
Total	13 \pm 19	107

“Figure 5 (page 65) shows the frequency distribution of days off before return-to-play. The relevance of Figure 5 for team management is that the average return-to-play time is between 16-19 days, but that they can expect a few severe injuries during the season where a player can be out for months or even the rest of the season. Most of the injuries (i.e. median) needed eight days of recovery before the player could return to play. An exponential decay function fitted to the data described the relationship between number of injured players and time off with a reasonable accuracy ($R^2 = 0.76$).

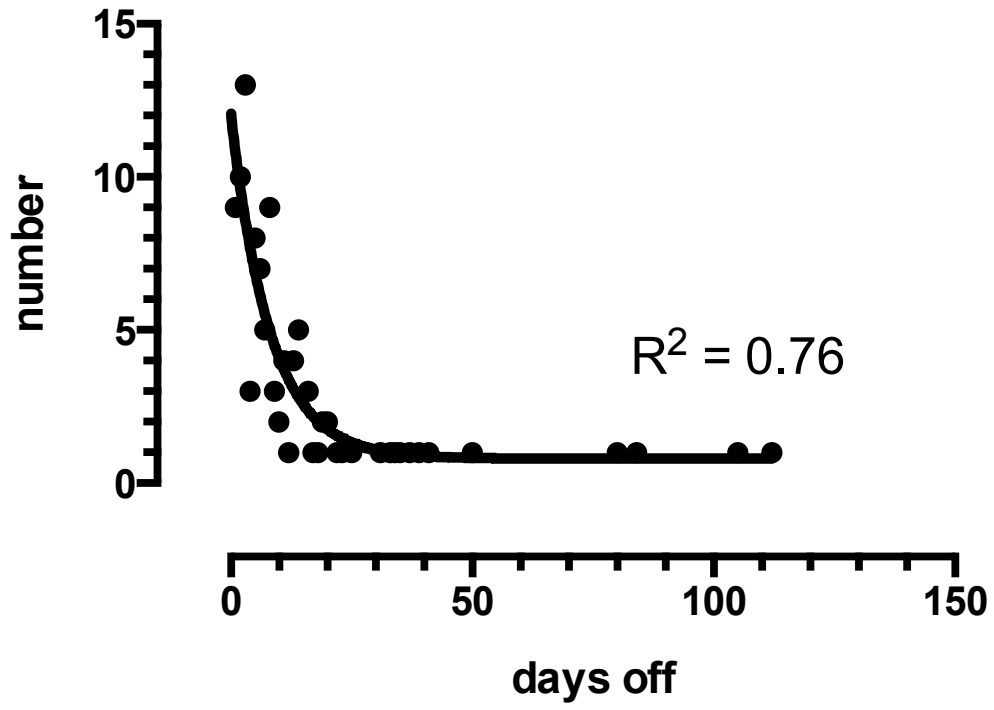


Figure 5: *Frequency distribution showing the days off before return-to-play*

Discussion

The first finding of this study was that the training and playing season for this rugby squad was 42 weeks long, with the players starting in January and continuing until the end of October. This included pre-season, pre-competition and the competition phase of the season. This is longer than the previous “rugby year” of most of the players who were at school in the previous year. In this case the season would have ended in August after starting in February (28 weeks). The duration of the season for the academy players compares to the duration of the senior professional squads who start early January and finish end of October. Only the International players continue with matches into November when they go on the European tour. Therefore it is clear that the duration of the junior professional rugby player’s rugby year is closer to the senior professional rugby player than the school boy rugby player.

The next finding was that the body mass of the players increased from about 93 kg to 94 kg in the six months between the testing batteries. Although this was significant, it was regarded as a trivial increase (Table 2). However, if the decrease in skinfolds (41.7 mm to 36.2 mm) is considered, it may be concluded that the increase in body mass can be attributed mostly to changes in lean body mass. Body mass of players competing in collision sports is an important variable associated with performance. Over the past three decades there has been a general increase in the overall body mass of all rugby players (Sedeaud *et al.*, 2012; Olds, 2001). Players at national under 20 level had an average increase of 10 kg in body mass over a 13 year period (Lombard *et al.*, 2015), which indicates that the transition into the professional era also had an effect on the junior professional players.

In the six months between the test batteries the players also had a significant increase in stature from 1.81 to 1.82 meters. This indicates the players were still maturing and developing physically. Increases in stature can be expected during this age (Faigenbaum, 2008). The fact that the

players were still growing places them in a high risk group particularly as their season was much longer than the previous year.

The next finding was that the players got stronger. Their bench press results increased from 102 kg to 110 kg, which translates into increased strength on the field (Young, 2006). Strength is an important attribute for performance in rugby, with certain positions requiring greater strength than other positions due to their varying demands (Durandt *et al.*, 2008). The current study showed an increase of almost 8% in the bench press test. This can be compared to a study on highly trained 24 year old professional rugby players, which showed an increase of 6% to 12% in upper body strength after two years of training (Appleby *et al.*, 2012). It has been shown that the magnitude of strength improvement is greater in players who do not have much experience with resistance training (McMaster *et al.*, 2013).

The pull up test was used to test upper body strength endurance. Players are expected to produce multiple muscle contractions using their upper bodies over the duration of a match, particularly in situations such as lineout play, defensive situations and rucks. The player that is more fatigue resistant will have a distinct advantage over the player that fatigues faster (Gamble, 2004). The number of pull ups improved by 113% (8 to 17 pull ups).

The players also became more powerful as shown by the 13% increase in vertical jump height (51.6 cm to 58.2 cm) over the season. This test measures the player's ability to display power, explosive strength and the ability to use the strength (Quagliariella *et al.*, 2011). This adaptation also explains the decrease in sprint times (10 m sprint time decreased an average of 0.05 seconds i.e. 2.8%, and the 40 m sprint time decreased an average of 0.16 seconds i.e. 2.9%). More specifically the adaptations increased the player's explosive acceleration (10 m) and the player's ability to maintain the speed over a more sustained distance (40 m) (Duthie *et al.*, 2003).

Long-term strength training can improve 10 m sprint times up to 10%, and can be more effective if the resistance training starts when the player is an adolescent (Keiner *et al.*, 2014). In addition to these changes in fitness characteristics the players' repeat sprint ability also increased. This was shown by the improved performance (6%) in the 5 meter shuttle test. The performance in the 5 m shuttle test best can be attributed to a combination of factors including body mass, strength and aerobic ability (Durandt *et al.*, 2006). In summary, the players got taller, and heavier, with an indication that lean body mass increased. They also became stronger, more powerful and faster and their local muscle endurance and repeat sprint ability improved. All these changes are regarded as favorable for a rugby player.

Although the changes in fitness have been presented as group averages, the importance of individual monitoring must be emphasized when examining the data, so the different rates of physical development can be assessed between the players. Some players mature faster ('fast developers') than others ('slow developers'), with the 'fast developers' having a physical advantage over the 'slow developers' (Gluckman and Hanson, 2006). Individual monitoring enables the player's training program to be individualized, which lowers the risk of injury.

Although we did not have training volume of the players from the previous year, it can be assumed that it was lower during school compared to during the study. For example, the total training (field) and match exposure time for the squad was 7995 hours (per player 235 hours average training exposure) and 580 hours (per player 17 hours match exposure) respectively. A limitation of this study was that the recording time was done without recording the intensity of the sessions. Therefore, although training load (time x intensity) cannot be reported, the volume (time) can. The values measured in this study are similar to the volume of training and match hours reported for senior professional players (Brooks *et al.*, 2008). The senior professional players trained on average 6 hours 12 minutes per week in relation to the average 5 hours 52 minutes per week of the junior professional players in the current study. The senior players had more competition

matches than the junior players, as there are more competitions in the senior professional leagues. For example in the Southern hemisphere the Super 15, Currie Cup and international matches increase the physiological load on the senior player. The junior professional players play more matches outside the competition because of the friendlies and trial games they play as they prepare for competition. The importance of this finding is that there is a major increase in training volume over a relative short period, which may be associated with acute or overuse injuries (Gabbett and Domrow, 2007). However, it has also been shown players need to be exposed to high training volumes to prepare them for the demands of the games. The balance between the minimum workload required to produce maximum adaptation in fitness and workload tolerance before sustaining marked increases in injury rates is the delicate balance that must be sought (Gabbett *et al.*, 2014). The challenge for the support staff is to increase the training volume in increments that enable the players to adapt appropriately.

The first finding on injuries was that there were 71 injuries over the whole season (pre-season, pre-competition and completion phase) with an overall injury rate of 8.3 injuries per 1000 player hours. The injury incidence was 4.4 injuries per 1000 player hours in training and 74.1 injuries per 1000 player hours in matches. Other studies of senior professional rugby players show an injury incidence of 3 injuries per 1000 player hours in training and 81 injuries per 1000 player hours in matches (Williams *et al.*, 2013). It may be argued that the injury incidence during matches was slightly higher for the senior professional players but lower during training compared to the junior professional players. However, the differences between senior and junior professional players should be interpreted with caution as the 95% confidence intervals overlap extensively. Further studies are needed to clarify the interpretation of these data.

The second finding on injuries was that non-contact injuries were dominant during the pre-season, but during the pre-competition and competition phase the contact injuries were more dominant than the non-contact injuries. This was expected because of the increase in matches

during the last two phases of the season. This also explains the increase in the incidence of injury, because with the increase in level of competition and matches the intensity of the contact situations increases. Although we did not measure the aspect of the game causing the injury previous studies showed the tackle situation (tackling and being tackled) is the most frequent injury incident (Fuller *et al.*, 2007; Quarrie and Hopkins, 2007; Williams *et al.*, 2013; Burger *et al.*, 2014).

When dividing the injuries into the pre-season, pre- competition phase and competition phase, there was a tendency that the injury rate in training was higher during the pre-season than the rest of the phases of the season. A bigger sample size may have made this difference significant. A possible explanation is that the players were still adjusting to the volume and intensity of the training sessions, particularly since the training load of the previous year's school season was lower than the professional demands. Risk of injury also increases with increased training volume (Gabbett *et al.*, 2014). Another reason for the high injury rate pre-season is that some of the players could also still have had chronic injuries from the previous season. There is a good chance that in the school environment, chronic injuries may not have been managed as well as in a professional environment. Also the transition from school into the academy system had high stakes with the players trying hard to impress to secure a professional contract. Therefore some of the chronic injuries may have been downplayed at the start of the season, and with the high training volume in the pre-season, these injuries would have been aggravated. The injury rate during matches was the highest in the competition phase. This was expected as most of the matches occurred during this period. An important finding of this study was that there were no significant differences between training and match injuries during the pre-season, pre-competition and competition phases of the season. Possible reasons for this finding can be that the injury rate during pre-season is relative high due to players still adapting to high load training, management of contact events and training volume during the competition phase of the

season.

The next finding was that the average return-to-play after injury was 17 days. There was no difference in the time to return-to-play following a contact or non-contact injuries (16 and 19 days). The difference of the return-to-play between the phases of the season was also not significant. Previous studies have shown that the most common injury severity is 'moderate' (8 – 28 days return to play) which shows this study is in accordance with the general findings of other rugby related research (Williams *et al.*, 2013). The practical relevance of these data is that management staff can expect that the average injury will be of moderate severity and they can plan the individual player's return-to-play accordingly. Figure 5 (page 65) shows the frequency distribution of days off before return-to-play. The relevance of Figure 5 for team management is that the average return-to-play time is between 16-19 days, but that they can expect a few severe injuries during the season where a player can be out for months or even the rest of the season. Most of the injuries (i.e. median) needed 8 days of recovery before the player could return to play.

Muscle, tendon and joint ligament injuries were the most prevalent injury groups with fractures being the injury with the highest severity. The lower limb region had the highest injury incidence, with the upper body region injuries being the most severe. These findings agree with findings from other studies (Williams *et al.*, 2013). A study on match injuries in the English youth academy system and schools rugby union showed the pattern of injuries and incidence of injury increase with level of play (Palmer-Green *et al.*, 2013). The location and type of injury were also similar to those observed in this study. The biggest difference between the two studies is that the match injury incidence in the English youth academy system was much lower than this study (47 injuries per 1000 player hours versus 74.1 injuries per 1000 player hours) (Palmer-Green *et al.*, 2013). A reason for this can be that the English youth academy system cater for players in the younger age groups and we know injury rates increase as players get older and the intensity of the game increases (Fuller *et al.*, 2011).

Pro-active injury prevention methods are important to minimize injuries that could be prevented. To have a good prehabilitation strategy the medical staff must analyze an uninjured player's posture, joint alignment, flexibility, muscle control, core stability and movement patterns (Evans *et al.*, 2010). The medical staff must understand the risk of the sport itself and consider other specifics like previous injuries and the player's position. Prehabilitation is an important intervention to minimize injuries during the season and can have a positive effect on soft tissue injuries (Meir *et al.*, 2007). Due to the collision nature of rugby, prehabilitation cannot always prevent injuries like fractures, concussion and impact injuries where ligaments are injured. The effectiveness of injury prevention programs like BokSmart and RugbySmart has been shown by the decrease in moderate to serious injury claims for targeted areas of the body (including neck, spine, shoulder and knees) (Freitag *et al.*, 2015).

In conclusion, this study has shown that young professional players are vulnerable because they have to adapt to rather sudden increases in training volume. Therefore to manage the well-being of the junior professional rugby players the incidence of injury and exposure time should be continually assessed. These data, in conjunction with the physical test results and medical screening results, can provide the management team (coaches and medical staff) with a clearer view of the demands on the elite developing rugby player. With this information decisions about the management of the team and individual players can be made from an evidence-based perspective.

Chapter 4:

Summary and conclusions

The aim of the study was to examine the training and match load and injuries during the different phases of the season in a provincial under 19 squad to determine whether there were associations between these variables. Although there are several studies on the demands of senior professional rugby, there is less data on the junior professional rugby player and therefore the factors associated with injury have not been well researched.

It is well documented that following the onset of professionalism in rugby in 1995, senior professional rugby players adopted better strength and conditioning programmes to prepare them for the different tournaments during the season. The emphasis of the training programmes was to prepare the players for fast, dynamic and physical matches. A consequence of this was that there were more frequent and powerful contact situations (van Rooyen *et al.*, 2008). The professional players were also exposed to longer seasons with more matches and greater training loads and the combination of these factors increased the risk of injuries in high level rugby. In response to these demands professional rugby teams have a team of support staff, usually consisting of doctors, physiotherapists, massage therapists, conditioning coaches and psychologists, who combine their skills to manage player welfare.

Professional teams have realized the importance of developing their own talent rather than purchasing talented players. As a consequence the franchises of the senior professional teams have developed academies and contracted young talented players with the goal of nurturing them and developing them into players with the skills and physical attributes needed to play at a senior level. The competitiveness of the senior professional rugby environment has filtered through to the under 19 and under 21 provincial levels where players compete for senior professional contracts. This study showed the younger players have similar training, match and injury stresses compared to the senior player. This poses unique challenges because the young players, who

are still maturing, are suddenly exposed to high demands. In the presence of the extra demands there are usually less support staff associated with the team to manage their welfare.

It should also be noted that in addition to developing physically, young players are also developing emotionally, tactically and technically (Gluckman and Hanson, 2006). These factors have not been well researched despite them having potential to impact on the players' development. The emphasis has rather been placed on the physical development of the junior professional player as there is a relationship between physical qualities, team selection and match performance (Gabbett, 2013). As the physical ability of players improves, their technical skills, for example tackling, lineout lifting and scrumming also improves (Gabbett, 2010). The professional rugby environment is a high stress environment as it is result-driven, in which some decisions are made at the expense of the welfare of the player. This is not different for the junior professional player as they compete for professional contracts in a competitive world. The young adult still has years of emotional and cognitive development before maturation (Gluckman and Hanson, 2006). There are different approaches to managing this problem. One approach is to adapt the load of the players carefully as they still have several areas of development that must be addressed during this stage of their careers. Another approach is to accept the principle of the "survival of the fittest", where load is not regulated carefully, assuming that only the good potential players will survive the rigors associated with rugby at this level. The approach of "survival of the fittest" is viable, assuming there is continual input of new young players into the system at school. However, a weakness of this approach is that the number of schoolboys playing rugby may decrease in the future, and if this happens this method of talent development will be compromised. A more pragmatic approach to talent development must be to:

- 1) Strategize to ensure rugby played at school is at a high level. The "rugby schools" should be assisted to get their players accustomed to the stresses they will experience when they leave school.

- 2) Empower players to take accountability/responsibility for their fitness and physical development.
- 3) Promote communication between support staff of senior and junior ranks.
- 4) Implement surveillance of training load, injuries and performance (at high level rugby playing schools and academies).
- 5) Support ongoing research to identify characteristics of players who do adapt, or do not adapt, to the rigors of the game.

The gap in the demands of the game and physical capabilities of the players between school rugby and professional academy level rugby is large, therefore the transition needs to be carefully managed. While managing the players through the transition, it must be clear that this is a highly competitive environment. Sensible and realistic decisions based on practical situations must be made and 'best practice' decisions may be overridden.

The data in this study showed no difference between injuries sustained during the training phase and competition phase of the season. This is probably because of the high stress load (i.e. training and adapting to new demands of being a fulltime rugby player) the players experienced in the pre-season block, in a period when the players were still adapting to the increased volume and intensity in training. School players do not have a base level to support the intensity and volume of training that the professional environment requires. Although I do not have research evidence to support this statement, I have interacted closely during the previous eight years with coaches and teams involved in these stages of junior rugby and therefore have based this comment on what I have observed through these interactions. Injuries also tend to be ignored and surface during the high intensity and volume training blocks. Also the competitive nature of schools rugby pressurizes coaches into playing their best players as much as possible, often at the expense of resting and proper rehabilitation of injuries.

Player welfare in rugby is currently topical with the focus being on player safety and off field career development. The needs of the young professional player need to enter the debate. The support regarding physical, emotional, tactical and technical development for a junior professional rugby player should arguably be more than the support needed by the senior professional player. This solution will have a high financial cost. Therefore there needs to be a more cost effective solution to the development of these young players. For example, the young players need to take more personal responsibility. They need to be identified early and informed about the systems they are working towards. They need to understand the expectations of the management. If coaches at school level understand the levels of training in a junior professional environment, they can prepare the players from a psychological, physical and technical perspective to handle the demands of the professional environment better. The study is not without limitations, and the following are the most important:

- Sample size is relative small
- Training load is defined just by time.
- The assumptions that the load at school is much lower than the junior professional year.

Finally, injury surveillance and monitoring training load provide useful data for coaches and administrators. For example, the data provides evidence to;

- 1) Make decisions about contracting players based on their injury history.
- 2) Determine the squad size for the season.
- 3) Appoint the correct number of well qualified medical staff.
- 4) Measure the efficacy of the treatment implemented by the medical staff.
- 5) Predict the return-to-play time following a specific injury.

In conclusion, further research on junior professional rugby players is needed as the demands on the players are not well understood. A long-term research project aiming to determine injury rates and training load at school level will bridge the gap between junior rugby and junior professional rugby. In particular, research on detecting signs of imminent fatigue can help with injury prevention as this may be related to non-contact injuries.

References

- Alsop, J., Chalmers, D., Williams, S., Quarrie, K., Marshall, S., & Sharples, K (2000). Temporal patterns of injury during a rugby season *Journal of Science and Medicine in Sport*, 3(2), 97-109.
- Appleby, B., Newton, R., & Cormie, P (2012). Changes in strength over a 2-year period in professional rugby union *Journal of Strength and Conditioning Research*, 26(9), 2538-46
- Argus, C., Gill, N., & Keogh, J (2012). Characterization of the differences in strength and power between different levels of competition in rugby union athletes *Journal of Strength and Conditioning research*, 26(10), 2698-704.
- Austin, D., Gabbett, T., & Jenkins, D (2011). The physical demands of Super 14 rugby Union *Sport Medicine Australia*, 14(3), 259 -63.
- Baker, D (2013). 10-year changes in upper body strength and power in elite professional rugby league players--the effect of training age, stage, and content *Journal of Strength and Conditioning Research*, 27(2), 285-92.
- Baker, D., & Newton, R (2008). Comparison of lower body strength, power, acceleration, speed, agility, and sprint momentum to describe and compare playing rank among professional rugby league players *Journal of Strength and Conditioning Research*, 22(1), 153-8.
- Baker, D (2002). Differences in strength and power among junior-high, senior-high, college-aged, and elite professional rugby league players *Journal of Strength and Conditioning Research*, 16(4), 581-5.
- Bathgate, A., Best, J., Craig, G., & Jamieson, M (2002). A prospective study of injuries to elite Australian rugby union players *British Journal of Sports Medicine*, 36(4), 265-9; discussion 269.

Batterham, A., & Hopkins, W (2006). Making meaningful inferences about magnitudes *International Journal of Sports Physiology and Performance*, 1(1) 50-57.

Borresen, J., & Lambert, M. I. (2009). The quantification of training load, the training response and the effect on performance. *Sports Medicine*, 39(9), 779–795.

Burger, N., Lambert, M. I., Viljoen, W., Brown, J. C., Readhead, C., & Hendricks, S. (2014). Tackle-related injury rates and nature of injuries in South African Youth Week tournament rugby union players (under-13 to under-18): an observational cohort study. *British Medical Journal Open*, 4(8).

Brooks, J, & Kemp, S (2011). Injury-prevention priorities according to playing position in professional rugby union players *British Journal of Sports Medicine*, 45(10), 765-75.

Brooks, J, Fuller, C., Kemp, S., & Reddin, D (2005a). Epidemiology of injuries in English professional rugby union: part 1 match injuries *British Journal of Sports Medicine*, 39(10), 757-66.

Brooks, J., Fuller, C., Kemp, S., & Reddin, D (2005b). Epidemiology of injuries in English professional rugby union: part 2 training Injuries *British Journal of Sports Medicine*, 39(10), 767-75.

Brooks, J., & Kemp, S (2008). Recent trends in rugby union injuries *Clinics in Sports Medicine*, 27(1), 51-73, vii-viii.

Brooks, J., Fuller, C., Kemp, S., & Reddin, D (2008). An assessment of training volume in professional rugby union and its impact on the incidence, severity, and nature of match and training injuries *Journal of Sports Sciences*, 26(8), 863-73.

Brown, J. C., Lambert, M. I., Verhagen, E., Readhead, C., van Mechelen, W., & Viljoen, W (2013). The incidence of rugby-related catastrophic injuries (including cardiac events) in South Africa from 2008 to 2011: a cohort study *BMJ Open*, 3(2).

Burgess, D., & Naughton, G (2010). Talent development in adolescent team sports: a review *International Journal of Sport Physiology and Performance*, 5(1), 103-16.

Coutts, A., Reaburn, P., Piva, T., & Rowsell, G (2007). Monitoring for overreaching in rugby league players *European Journal of Applied Physiology*, 99(3), 313-24.

Cunniffe, B., Griffiths, H., Proctor, W., Davies, B., Baker, J., & Jones, K (2011). Mucosal immunity and illness incidence in elite rugby union players across a season *Medicine and Science in Sports and Exercise*, 43(3), 388-97.

Cunniffe, B., Proctor, W., Baker, J., & Davies, B (2009). An evaluation of the physiological demands of elite rugby union using Global Positioning System tracking software *Journal of Strength and Conditioning Research*, 23(4), 1195-203.

Devlin, L (2000). Recurrent posterior thigh symptoms detrimental to performance in rugby union: predisposing factors *Sports Medicine (Auckland, N.Z.)*, 29, 273-87.

Durandt, J., Tee, J., Prim, S., & Lambert, M (2006). Physical fitness components associated with performance in a multiple-sprint test *International Journal of Sports Physiology and Performance*, 1(2), 150-60.

Durandt, J., Toit, Du, S., Borresen, J., Hew-Butler, T., Masimla, H., Jokoet, I., & Lambert, M. (2008). Fitness and body composition profiling of elite junior South African rugby players *South African Journal of Sports Medicine*, 18(2), 46.

Durandt, J, Parker, Z, Masimla, H, & Lambert, M (2011). Rugby – playing history at the national u 13 level and subsequent participation at the national u 16 and u 18 rugby tournaments. *South*

African Journal of Sports Medicine, 23(4), 103.

Duthie, G., Pyne, D., & Hooper, S (2003). Applied physiology and game analysis of rugby union *Sports Medicine (Auckland, N.Z.)*, 33(13), 973-91.

Toit, Du, J., Durandt, J., Joshua, J., Masimla, H., & Lambert, M. (2012). Playing time between senior rugby players of different ethnic groups across all levels of South African rugby, 2007-2011. *South African Journal of Sports Medicine*, 24(3), 81–86.

Evans, K., Cady, K., Dobson, A., & Towers, P (2010). Results of a musculoskeletal preparticipation screening programme in BUCS Super 8 Rugby League players *British Journal of Sport Medicine*, 44(14), 15.

Faigenbaum, AD., Kraemer, WJ., Blimkie, CJR., Jeffreys, I., Micheli, IJ., & Nitka, M., *et al* (2009). Youth resistance training: Updated positional statement paper from the National Strength and Conditioning Association *Journal of Strength and Conditioning*, 23 (5), 60-79.

Ford, P., Croix, M., Lloyd, R., Meyers, R., Moosavi, M., Oliver, J., *et al* (2011). The long-term athlete development model: physiological evidence and application *Journal of Sports Sciences*, 29(4), 389-402.

Fuller, C., Molloy, M., Bagate, C., Bahr, R., Brooks, J., Donson, H., *et al* (2007a). Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union *Clinical Journal of Sport Medicine*, 17(3), 177-81.

Fuller, C., Ashton, T., Brooks, J., Cancea, R., Hall, J., & Kemp, S (2010). Injury risks associated with tackling in rugby union *British Journal of Sports Medicine*, 44(3), 159-67.

Fuller, C., Brooks, J., Cancea, R., Hall, J., & Kemp, S (2007). Contact events in rugby union and their propensity to cause injury *British Journal of Sports Medicine*, 41, 862-7.

Fuller, C., Molloy, M., & Marsalli, M (2011). Epidemiological study of injuries in men's international under-20 rugby union tournaments *Clinical Journal of Sport Medicine*, 21(4), 356-8.

Fuller, C., Molloy, M., Bagate, C., Bahr, R., Brooks, J., Donson, H., et al (2007b). Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union *British Journal of Sports Medicine*, 41(5), 328-31.

Fuller, C., Taylor, A., Brooks, J., & Kemp, S (2013). Changes in the stature, body mass and age of English professional rugby players: a 10-year review *Journal of Sports Sciences*, 31(7), 795-802.

Freitag, A., Kirkwood, G., Pollock, A.M. (2015). Rugby injury surveillance and prevention programmes: are they effective? *British Medical Journal*, 350.

Gabbett, T (2004a). Reductions in pre-season training loads reduce training injury rates in rugby league players *British Journal of Sports Medicine*, 38(6), 743-9.

Gabbett, T (2004b). Incidence of injury in junior and senior rugby league players *Sports Medicine (Auckland, N.Z.)*, 34(12), 849-59.

Gabbett, T (2004c). Influence of training and match intensity on injuries in rugby league *Journal of Sports Sciences*, 22(5), 409-17.

Gabbett, T (2005). Changes in physiological and anthropometric characteristics of rugby league players during a competitive season *Journal of Strength and Conditioning Research*, 19(2), 400-8.

Gabbett, T (2006). Performance changes following a field conditioning program in junior and senior rugby league players *Journal of Strength and Conditioning Research*, 20(1), 215-21.

Gabbett, T (2008). Incidence of injury in junior rugby league players over four competitive seasons *Journal of Science and Medicine in Sport*, 11(3), 323-8.

Gabbett, T (2014). Influence of playing standard on the physical demands of junior rugby league tournament match-play *Journal of Science and Medicine in Sport*, 17(2), 212-7.

Gabbett, T (2009). Physiological and anthropometric correlates of tackling ability in rugby league players *Journal of Strength and Conditioning Research*, 23(2), 540-8.

Gabbett, T., & Domrow, N (2005). Risk factors for injury in sub elite rugby league players *The American Journal of Sports Medicine*, 33(3), 428-34.

Gabbett, T., & Domrow, N (2007). Relationships between training load, injury, and fitness in sub-elite collision sport athletes *Journal of Sports Sciences*, 25(13), 1507-19.

Gabbett, T., Jenkins, D., & Abernethy, B (2010). Physiological and anthropometric correlates of tackling ability in junior elite and sub elite rugby league players *Journal of Strength and Conditioning Research*, 24(11), 2989-95.

Gabbett, T., Johns, J., & Riemann, M (2008). Performance changes following training in junior rugby league players *Journal of Strength and Conditioning Research*, 22(3), 910-7.

Gabbett, T., Stein, J., Kemp, J., & Lorenzen, C (2013). Relationship between tests of physical qualities and physical match performance in elite rugby league players *Journal of Strength and Conditioning Research*, 27(6), 1539-45.

Gabbett, T., Whyte, D.G., Hartwig, T.B., Westcombe, H., & Naughton, G.A (2014). The relationship between workloads, physical performance, injury and illness in adolescent male football players *Sports Medicine (Auckland, N.Z)*, 44(7), 989-1003.

Gamble, P (2004). Physical preparation for elite rugby union football *Strength and Conditioning Journal*, 24(4).

Garraway, W., Lee, A., Hutton, S., Russell, E., & Macleod, D (2000). Impact of professionalism on injuries in rugby union *British Journal of Sports Medicine*, 34(5), 348-51.

Gastin, P. B., Bennett, G., & Cook, J (2013). Biological maturity influences running performance in junior Australian football *Journal of Science and Medicine in Sport*, 16(2), 140-5.

Gluckman, P., & Hanson, M (2006). Evolution, development and timing of puberty *Trends in Endocrinology and Metabolism: TEM*, 17(1), 7-12.

Hartwig, T., Naughton, G., & Searl, J (2008). Defining the volume and intensity of sport participation in adolescent rugby union players *International Journal of Sports Physiology and Performance*, 3(1), 94-106.

Hartwig, T., Naughton, G., & Searl, J (2009). Load, stress, and recovery in adolescent rugby union players during a competitive season *Journal of Sports Sciences*, 27(10), 1087-94.

Hartwig, T., Naughton, G., & Searl, J (2011). Motion analyses of adolescent rugby union players: a comparison of training and game demands *Journal of Strength and Conditioning Research*, 25(4), 966-72.

Haseler, C., Carmont, M., & England, M (2010). The epidemiology of injuries in English youth community rugby union *British Journal of Sports Medicine*, 44(15), 1093-9.

Hendricks, S., Karpul, D., & Lambert, M. (2014). Momentum and Kinetic energy before the tackle in rugby union *Journal of Sport Science and Medicine*, 13, 557-563.

Hulin, B.T., Gabbett, T.J., Blanch, P., Chapman, P., Bailey, D. & Orchard, J.W. (2014) Spikes in acute workload are associated with increased injury risk in elite cricket fast bowlers. *British Journal of Sports Medicine*, 48, 708-12.

Keiner, M., Sander, A., Wirth, K., & Schmidtbleicher, D (2014). Long-Term Strength Training Effects on Change-of-Direction Sprint Performance *Journal of Strength and Conditioning Research*, 28(1), 223-31.

Killen, N., Gabbett, T., & Jenkins, D (2010). Training loads and incidence of injury during the preseason in professional rugby league players *Journal of Strength and Conditioning Research*, 24(8), 2079-84.

Knowles, S. B., Marshall, S. W., & Guskiewicz, K. M. (2006). Issues in estimating risks and rates in sports injury research *Journal of Athletic Training*, 41(2), 207–215.

Lambert, M. I., & Durandt, J. (2011). Long-term player development in rugby—how are we doing in South Africa? *South African Journal of Sports Medicine*, 22(3), 67–68.

Lee, A., Garraway, W., & Arneil, D (2001). Influence of preseason training, fitness, and existing injury on subsequent rugby injury *British Journal of Sports Medicine*, 35(6), 412-7.

Lefevre, J., Beunen, G., Steens, G., Claessens, A., & Renson, R (1990). Motor performance during adolescence and age thirty as related to age at peak height velocity *Annals of Human Biology*, 17(5), 423-35.

Lehance, C., Binet, T., & Croisier, J (2009). Muscular strength, functional performances and injury risk in professional and junior elite soccer players *Scandinavian Journal of Medicine & Science in Sports*, 19(2), 243-51.

Lin, J., Brown, J., & Walsh, E (1994). Physiological maturation of muscles in childhood *Lancet*, 343(8910), 1386-9.

Lloyd, R. S., Faigenbaum, A. D., Stone, M. H., Oliver, J. L., Jeffreys, I., Moody, J. A., et al (2013). Position statement on youth resistance training: the 2014 International Consensus *British Journal of Sports Medicine*.

Lombard, W., Durandt, J., Masimla, H., Green, M., & Lambert, M (2015). Changes in body size and physical characteristics of South African under-20 rugby union players over a 13-year period *Journal of Strength and Conditioning*, 29(4), 980-8.

Malina, R.M., Reyes, M.E., Eisenmann, J.C., Horta, L., Rodrigues, J., & Miller, R (2000). Height, mass and skeletal maturity of elite Portuguese soccer players aged 11-16 years *Journal of Sports Sciences*, 18(9), 685-93.

McCorry, P., Meeuwisse, W. H., Aubry, M., Cantu, R. C., Dvořák, J., Echemendia, R. J., et al (2013). Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport, Zurich, November 2012 *Journal of Athletic Training*, 48(4), 554-75.

McCurdy K, Langford G, Jenkerson D, Doscher M. The validity and reliability of the 1RM bench press using chain-loaded resistance. *Journal of Strength and Conditioning Research*. 2001;15:450-458.

McCurdy K, Langford G, Jenkerson D, Doscher M. The validity and reliability of the 1RM bench press using chain-loaded resistance. *Journal of Strength and Conditioning Research*. 2001;15: 450-458.

McMaster, D.T., Gill, N., Cronin, J., & McGuigan M (2013). The development, retention and decay rates of strength and power in elite rugby union, rugby league and American football *Sports Medicine*, 43(5), 367-384.

Meeusen, R., Duclos, M., Foster, C., Fry, A., Gleeson, M., Nieman, D., et al (2013). Prevention, diagnosis, and treatment of the overtraining syndrome: joint consensus statement of the European College of Sport Science and the American College of Sports Medicine *Medicine and Science in Sports and Exercise*, 45(1), 186-205.

Meir, R.A., Diesel, W., & Archer, E (2007). Developing a prehabilitation programme in a collision sport: a model developed within English premiership rugby union football *National Strength and Conditioning Association*, 29(3), 50-62.

Nederhof, E., Lemmink, K., Visscher, C., Meeusen, R., & Mulder, T (2006). Psychomotor speed: possibly a new marker for overtraining syndrome *Sports Medicine (Auckland, N.Z.)*, 36(10), 817-28.

Nutton, R., Hamilton, D., Hutchison, J., Mitchell, M., Simpson, A., & Maclean, J (2012). Variation in physical development in schoolboy rugby players: can maturity testing reduce mismatch *BMJ Open*, 2(4).

Palmer-Green, D., Stokes, K., Fuller, C., England, M., Kemp, S., & Trewartha, G (2013). Match injuries in English youth academy and schools rugby union: an epidemiological study *The American Journal of Sports Medicine*, 41(4), 749-55.

Parsonage, J., Williams, R., Rainer, P., Mckeown, I., & Williams, M (2014). Assessment of conditioning specific movement tasks and physical fitness measures in talent identified under 16-year old rugby union players *National Strength and Conditioning Association*, 28(6), 1496 - 506.

Quagliarella, L., Sasanelli, N., Belgiovine, G., Moretti, L., & Moretti, B (2011). Power output estimation in vertical jump performed by young male soccer players *Journal of Strength and Conditioning Research*, 25(6), 1638-46.

Quarrie, K., Alsop, J., Waller, A., Bird, Y., Marshall, S., & Chalmers, D (2001). The New Zealand rugby injury and performance project. VI. A prospective cohort study of risk factors for injury in rugby union football *British Journal of Sports Medicine*, 35, 157-66.

Quarrie, K., & Hopkins, W (2007). Changes in player characteristics and match activities in Bledisloe Cup rugby union from 1972 to 2004 *Journal of Sports Sciences*, 25(8), 895-903.

Quarrie, K., Hopkins, W., Anthony, M., & Gill, N (2013). Positional demands of international rugby union. Evaluation of player actions and movement *Journal of Science and Sport/ Sports Medicine Australia*, 16(4), 353-9

Scharhag, J., & Meyer, T (2014). Return to play after acute infectious disease in football players *Journal of Sports Sciences*, 32(13), 1237-42.

Schwellnus, M., Derman, W., Page, T., Lambert, M. M., Readhead, C., Roberts, C., et al. (2012). Illness during the 2010 Super 14 Rugby Union tournament - a prospective study involving 22 676 player days. *British Journal of Sports Medicine*, 46(7), 499–50.

Sedeaud, A., Marc, A., Schipman, J., Tafflet, M., Hager, JP, & Toussaint, JF (2012). How they won Rugby World Cup through height, mass and collective experience *British Journal of Sports Medicine*, 46, 580–584.

Smart, D., Hopkins, W., Quarrie, K., & Gill, N (2011). The relationship between physical fitness and game behaviors in rugby union players. *European Journal of Sport Science*, 1-10.

Takarada, Y (2003). Evaluation of muscle damage after a rugby match with special reference to tackle plays *British Journal of Sports Medicine*, 37(5), 416-9.

Van Rooyen, M, Rock, K., Prim, S, & Lambert, M (2008). The quantifications of contacts with impact during professional rugby matches *International Journal of Performance Analysis in Sport*, 8(1), 113 – 126.

Veale, J., Pearce, A., Koehn, S., & Carlson, J (2008). Performance and anthropometric characteristics of prospective elite junior Australian footballers: a case study in one junior team *Journal of Science and Medicine in Sport*, 11(2), 227-30.

Viljoen, W., Saunders, C. J., Hechter, G. D., & Aginsky, K. D. (2009). Training volume and injury incidence in a professional rugby union team: original research article. *South African Journal of Sports Medicine*.

Williams, S., Trewartha, G., Kemp, S., & Stokes, K (2013). A meta-analysis of injuries in senior men's professional rugby union *Sports Medicine (Auckland, N.Z.)*, 43(10), 1043-55.

Young, W. (2006). Transfer of strength and power training to sports performance. *International Journal of Sports Physiology and Performance*, 1(2), 74.

Appendices

Appendix 1 Western Province Rugby Institute letter to Ethics committee



W.P. RUGBY
INSTITUTE

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To whom it may concern:

The Western Province Rugby Institute (WPRI) opened its doors in January 2007. The main aim of the institute is to select, develop and deliver junior rugby players to the Western Province Rugby system that would be good enough (work ethic, talent, physically and mentally) to compete in Super Rugby. Players are scouted through the Western Province Elite Squad system or at Craven Week, there are also recommendations from agents and rugby coaches throughout South Africa.

The year runs from January to October and consists of pre-season training, intensive rugby training, 2 competitions (of which one is the u/19 Currie Cup).

The job description of Johan van Wyk at the WPRI is Head of Medical & Sport Science Department. If any additional information is needed, please go to the WPRI website. (www.wpri.co.za)

Kind regards

Johan van Wyk

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0837960040

Ethics form for the Western Province

Rugby Institute's Database

- 1. The names and details of all persons with access to the data base.**

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2. The sample population.

All players part of the Western Province Rugby Institute.

3. Source of the data.

Medical records, Strength and Conditioning monitoring and match data.

4. The process of the data collection.

Medical data: Players undergo a musculoskeletal screening at the beginning of each year, weak links are identified and short & long term goals are set for each player. Short and long term injuries are monitored by Johan van Wyk by arranged injury report meetings every day. The injury data includes date injured, date back on field, diagnoses, referrals and mechanism of injury. Treatment notes of each injury are also kept by the physiotherapists.

Individual rehabilitation sessions are accounted for in the physiotherapy treatment notes.

Strength and conditioning monitoring

Group rehabilitation sessions are included in the conditioning data.

Each player undergoes a fitness testing which are monitored by the conditioning coaches. The fitness tests include the following.

- Anthropometric evaluation – body mass

Height

Skinfold thickness

- Speed (10m and 40m) – the purpose of these tests is to determine the player's maximum sprint speed and the ability to accelerate from a stationary position.
- Vertical jump – the purpose of this test is to measure the player's leg power.
- 1 RM Bench press – the purpose of this test is to determine the player's maximum muscle strength of the upper body.
- Wide grip pull ups – the purpose of this test is to measure the player's upper body endurance.
- 5m shuttle run (Repeated sprint) – the purpose of this test is to measure the player's repeat sprint ability, local muscle endurance of the legs and lower back, as well as agility.

The training and match load are recorded by the Medical and Sport Science department.

Match data

Information in each match (scrums, rucks, lineouts, distance covered by each player, tackles made and received, number of contacts) is recorded by the Fair Play sports analysis systems (Fair Play Pty,Ltd, Queensland, Australia)

5. Personal data that are collected.

Name, Date of birth, age, gender, race, area in which they they live, ID number, medical aid details.

6. How the data are protected so that confidentiality is maintained.

Paper Based: It is stored in a filing cabinet in the WPRI physiotherapy practice. The only people with access are the staff members in section 1.

Electronic: Protection of all electronic access is by passwords.

7. What happens to data once it is no longer needed for research or audit?

The paper copies will be disposed of after 10 years.

The electronic data will be kept for future inquiries.

8. Permission to access the player's records from the person who is responsible for the records.

Permission is obtained from the head of the Medical and Sport Science department of the Western Province Rugby Institute.

9. Intended Use of the Database: Methods/Aims: Expected medical, scientific and research benefits.

Medical, Scientific

- The purpose of the database is to provide feedback to the WPRI Staff (physiotherapists, conditioning coaches and rugby coaches) with regards optimal player management (integration of training, recovery, competition and treatment),
- Information on periodization of training
- Database provides a check on clinical practice and player management.
- Data on injuries also helps the WPRI medical department to observe clusters of injuries and determine mechanisms of injury.

Research benefits

All the information described above has relevance for research, in particular determining the cause-effect relationships between training load, match performance and injuries.

10. The process for releasing information on the database to fellow researchers.

All WPRI staff of the Medical and Sports Science department will have access to the data. The authorship of any publications arising from these data will be discussed at the onset of a project.

11. Informed consent.

- Informed consent was not obtained for the player's data to be used for research. This permission will be obtained in retrospect (the informed consent form follows below)
- The benefits to the players will be noticed once the data are analyzed. There are two main areas, (I) prevention of lowering risk of injury, (ii) improving management of those who suffers from injury.

Appendix 3 Informed Consent Form

Informed Consent Form

Dear Participant,

I, *Johan Van Wyk*, will be conducting a study to describe the incidence of injuries and their association with training load and match playing characteristics during a full season. All the data collected during the 2010 season when you were part of the Western Province u/19 squad will be used for this purpose. The following data will form part of the study:

Injuries

- diagnoses
- time off training and matches
- referrals
- mechanism of injury

Training

Duration of:

- Strength & Conditioning sessions.
- Rugby field sessions
- Extra conditioning sessions (injured players).

- Rehabilitations sessions.

Match statistics

- Games played.
- Match time.
- Tackles made.
- Tackles received.

Fitness data

All data of fitness tests during the 10 month period.

- Anthropometry (skinfolds, body weight, height)
- 1RM Bench Press
- Wide grip pull ups
- Vertical jump
- Repeated sprint
- Sprinting speed: 10 meter & 40 meter

By signing below it serves as confirmation that you have had adequate time to ask questions about the study and are willing that your data are used for analysis. You have the right to withdraw your data at any time, you may ask questions at any time during the study and all the information recorded is confidential. Your identity will not ever be disclosed in the data analysis.

Signature of Volunteer

Name (Please Print)

Date

Signature of Witness

Name (Please Print)

Date

Signature of Investigator

Johan Van Wyk

Name (Please Print)

Date

Appendix 4 Letter of Consent from the Research Ethics Committee UCT



UNIVERSITY OF CAPE TOWN

Health Sciences Faculty
Research Ethics Committee
Room E52-24 Grootte Schuur Hospital Old Main Building
Observatory 7925
Telephone [021] 406 6338 • Facsimile [021] 406 6411
e-mail: nosi.tsama@uct.ac.za

25 January 2011

HREC REF: 002/2011

Prof M Lambert
Human Biology
Sports Science Institute

Dear Prof Lambert

PROJECT TITLE: WESTERN PROVINCE RUGBY INSTITUTE DATABASE

Thank you for your ethics submission to the Faculty of Health Sciences Human Research Ethics Committee.

It is a pleasure to inform you that the HSF HREC has **formally approved** the above mentioned study.

Approval is granted for one year until 26 January 2012.

Please send us an annual progress report if your research continues beyond the approval period. Alternatively, please send us a brief summary of your findings so that we can close the research file.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please quote the REC. REF in all your correspondence.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, HSF HUMAN ETHICS
Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938

This serves to confirm that the University of Cape Town Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-

Ntsama

Appendix 5 Ethics Renewal 2013 - 2015



UNIVERSITY OF CAPE TOWN
 (YUNIBESITHI YALIKAPA - UNIVERSITEIT VAN KAAPSTAD)



FACULTY OF HEALTH SCIENCES
 Human Research Ethics Committee

FHS017: Annual Progress Report / Renewal

Record Reviews/Audits/Collection of Biological Specimens/Repositories/Databases/Registries

HREC office use only (FWA00001637; IRB00001938)			
This serves as notification of annual approval, including any documentation described below.			
<input checked="" type="checkbox"/> Approved	Annual progress report	Approved until/next renewal date	20 JAN 2014
<input type="checkbox"/> Not approved	See attached comments		
Signature Chairperson of the HREC		Date Signed	18/2/13

Principal Investigator to complete the following:

1. Protocol information

Date form submitted	February 2013		
HREC REF Number	002/2011	Current Ethics Approval was granted until	Jan 2013
Protocol title	The relationship between training/match load and injuries in rugby union during a provincial under 19 pre- season and competition.		
Principal Investigator	Johan van Wyk		
Department / Office Internal Mail Address	jo@sastraining.co.za		
1.1 Does this protocol receive US Federal funding?		<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No

2. Protocol status (tick ✓)

<input type="checkbox"/>	Research-related activities are ongoing
<input checked="" type="checkbox"/>	Data collection is complete, data analysis only

3. Protocol summary

Total number of records or specimens collected, reviewed or stored since the original approval	-
Total number of records or specimens collected, reviewed or stored since last progress report	-
Have any research-related outputs (e.g. publications, abstracts, conference presentations) resulted from this research? If yes, please list and attach with this report.	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No

4. Signature

Signature of PI		Date	4/2/2013
Signature of Supervisor (if PI is a student)		Date	7/2/2013



FHS017: Annual Progress Report / Renewal

Record Reviews/Audits/Collection of Biological Specimens/Repositories/Databases/Registries

HREC office use only (FWA00001637; IRB00001938)

This serves as notification of annual approval, including any documentation described below.

<input checked="" type="checkbox"/> Approved	Annual progress report	Approved until/next renewal date	Jan 2015
<input type="checkbox"/> Not approved	See attached comments		

Signature Chairperson of the HREC	Date Signed
-----------------------------------	-------------

Principal Investigator to complete the following:

1. Protocol information

Date form submitted	January 2014
HREC REF Number	002/2011
Current Ethics Approval was granted until	Jan 2014
Protocol title	The relationship between training/match load and injuries in rugby union during a provincial under 19 pre-season and competition.
Principal Investigator	Johan van Wyk
Department / Office Internal Mail Address	j.v@sastraining.co.za

1.1 Does this protocol receive US Federal funding?

Yes No

2. Protocol status (tick ✓)

<input type="checkbox"/> Research-related activities are ongoing
<input checked="" type="checkbox"/> Data collection is complete, data analysis only

RESEARCH ETHICS COMMITTEE
2014-02-06
**HEALTH SCIENCES FACULTY
UNIVERSITY OF CAPE TOWN**

3. Protocol summary

Total number of records or specimens collected, reviewed or stored since the original approval	-
Total number of records or specimens collected, reviewed or stored since last progress report	-
Have any research-related outputs (e.g. publications, abstracts, conference presentations) resulted from this research? If yes, please list and attach with this report.	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No

4. Signature

Signature of PI	Date	27/6/2014
Signature of Supervisor (if PI is a student)	Date	30/01/2014

HUMAN RESEARCH ETHICS COMMITTEE

08 JUL 2015



UNIVERSITY OF CAPE TOWN
www.ucc.ac.za

HUMAN RESEARCH ETHICS COMMITTEE

FACULTY OF HEALTH SCIENCES
Human Research Ethics Committee



FHS016: Annual Progress Report / Renewal

HREC office use only (FHS00001637: (R)00000000)			
This serves as notification of annual renewal, including any documentation described below.			
<input checked="" type="checkbox"/> Approved	Annual progress report	Approved (revised renewal date)	30/1/2016
<input type="checkbox"/> Not approved	See attached comments		
Signature: Chairperson of the HREC		Date Signed	8/7/15

Comments to PI from the HREC

Principal Investigator to complete the following:

1. Protocol information

Date (when submitting this form)	06/07/2015		
HREC REF Number	02/2011	Current Ethics Approval was granted until	January 2015
Protocol title	The relationship between training/match load and injuries in rugby union during a provincial under 19 pre-season and competition phase		
Protocol number (if applicable)			
Are there any sub-studies linked to this study?	<input checked="" type="checkbox"/> No	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No
If yes, could you please provide the HREC Refs for all sub-studies? Note: A separate FHS016 must be submitted for each sub-study.			
Principal Investigator	Johan van Wyk		
Department / Office Internal Mail Address	c/o M.J. LAMBERT ESSM SPORT SCIENCE INSTITUTE		

1.1 Does this protocol receive US Federal funding?	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No
1.2 If the study receives US Federal Funding, does the annual report require full committee approval?	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No
1.3 Has sponsorship of this study changed? If yes, please attach a revised summary of the budget	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No

Form FHS006: Protocol Amendment

HREC office use only (FWA06001657; HRB00001936)		
<input type="checkbox"/> Approved	<input checked="" type="checkbox"/> Type of review: Expedited	<input type="checkbox"/> Full committee
This serves as notification that all changes and documentation described below are approved.		
Signature Chairperson of the HREC	Date	7/8/2015
Note: All major amendments should include a PI Synopsis justifying the changes for the amendment (please see notice dated 23 April 2012)		
Comments to PI from the HREC		

Principal Investigator to complete the following:

1. Protocol Information

Date (when submitting this form)	20/07/2015	
HREC REF Number	02/2011	
Protocol title	The relationship between training/match load and injuries in academy players during a provincial under 18rugby union season	
Protocol number (if applicable)		
Principal Investigator	Johan van Wyk	
Department / Office Internal Mail Address	jv@sesstraining.co.za	
1.1 Is this a major or a minor amendment? (see FHS006h/p) Major (tick box) Minor (tick box)	<input type="checkbox"/> Major	<input checked="" type="checkbox"/> Minor
1.2 Does this protocol receive US Federal funding?	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No
1.3 If the amendment is a major amendment and receives US Federal Funding, does the amendment require full committee approval?	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No

