

**EPIDEMIOLOGY OF TACKLE INJURIES
IN PROFESSIONAL RUGBY**

by

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DECLARATION

I, Georg Linde Strauss, hereby declare that the work on which this dissertation is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work or any part of it has been, is being, or has to be submitted for another degree at this or any other University.

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It is being submitted for the degree of Masters of Sport Medicine in the School of Medicine in the Faculty of Health Sciences of the University of the Free State, Bloemfontein.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACC	Accident compensation corporation
IRB	International Rugby Board
MSC	Moderate to serious injuries claims
NZRFU	New Zealand Rugby Football Union
OR	Odds Ratio
RCT	Randomised control trial
RICG	Rugby Injury Consensus group
RIPP	Rugby Injury and Prevention program
RWC	Rugby World Cup
SARU	South African Rugby Union

ABSTRACT

Key words: Rugby injury, tackle, mechanism of injury, biomechanical aspects, injury rate, practical and statistical significance, odds ratio, attacking 22m area, injury prevention

Objectives: Rugby union is a contact sport with a high injury rate. The tackle situation in rugby union is the cause of most injuries. The aim of this study was to investigate biomechanical aspects of the tackle in professional rugby to identify possible mechanisms of injury in the tackle. From this recommendations can be made to make the tackle safer.

Methods: Video material from six Super 14 rugby matches involving the Cheetahs was analysed. The number of tackles (20) resulting in injury to a player was reported and nine further associated factors explored by determining differences using 95% confidence intervals. Significance was set at $p = 0.05$ and calculated from the proportional number of injuries from each category relative to the total number of tackles made. An odds ratio was calculated to determine practical significance where clinical significance could not be found. A total number of 744 tackles were analysed which occurred during 480 minutes of rugby accounting for 7200 player minutes.

Results: From the 744 tackles that were made or received, 20 (2.7%) tackles resulted in injury, accounting to 167 tackle injuries per 1000 player match hours. The study found that significantly more injuries ($p = 0.048$) were sustained by tacklers performing a tackle in the attacking 22m compared to the other field positions. Most of the tackles occurred in Channel 2+ ($n = 622$, 83.6%) which resulted to the vast majority of tackles occurring in this game situation. Seventeen (85.0%) of the 20 injuries were sustained during Channel 2+ play, of which 13 (65.0%) ball carriers and 4 (20.0%) tacklers were injured. This had an odds ratio with practical significance. The body part hit in the tackle was often not the body part injured. Muscle contusions were the most common type of injury.

Conclusions: A high incidence of tackle injuries was recorded. The tackle remains the most dangerous phase of play in rugby union. Different biomechanical aspects occur in the tackle that contribute to injury. The field position where a tackle takes

place was found to be an important risk factor in the cause of injury. Front-on tackles and high impact vectors are associated with increased injury rates. The channel of play was also an important area where ball carriers sustained injuries. Factors influencing the tackle situation in certain areas of the field and certain channels of play can be made safer by placing emphasis on mental coaching, composure in pressure situations and maintaining the correct playing and tackle techniques to prevent tackle injuries in these areas and channels of play. Further research on these aspects is recommended.

EPIDEMIOLOGY OF TACKLE INJURIES IN PROFESSIONAL RUGBY

CHAPTER 1

INTRODUCTION AND SYNTHESIS OF STUDY

1.1 SCOPE OF THE RESEARCH

Rugby union as a contact sport has a high rate of injury compared to other contact sports (Quarrie and Hopkins, 2008). According to injury rates in different phases of play, the tackle is the most dangerous phase of play in rugby union (Quarrie and Hopkins, 2008). This study investigates different biomechanical factors in the tackle situation in professional rugby at Super 14 level to identify risk factors that contribute to injuries in the tackle, in order to ultimately make recommendations to prevent tackle injuries.

1.2 AIMS

The aim of this study is to identify and analyse certain biomechanical factors in the tackle situation in rugby, with special focus on tackles that caused injuries. From this certain recommendations can be made with regards injury prevention, including improvement of tackle technique, rule changes and appropriate further research.

1.3 STUDY SYNTHESIS

Chapter one is a short summary of the study commenting on the scope of the study, what the study aims to achieve, study synthesis and a short conclusion.

Chapter two is a review of available literature with regards to the mechanism of injury in the tackle. The chapter starts by giving the definition of injury and then discusses injury rates in different levels and formats of rugby. This emphasises the importance of the tackle in causing injury at all levels of rugby and the importance of this study. The type, location and severity of injuries are then discussed highlighting the importance of injuries in rugby. The mechanisms of injuries in rugby are then discussed, commenting on the lesser contributors to injury compared to the tackle. The chapter also discusses methods of injury prevention and effects of prevention programmes in sport and rugby in particular. If the principals of injury prevention are not known, one will not be able to make appropriate recommendations across the

scope of injury prevention methods. As far as the tackle is concerned the chapter presents a detailed review of the available literature regarding the tackle and injuries in the tackle. It comments on the rate of tackle injuries in different levels and formats of rugby. The biomechanics of the tackle are discussed. Mechanism of injuries in the tackle and associated factors contributing to injury in the tackle are discussed and categorised under the following headings:

- Type of tackle
- Body part hit in the tackle and other impact areas
- Speed of the ball carrier and tackler in the impact area
- Level of play
- Player position
- Level of coaching
- Player conditioning
- Weather conditions and type of surface
- Number of players involved in the tackle
- Psychological factors

The rules of the tackle are mentioned. The chapter concludes with thoughts on prevention of tackle injuries.

Chapter three describes that a retrospective descriptive study was undertaken to investigate mechanisms of injury in the tackle. This method was chosen due to the fact that video footage of tackles was analysed to identify risk factors causing injury in this phase of play. It comments on the study design and participants included in the study. The chapter then gives a short definition of the tackle and injury. It then discusses the measurement used in the analyses of each tackle by describing in detail the nine aspects looked at. The chapter also explain how the data of each tackle injury is noted and captured. Care was taken to identify possible measurement and methodology errors, these were:

- Random error
- Systematic error
- Sample size
- Level of technical analyses

Precaution to prevent these errors is described. The scope and measure of the pilot study are discussed. The chapter also comment on the method of data analyses, implementation of findings and ethical aspects considered for the study.

Chapter four describes the results found in the study. The chapter starts by mentioning playing time, number of tackles and tackle injury rate. The results of nine different aspects looked at in the tackle situation and tackles causing injuries were examined and presented. The nine aspects examined were the following:

- Whether a tackle was made or received by the analysed team. Tackles made by tacklers and received by ball carriers was noted separately.
- The running line of the ball carrier was also analysed in relative relation to the length of the field. This was estimated and classified as either straight or diagonal. The difference in running lines for ball carriers in tackles causing injury were analysed and compared to each other.
- The angle from which the tackle was made relative to the ball carrier was and defined as side on (Angle one) and front on (Angle two) tackles. The different angles in that occurred in tackles causing injury were compared.
- The part of the body of the ball carrier/tackler hit in the tackle was and categorised as multiple (more than two different parts of the body hit), upper body and limb, lower body and limb, head and neck. The different body parts hit in tackles causing injury were compared.
- The approximate speed at which the ball carrier was moving was analysed and noted as a “slow” jog, being “slow”, a sub-maximal run was defined as being “medium” and a sprint was defined as being “fast” speed. The different speeds of ball carriers in tackles causing injury were compared.
- The approximate speed at which the tackler was moving was and defined as a slow jog, being “slow”, a sub maximal run was defined as being “medium” and a sprint was defined as being “fast” speed. The combined impact vector speed between ball carrier and tackler was determined and defined. The different impact vectors in tackle injuries were compared.
- The phase of play when the tackle took place was also analysed and defined as channel one and channel two+. Channel one is defined as

the area around the ruck and maul, scrum, line out and the first channel of play next to it. The different tackles causing injury in these phases of play were compared.

- The part of the field where the tackle was made were and divided into 0-22m or 22-22m areas. Where injuries occurred between the 0-22m lines, we differentiated between the attacking and defending 0-22m area depending on the direction of play. The tackles causing injury in these areas were compared.
- The number of players making the tackle (bringing the ball carrier to the ground), were looked at. Number of tacklers involved in tackles causing injury was compared.

During analyses of all the above mentioned aspects we looked for statistical and practical significance.

The section on tackle injury profiles noted the nature and severity of injuries and compared the body part hit and the body part injured in the tackle. The chapter ends with a short conclusion.

Chapter five discusses the results found in this study with detailed discussions on aspects that had statistical and practical significance. This chapter also indentifies certain trends in injury tackles made and makes recommendations to make the tackle safer. A particularly high incidence of tackle injuries was recorded. The aspect of field position where tackles occurred receives much attention in this chapter. This aspect had statistical significance, with the most injuries occurring in the attacking 22m area. The different reasons for this finding are discussed and recommendations are made. Practical significance according to odds ratios was ascribed to the findings that most tackle injuries were sustained by ball carriers, front-on tackles were associated with higher odds of injury, and that higher vector speeds of contact were generally associated with higher odds for injury. An interesting trend with possible value in determining focus of injury prevention, was that the most tackles as well as the most tackle injuries occurred in open play, in channels further away from the set pieces of play. A further trend that may be modifiable by preventative measures or reduction of severity, is that a high percentage of injuries were contusions. Analysing tackle injury profiles found that the body part hit in the tackle was not often the body part injured. The different

reasons for this are discussed. The findings on nature and severity of injury are noted and compared to other studies done on similar levels of play.

The chapter concludes with a summary of the main findings and recommendations, and highlights certain learning experiences. The study succeeded in making a positive contribution to the understanding of the mechanisms of tackle injuries, research of the tackle, and prevention of tackle injuries.

1.4 CONCLUSION

This study aims to contribute to the safety of the tackle situation in rugby. This will reduce the risk of injury in the tackle and therefore reduce injuries in the tackle. From this study recommendations can be made to improve coaching techniques for tacklers and ball carriers in the tackle, possible rule changes and also improve or lessen the risk of other contributing factors to reduce injury in this phase of play in rugby union.

CHAPTER 2

REVIEW OF THE LITERATURE

2.1 INTRODUCTION

Rugby union is played in more than 100 countries across 5 continents by more than 3 million people between the age of 6 and 60. In South Africa a reported total of 326565 rugby players were participating in club and school rugby matches in 2008 (Posthumus and Viljoen, 2008).

Injuries are common in contact sport like rugby union. The tackle is the most dangerous phase of play in rugby as most injuries occur during this phase of play (Quarrie and Hopkins, 2008). This study investigates the mechanism of injuries in the tackle situation in professional rugby by means of video analysis of tackles in which injuries were sustained. The outcome of the study should enable us to make recommendations with regards to making the tackle safer for players and therefore reduce injuries. Many disparities are seen in the literature on rugby injuries due to differences in collection of data (Fuller et al., 2007), differences in levels of play and types of rugby (Fuller et.al., 2008). Continuous changes in the rules and profile of rugby matches, mostly intended to increase safety and to make rugby more spectator friendly by increasing the time of ball in active play have also altered injury patterns. Such changes have succeeded in increasing the time of ball in play from 33% of a match in the last amateur Rugby World Cup (RWC) in 1995 to 44% in the most recent RWC in 2011 (IRB, 2011).

2.2 EPIDEMIOLOGY OF RUGBY INJURIES

2.2.1 Injury definition

The International Rugby Board established a Rugby Injury Consensus Group (RICG) to reach an agreement on the appropriate definitions and methodologies to standardise the recording of injuries and reporting of studies in rugby union. This was done to make research more comparable (Fuller et al., 2007). A rugby injury is defined as 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 (Fuller et al., 2007). 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 a full part in future rugby training or match play as a *time loss injury*. In rugby union, non-fatal catastrophic injuries are of particular interest and therefore a third subgroup of reportable injuries was added: A brain or spinal cord injury that results in permanent (>12 months) severe functional disability is referred to as a *non-fatal catastrophic injury*. Severe functional disability is defined by the World Health organization as a loss of more than 50% of the capability of the structure (Fuller et al., 2007).

2.2.2 Injury rates in different levels and formats of rugby

Injury rates differ in different levels of rugby. A number of studies found this to be true (Lee and Garraway, 1996)(Haseler et al., 2010)(Fuller and Molloy, 2011). This literature will enable us to compare the rates found in this study with rates in similar studies and levels of rugby.

2.2.2.1 Schoolboy and youth rugby

During the 1993/94 season in English rugby 154 school players (9%) experienced 210 separate injuries in 186 injury episodes, 80% of which arose in matches. The prevalence rate of schoolboy match injuries was 86.8 per 1000 player-seasons. Senior club match injury incidence was much higher at 367 per 1000 player-seasons. Club players had a higher rate of match injuries than schoolboys for all injury types (Lee and Garraway, 1996).

In a study done on English youth community rugby in 2008, 39 injuries were reported (overall injury rate 24/1000 player-hours). Injury rates ranged from 0 to 49.3/1000 player-hours. More injuries occurred in junior (34.2/1000 player-hours) than in minis (11.9/1000 player-hours) ($p < 0.025$) (Haseler et al., 2010).

In the 2008 and 2010 Under 20 Junior World Championships and Junior World Rugby Trophies, the incidence of injury was 57.2 per 1000 player-match-hours (Fuller and Molloy, 2011).

2.2.2.2 Senior amateur rugby

There is a dearth of literature on senior amateur rugby. During a men's amateur sevens tournament in the United States in 2011, 48 injuries occurred over 4 tournaments, for an injury rate of 55.4 injuries per 1000 playing hours (Lopez et al., 2012).

2.2.2.3 Senior professional provincial rugby

Incidence of injuries in the 2008 Super 14 competition (96.3 injuries/1000 player-match hours; 95% confidence interval: 69.0 to 111.7) was significantly higher ($p=0.003$) than that in the 2008 Vodacom Cup (71.2; 60.0 to 84.5) (Fuller et al., 2008). The overall incidence of injuries was 55.4 injuries/1,000 player game hours, and 4.3 injuries/1,000 player training hours during the 2005 Super 12 competition. The majority of injuries were minor injuries. The most dangerous phase of play was the tackle. Training in tackling and rucking techniques, as well as rule enforcement is therefore recommended to reduce risk of injury. Injuries tended to occur late in games and early in the season, suggesting lack of physical conditioning and fatigue as possible causes of injury (Holtzhausen et al., 2006). There was a significant difference between the injury rates found in two different Super Rugby competitions, the reason is not clear. The 2008 Super 14 had two more games per side compared to the 2005 Super 12, which might have an influence on the injury rate.

2.2.2.4 Senior international rugby

During the 2006 Women's Rugby World Cup 16% of players sustained injuries at a rate of 10 injuries/1000 player hours (Shick et al., 2008). During the 2010 Women's Rugby World Cup the incidence of match injuries was 35.5/1000 player-hours (Taylor et al., 2011). In the 2007 Rugby World Cup, the incidence of injuries was 83.9/1000 player match hours and 3.5/1000 player-training hours (Fuller et al., 2008).

The studied literature shows that in general injury rates increased at higher levels of rugby and it also shows that injuries increase at a higher age group of rugby. Men's rugby has more injuries than women's rugby. There are, however, a huge variability in the recording of injury rates due to the difference in the nature and length of rugby competitions and tournaments. There was a difference in the methodologies of injury recording in the literature studied and also in the way it was reported, which

makes the interpretation of data very difficult despite the efforts of the RIGG to standardise the recording of data.

2.2.3 Type and location of injuries

2.2.3.1 *Musculotendinous injuries (including contusions and hematomas)*

During a sevens tournament in American amateur rugby, muscle strains (10.4%) was only the fourth most common type of injury, whereas contusions and hematomas accounted for 12.5% of injuries (Lopez et al., 2012). In 2008 and 2010 U-20 World tournaments muscle injuries (21.3%), were the second most common type of injury (Fuller and Molloy, 2011).

The 2008 Vodacom Cup and Super 14 competitions had a high prevalence of lower limb muscle/tendon injuries (Super 14: 27.8%; Vodacom Cup: 25.7) (Fuller et al., 2008). Injury surveillance on three teams during the 2010 Currie Cup competition showed that muscle injuries were the most common type of injury (30%) (Redhead and Viljoen, 2011). During the 2010 Super 14 contusions/bruises were the most common type of injury in the Bulls (33%) and the Lions Super Rugby squads (21%) (Redhead and Viljoen, 2011).

At international level the most common type of injuries recorded in the Springbok national team during the 2010 season were muscle injuries (30%) (Redhead and Viljoen, 2011). The 2006 Women's Rugby World Cup produced a majority of sprains, muscle injuries and contusion type injuries (Shick et al., 2008). During the 2007 Rugby World Cup lower limb muscle injuries were the most prevalent injuries during both matches and training (Fuller et al., 2008).

Typically, soft tissue injuries account for more than 50% of all rugby-associated injuries, including musculotendinous strains and tears, in addition to hematomas, and contusions. Jakoet and Noakes (1997) found that 44% of injuries involved soft tissue areas during the 1995 Rugby World Cup and Bathgate et al. (2002) (55%) found similarly high rates of soft tissue injuries among Australian elite rugby players. Brooks et al. (2003) found that the majority of injuries (87%) in the England 2003 Rugby World Cup Squad involved muscles (Kaplan et al., 2008).

2.2.3.2 Ligament or joint injuries

In American amateur rugby the most common type of injury was ligament sprains (25.0%) (Lopez et al., 2012). Lower limb ligament injuries were at 25.3% the most common type of injury in the 2008 and 2010 U-20 World Rugby tournaments (Fuller and Molloy, 2011). During the 2010 Currie Cup competition, ligament sprains (27%) were the most common type of injury for two of the five teams investigated (Redhead and Viljoen, 2011).

Joint (non-bone)/ligament (Super 14: 18.8%; Vodacom Cup: 24.3) were the second most common type of injury during the 2008 Super 14 and Vodacom cup competitions (Fuller et al., 2008).

During the 2007 Rugby World Cup ligament injuries was one of the most common injuries that occurred (Fuller et al., 2008), whereas knee ligament injuries were the most common (15%) during the 2010 Women's Rugby World Cup (Taylor et al., 2011).

2.2.3.3 Concussion and head injuries

In English youth community rugby, concussion (1.8/1000 player hours) accounted for half of the head injuries (Haseler et al., 2010). At a sevens tournament in amateur rugby in the United States, concussion (14.6%) were the second most common type of injury (Lopez et al., 2012).

In English professional rugby over three years the overall incidence of match head injuries was 6.6 injuries/1000 player-hours. The overall incidence of match concussions was 4.1 injuries/1000 player-hours (Kemp et al., 2008).

2.2.3.4 Fractures

During the 2010 Super 14 competition, fractures (27%) were one of the most common types of injuries in the Cheetahs Super Rugby squad (Redhead and Viljoen, 2011). There were 5 fractures during the 2006 Women's Rugby World Cup (Shick et al., 2008). Incidence of fractures in other studies was not available.

2.2.3.5 Lacerations and abrasions

A study on American amateur sevens rugby showed that abrasions accounted for 8.3% of injuries (Lopez et al., 2012). The literature studied had very little information on incidence of lacerations and abrasions as injury types. The Cheetahs Super rugby squad had lacerations accounting for almost 18% of all injuries during the 2010 Super Rugby competition (Redhead and Viljoen, 2011). During the 2006 Women's Rugby World Cup, a high number of lacerations to the face occurred. The exact percentage was not stated (Shick et al., 2008). Injuries to the face of which lacerations form a high percentage, accounted for 14% - 29% of injuries in different levels of rugby (Kaplan et al., 2008). These injuries are usually medical attention injuries and not time loss injuries and this might be the reason for the poor record keeping and reporting of these injuries.

2.2.3.6 Body location of injuries

Current literature suggests that the lower limb is the most commonly injured anatomical region across all experience levels, accounting for approximately 42% to 55% of all injuries sustained in rugby (Kaplan et al., 2008).

English Youth community rugby in 2008 had injuries affecting the following regions: The knee (4.9/1000 player-hours), shoulder (4.9/1000 player hours) and head (4.3/1000 player-hours) were the most commonly affected areas (Haseler et al., 2010). In amateur rugby in the United States, head and neck injuries were most common (33.3% of injuries), followed by upper extremity (31.3%), trunk (18.8%) and lower extremities (14.6%) (Lopez et al., 2012).

The 2010 Currie Cup competition produced the most injuries to the upper leg/hip/buttock (30%) and head/face (20%) (Redhead and Viljoen, 2011). During the 2010 Super 14 the upper leg/buttock area (28%) was the most frequently injured region in the Bulls Super Rugby squad (Redhead and Viljoen, 2011). The shoulder, ankle and head/face (18%) were the most commonly affected areas for injuries during the 2010 Super 14 in the Cheetahs Super Rugby squad (Redhead and Viljoen, 2011). In the Lions Super Rugby squad the shoulder (19%) was the most frequently injured region of the body (Redhead and Viljoen, 2011). The neck was the most commonly affected area of the body in the Sharks squad during the 2010 Super 14 (Redhead and Viljoen, 2011). During the 2010 Springboks season the

lower leg (24%) was the most frequently injured region of the body in the Springbok squad (Redhead and Viljoen, 2011).

At the 2006 Women's Rugby World Cup most injuries occurred to the neck, knee and head/face (Shick et al., 2008).

To give an indication of where injuries occur in the lower limb(s), Bathgate et al, 2002 further subdivided their data associated with the lower limb into hip (2%), thigh (19%), knee (20%), lower leg (6%), ankle (11%) and foot (3.5%) injuries. Injuries to the trunk comprise 4% to 11% of all professional rugby union injuries, the majority of which tend to be less severe than injuries to other areas (Kaplan et al., 2008). Professional rugby union literature suggests that the upper limb accounts for 13% to 19% of all injuries (Kaplan et al., 2008).

Injuries to the head and neck account for 14% to 29% of all injuries (Kaplan et al., 2008). Facial fractures and jaw injuries account for a minimal proportion of head and neck injuries (Kaplan et al., 2008).

Despite the difficulties in interpreting data from studies with different methodologies, trends could be identified from the literature. In summary, according to the literature over a broad spectrum of rugby, the highest concentration of injuries occur in muscles and ligaments of the lower limb.

2.2.4 Severity of injuries

Definition

Injury severity is described by the RICG as time (days) lost from competition and practice as the basis for defining injury severity. This is calculated according to 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 availability for match selection. Injuries should be grouped as slight (0-1 days), 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).

A study done to determine the epidemiological difference between school boy and senior rugby found that nine percent of schoolboy match injury episodes were

classified as severe, compared to 13% for clubs. Sixteen percent (n = 23) of all schoolboy match injury episodes resulted in missed school attendance compared with 27% (n = 117) of all senior club match injury episodes which involved loss of employment or education (Lee and Garraway, 1996). During the 2008 and 2010 U-20 World Rugby Championships the mean severity was 22.4 days and a median severity of 6 days (Fuller and Molloy, 2011).

During the 2007 Rugby World Cup the average severity of injuries was 14.7 days during matches and 17.8 during training (Fuller et al., 2008). The surveillance study done on the 2010 Women's Rugby World Cup found that the mean severity of injuries was 55.0 days and median severity 9 days (Taylor et al., 2011).

There was no clear difference in severity of injuries between different age groups and levels of rugby out of the literature studied. The general trend seems to be that most injuries fall within the mild and moderate categories. However, many studies do not record slight or medical attention injuries where no or very little playing time is lost.

2.2.5 Mechanism of injuries

The tackle causes most injuries in rugby union (Quarrie and Hopkins, 2008). The different aspects of the tackle are discussed in paragraphs 2.4.1 – 2.4.6. Other lesser contributors to injury are the scrum, open play and contact situations like the ruck and maul, collisions and foul play (Quarrie and Hopkins, 2008).

In the literature studied the above mentioned factors all contributed to injuries. The tackle was, however, still the major contributor as discussed later. A few studies reported on the other factors contributing to injury apart from the tackle.

At the 2008 and 2010 U-20 World Junior Championships collisions caused 17.7% of injuries (Fuller and Molloy, 2011). During the 2010 Currie Cup competition no injuries were caused by the scrum or foul play in three teams studied (Redhead and Viljoen, 2011). During the 2010 Super 14, 36% of injuries in the Bulls Super Rugby team happened at the ruck (Redhead and Viljoen, 2011). The Cheetahs Super Rugby team had no injuries during the 2010 Super 14 due to scrums or foul play (Redhead and Viljoen, 2011). The Lions Super Rugby team had 8% of injuries caused by the scrum during this competition and no injuries caused by foul play

(Redhead and Viljoen, 2011). The Sharks Super Rugby Team had 4% of injuries caused by the scrum and three injuries were caused by foul play (Redhead and Viljoen, 2011).

During the 2008 Super 14 and Vodacom Cup the injuries were caused as follows: Injury causation was similar for the two competitions but there were significantly fewer ruck/maul ($p=0.001$) and more tackled ($p=0.01$) injuries in Super 14 compared to English Premiership rugby and fewer collision ($p=0.002$) and more tackling ($p<0.001$) injuries compared to Rugby World Cup. For the Vodacom Cup, there were significantly more tackling ($p<0.001$) injuries compared to Rugby World Cup (Fuller et al., 2008).

2.3 PREVENTION OF INJURIES

In order to understand the role and place of this study, to interpret the results and make appropriate recommendations, the philosophy, theories and components of prevention of sport injuries must be considered.

2.3.1 Prevention of sport injuries

A systematic approach to the prevention of sport injuries as shown in Figure 2.1 has been described by Van Mechelen and Verhagen (2010):

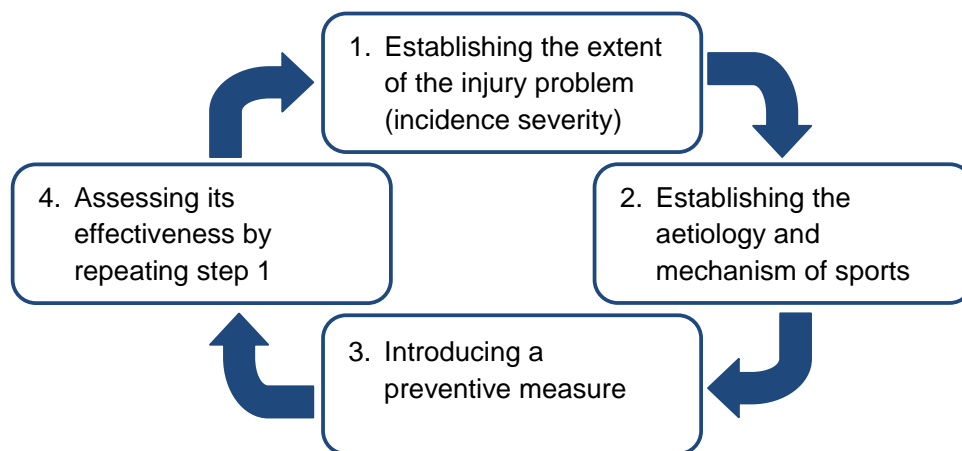


Figure 2.1: A systematic approach to the prevention of sport injuries

Step 1: Establish the extent of the injury, incidence and severity

The following aspects can contribute to this step:

Screening

Coaching and medical staff should use screening to identify players at risk of injury and identify factors that may make players prone to injury. Screenings are usually done before pre-season training starts or before major sporting events (Brukner and Khan, 2012).

Injury reporting

Administrators, coaches and medical personal should be knowledgeable in the collection and analysis of injury information, to find ways of preventing the same injuries happening again (SportSmart, 2009).

Step 2: Establish the aetiology and mechanism of injury

By minimizing the exposure to aetiology and mechanism of injury, many injuries can be prevented (SportSmart, 2009).

Step 3: Introduce preventative measures

- **Warm-up, cool-down and stretch**

Players should warm-up correctly to prepare their bodies for play, and cool-down and stretch the right way to help the body recover and to prevent injury. Types of stretching are static stretching, ballistic stretching and proprioceptive neuromuscular facilitation stretching (Brukner and Khan, 2012).

- **Physical conditioning**

Being prepared physically can help prevent injuries and improve one's performance. Appropriate training and training methods include periodization, overload, specificity and individuality. Methods include aerobic training, anaerobic training, strength and power training, flexibility training, speed

training, agility training, specific skill training and cross training. Adequate recovery and rest also plays a big role in injury prevention (Brukner and Khan, 2012).

- **Technique**

Coaches and administrators should identify the risky elements in their sport and ensure players learn and use the correct techniques at all times, to help prevent injury. Coaching of correct techniques in different sporting codes is a major preventer of sports injuries (Brukner and Khan, 2012).

- **Fair play**

The principles of fair play should be upheld to reduce the risk of injury. This is the responsibility of everyone involved including coaches, players, referees and supporters. Proper implementing of rules in a specific sporting code can also play a major role in preventing sports injuries. The rules of different sports are also adjusted to make sports safe and prevent injuries (Brukner and Khan, 2012).

- **Protective equipment**

The player has to buy the correct sporting equipment to help protect him/her and others from injury. Wearing of protective equipment and wearing of suitable equipment all help to prevent injuries. There is, however, no clear evidence that taping and bracing help prevent injuries (Brukner and Khan, 2012).

- **Hydration and nutrition**

The player has to understand how hydration and nutrition affect his/her body and make better choices before, during and after exercise. Proper nutrition and supplementation use plays a role in injury prevention in the way it helps recovery (SportSmart, 2009).

- **Environment**

Administrators and coaches should ensure that sporting facilities and equipment are safe, and players have the correct gear. Training and competing/playing should be on suitable surfaces (SportSmart, 2009).

- **Injury management**

The correct identification and diagnosis, treatment and rehabilitation of injuries will help players return to training and competition sooner (Brukner and Khan, 2012). The role of the medical team as a multi-professional unit is very important.

A study was done to analyse published articles that used interventions aimed at investigating biomechanical and physiological outcomes for sport injury prevention in order to characterise the state of the field and identify important areas not covered in the literature (McBain et al., 2012). The results showed only 144 of 2525 articles retrieved by the search strategy met the inclusion criteria. Crossover study designs increased by 175% in the late 1980s until 2005 but have declined 32% since then. Randomised controlled trial (RCT) study designs increased by 650% since the early 1980s. Protective equipment studies (61.8% of all studies) declined by 35% since 2000, and training studies (35.4% of all studies) increased by 213%. Equipment research studied stability devices (83.1%) and attenuating devices (13.5%) whereas training research studied balance and coordination (54.9%), strength and power (43.1%) and stretching (15.7%). Almost all (92.1%) studies investigated the lower extremity and 78.1% were of the joint (non-bone)-ligament type. Finally, 57.5% of the reports studied contact sports, 24.2% collision and 25.8% non-contact sports. The conclusion of this study showed a decrease in crossover study design and an increase in RCTs over time, which suggests a shift in preferred study design for injury prevention research. Another notable finding was the change in research focus from equipment interventions, which have been decreasing since 2000 (35% decline), to training interventions, which have been increasing (213% increase) (McBain et al., 2012). This study emphasises the importance of research on training interventions to decrease injuries in sport. This study might help us identify certain aspects of tackle technique to be improved in training to reduce injury risks.

The effectiveness of injury prevention in youth sport was studied and emphasised the fact that knowledge about injury incidence, injury type and modifiable and non-modifiable risk factors makes it possible to design pertinent prevention programmes. Their effectiveness depends on a number of characteristics related to content, compliance, duration and frequency. Practical issues regarding implementation of and adherence to these prevention exercises require special attention. The proposed programmes should be time-efficient for the trainers and motivating for the athletes (Frisch et al., 2009).

Step 4: Assess its effectiveness by repeating step 1

A study done to evaluate the four steps of Van Mechelen in the prevention of injury found that with a few exceptions, progress has not yet gone beyond step one in the model. Challenges for the future include deciding where research efforts should be placed, standardising of definitions and methods of data collection and reporting, identification of risk factors and mechanisms of injury and the evaluation of interventions (Chalmers, 2002).

2.3.2 Prevention of rugby injuries

2.3.2.1 *Rugby specific conditioning*

One of the factors that has improved to prevent injuries in rugby was conditioning of players, this included improvement of endurance, speed, power and agility. Conditioning in the pre-season improved remarkably in the early 1990s (Noakes and Du Plessis, 1996). Most of the major rugby playing countries improved and evolved their conditioning programmes at different stages over a period of time. The success and decreasing of injury incidence of these countries at different stages could be linked to better conditioning programmes and planning put in place (Noakes and Du Plessis, 1996). The game turning professional in the mid 1990s brought about a greater scientific approach to conditioning in rugby. The conditioning of players in different positions also improved and gave players position specific conditioning (Noakes and Du Plessis, 1996).

2.3.2.2 Coaching techniques and other factors

Coaching of the correct playing techniques also improved over the last few decades and this decreased the incidence of injuries. This includes the correct way to tackle, the best way to fall when tackled, the correct way to bind, engage in the scrum and scrum and the correct way to clean and defend at the ruck or maul (SA Rugby, 2011). Players are coached to be aware of and avoid dangerous situations during a game and training session. Preparation before any game is very important and all the different factors mentioned above need attention during this phase (Noakes and Du Plessis, 1996). The role of the coach has become very important. He should select the right players in the right positions to avoid injuries. He should have a good balance in his team talks between aggression and win at all cost on the one hand and safety on the other. Players carrying injuries like concussion, for instance, should not be forced to play before they have recovered completely and run the risk of further damage. Players should be coached the correct and best techniques in all facets of play. The use of mouth guards should be compulsory. Players guilty of continuous dirty play and not playing within the rules should not be selected for a team (NZ Rugby, 2012).

Most research suggest that coaching of techniques should focus on improving technique of tackling and other phases of play to help reduce injury rates in rugby. Educational initiatives that focus on technique, physical conditioning and the wearing of protective equipment are another avenue for reducing injuries in rugby. The use of incorrect technique has been identified as a risk factor for reducing injury in rugby. Injury prevention efforts among schoolboy and amateur rugby players in New Zealand focussed on correct techniques for ball carriers and tacklers to adopt when being tackled or when tackling. There were also instances in professional rugby where poor technique contributed to injuries. Dropping the chin forward into the contact appears to increase the risk of head/neck injury through hyperflexion of the cervical spine. 23 Head-to-head contacts, either between the tackler and the ball carrier or between 2 tacklers who concurrently tackled the ball carrier from either side, comprised a substantial proportion (40%) of inciting events to the head/neck in the current study. Education measures that focus on teaching players to keep their chins off their chests, their eyes open, and to be aware of the location of other players as they move into the tackle situation may help reduce the risk of this type of injury (Quarrie et al., 2008).

2.3.2.3 *Protective equipment*

The use of protective equipment like mouth guards, taping of ears, shoulder pads, preventative taping of joints, head gear and rugby boots improved a lot over the last few years. The manufacturing of this equipment and improving of taping techniques have become a scientific industry on its own (NZ Rugby, 2012). Rugby players' self-reported use of mouth guards increased from 67% in 1993 to 93% in 2003. At the same time rugby related dental claims decreased by 43%. A study was done on players wearing thermal pants during rugby matches. The group who wore thermal pants some of the time had a lower injury rate (3 injuries/1000 hours) compared to the 57 injuries/1000 playing hours when not wearing the thermal warmer (Sinclair, 2009). A few studies reported an insignificant reduction in neurological injury with the use of head gear and some studies on the effectiveness of mouth guards in reducing injury were inconclusive (Cusimano et al., 2010). During a season of club rugby in 1993 in New Zealand a study done found that the use of mouth guards lowered the risk of orofacial injuries and padded head gear tended to prevent damage to the scalp and ears. Support sleeves tended to reduce the risk of sprains and strains, whereas the risk of concussion was not lessened by the use of mouth guards and padded head gear. This study could not proof any protective effects for other equipment like taping, shin guards and grease (Marshall et al., 2005). The use of protective equipment in the prevention of injuries has proofed to be effective in some instances and was inconclusive in other.

2.3.2.4 *Administration and research*

Rugby administrators play a big role in the prevention of injuries through the research they do on the incidence of injuries and changes in injury trends. They also put standardised logging of injuries in place. This makes the capturing of injury trends and changing of rules etc easy (NZ Rugby, 2012). The administrators are responsible for the implementing of rule changes and the cooperation of all role players in this regard (Australian Rugby, 2012). Recent rule changes were the introduction of the red and yellow cards for dangerous, spear tackles and tackles above the line of the shoulder. The referees are also very strict on penalising dangerous tackles in general (IRB, 2012). Although changes in legislation can effect change quickly, we believe that research into their probable effects on patterns of match activity and the overall risk of injury to participants should be done before their introduction. Historical evidence shows that changes in legislation have

resulted in changes in the relative frequency and nature of match activities, characteristics of players, and epidemiology of injuries that were not foreseen when the changes were introduced (Quarrie et al., 2007). There were examples of injuries to ball carriers where the initial impact of the tackler was below the shoulder line of the ball carrier at legal height, but the direction of the tackler led to the tackler's shoulder impacting the head of the ball carrier, which resulted in injury. Calls to lower the height of the tackle line from the top of the shoulder to the axilla have been made by previous researchers (Milburn, 1995). The IRB set out a change to the interpretation of the law regarding dangerous tackles in 2008, which stated that a tackle which made contact with the ball carrier above the line of the shoulder was dangerous regardless of whether the head or neck was the point of the first or subsequent contact. This change might reduce the risk of tackles that start at the level of the chest connecting with the head of the ball carrier and lower the risk of head to head contact (Quarrie et al., 2008).

2.3.2.5 Other role players

The role of the referee is also very important in preventing injuries. He should know the rules and implement them correctly at all times during matches. He should also know the technicalities of play stoppages when an injury and blood injuries occur. These are all put in place to prevent injury and illness. The referee is also responsible to make sure the playing field and playing environment is safe for the players, as well as that necessary medical assistance is present at all games (Australian Rugby, 2012). Parents, teachers and schools play an important part in rugby at this level. Young rugby players must be coached and conditioned correctly. Motivation and love for the sport should also be developed in a healthy way (Noakes and Du Plessis, 1996). A study done in the 1980s, found that 40% of injuries surveyed in South Africa were a result of illegal or dirty play (Milburn, 1995). Stricter control of the game would ensure any tacklers who arrive later to assist in a tackle, do so safely and legally (Milburn, 1995). The task of ensuring consistent policy on dangerous and illegal tackling is the responsibility of administrators, club officials, coaches and referees (Milburn, 1995).

2.3.2.6 Prevention programmes

The Boksmart programme in South Africa has put a great structure and tool in place to teach everybody at all levels involved in the game the right fundamentals of rugby (SA Rugby, 2012). The programme gives information on general medical protocols like stretching, nutrition and more. Boksmart does research on incidence of injuries in different levels of rugby and keeps injury statistics on serious catastrophic injuries (SA Rugby, 2012).

Sharksmart is a programme used by the Sharks Rugby Union to improve the safety of rugby at this union. The programme gives information on first aid training, strapping and basic coaching skills. Their website also offers information about concussion management, supplement use, nutrition, life skills and eye drills (Sharks Rugby, 2012).

RugbySmart was started in New Zealand in 2001 as an initiative to make rugby safer on all levels of the game in this country (Gianotti et al, 2009). On the website one can get information on coaching skills and other coaching drills (NZ Rugby, 2012). Other relevant topics discussed here are game development, correct techniques in different aspects of rugby, fair play, protective equipment, hydration, nutrition, injury reporting, injury management, player profiling, warm up, cool down and environmental safety (NZ Rugby, 2012).

The IRB, Rugby Ready programme was launched in October 2007 to educate, aid and support players, coaches, match officials and Unions on the importance of sufficient preparation for training and playing in order for rugby to be played and enjoyed while reducing the risk of serious injury. The programme focuses on correct coaching techniques and sufficient levels of coaching. It also has some information on injury prevention strategies (IRB, 2012).

SmartRugby was implemented in Australia the past few years as an injury prevention tool in rugby union. SmartRugby is an occupational health and safety programme for Australia's rugby participants. It is a compulsory minimum requirement for every coach and referee participating in rugby where there is a tackling component. SmartRugby is a mandatory requiring qualification every two years. The programme provides information on basic playing and coaching skills. It also touches on injury prevention (Australian Rugby, 2012).

2.3.3 Effects of prevention programmes

After 5 years of implementation of RugbySmart in New Zealand in 2001, the programme partners, Accident Compensation Corporation (ACC) and New Zealand Rugby Union evaluated RugbySmart to determine its effectiveness in reducing injuries. The purpose was to evaluate the effect of RugbySmart on reducing injury rates per 100,000 players and resulting injury prevention behaviours. The RugbySmart programme was associated with a decrease in injury claims per 100,000 players in most areas the programme targeted. The injury sites that RugbySmart targets represented approximately 65% of the new rugby moderate to serious injuries claims (MSC) and 73% of the cost to ACC in the 2005/2006 financial year. Neck/spine injuries (including neck/back of head/vertebrae, upper back/spine, back/spine and lower back/spine) contributing 4.2% in number and 5.4% in cost. Shoulder injuries (including clavicle/blade) contributing 19% in number and 20% in cost. Knee injuries contributing 25% in number and 31% in cost. Leg injuries (upper and lower, excluding knee and ankle) contributing 6.4% in number and 7.1% in cost. Ankle injuries contributed 10% in number and 9.1% in cost. The programme had negligible impact on non-targeted injury sites. The decreases in injury claim numbers were supported by results from the player behaviour surveys pre and post RugbySmart. There was an increase in safe behaviour in the contact situations of tackle, scrum and ruck technique (Gianotti et al., 2009).

A few studies have found a significant reduction in reducing neurological injury after the implementation of nationwide multifaceted injury prevention strategies with a focus on education (Cusimano et al., 2010).

Although the effect is not clear, the RugbySmart programme seems to have been unsuccessful in reducing the number of spinal injuries unrelated to the scrum. Compared with the relatively controlled environment of the scrum, the direction and size of forces applied to players' bodies in the tackle, ruck, and maul are much less predictable. The scrum may thus be more amenable to education based injury prevention initiatives than the tackle, ruck or maul (Quarrie et al., 2007).

Since its establishment Rugby Ready has established a strong profile as the leading global education resource for the Game's stakeholders in the important areas of match preparation, technique, injury prevention and management and also discipline. Rugby Ready supplements programmes successfully delivered by some

IRB Member Unions such as the SmartRugby, RugbySmart and Boksmart programmes established in Australia, New Zealand and South Africa (IRB, 2012).

A study was done in Potchefstroom, South Africa, to determine the effect of an injury prevention programme on the incidence of rugby injuries (overall, intrinsic and extrinsic injuries) among 15- and 16-year-old schoolboys, over a 2-year period. A secondary aim was to identify the percentage of intrinsic rugby injuries associated with a previous injury history. A non-equivalent experimental-control group design with multiple post-tests was used, as well as A- and B-team rugby players ($N = 120$) from 2 secondary schools in the North West province of South Africa. The injury prevention programme was planned according to the physical, motor, biomechanical and postural status of all players. Players in the experimental group received exercises to improve biomechanical and postural deficits identified, as well as drills to address shortcomings in speed, agility, and explosive power. The prevention programme did have a positive effect on the intrinsic injury incidence of both the 15- ($d = 1.61$) and 16-year-old ($d = 0.83$) groups during the study period. During the second season the intervention programme did not have a practically significant effect on the incidence of overall rugby injuries and extrinsic rugby injuries in 15- and 16-year-old schoolboys over a 2-year period. However, in practice the prevention programme did have a significantly positive effect on the incidence of intrinsic rugby injuries among 15- and 16-year-old schoolboys over a period of 2 years. Timely introduction of this programme during the off-season is advised (Erasmus and Spamer, 2007).

A study was done in New Zealand in 2004 on the lessons learned from implementing an injury prevention programme called 'Tackling injury'. This programme was implemented on the findings of the *Rugby Injury and Prevention Programme*. Among the lessons learned were the importance of basing injury prevention strategies on scientific evidence rather than popular belief, the difficulty in implementing complex interventions, the advantages of a formal agreement between partners in the implementation of a programme, the central role played by coaches in promoting injury prevention strategies, and the value of describing the process of implementation as well as monitoring injury outcomes and changes in knowledge, attitudes and behaviour. It is hoped that other sports wishing to develop injury prevention programmes can learn from this experience (Chalmers et al., 2004).

2.4 THE TACKLE

2.4.1 Incidence

The tackle is much more common in rugby than any other phase of play (Vaz et al., 2010). Games at provincial level have an average of 150-220 tackles per game. This statistic makes the tackle the most important phase to be studied and improved to limit injuries and make the game safer (Vaz et al., 2010). The high impact and physical nature of the tackle during a rugby match places the tackler(s) and ball-carrier at risk of injury. Injuries as a result of the tackle account for up to 61% of all injuries that occur during a rugby match (Hendricks and Lambert, 2010). Tackle injuries account for up to 58% of injuries in New Zealand rugby (Quarrie et al., 2008).

2.4.2 Mechanism of injuries in the tackle

2.4.2.1 *Type of tackle*

A study in New Zealand found that ball carriers were at highest risk from tackles to the head-neck region, whereas tacklers were most at risk when making low tackles (Quarrie and Hopkins, 2008). A study done on the effect of the nationwide injury prevention programme on serious spinal injuries in New Zealand found that over the past 10 years there has been an increase in the high impact, chest high ball and all tackles causing injuries. This area of the game is now associated with the most injuries and this type of tackle puts the tackling player at risk of a head-on torso collision and spinal injury (Quarrie et al., 2007).

2.4.2.2 *Body part hit in the tackle and other impact areas*

In New Zealand it was also found that the impact of the tackle was the most common cause of injury, and the head was the most common site, but an important mechanism of lower limb injuries was loading with the weight of another player (Quarrie and Hopkins, 2008). Contact with a player's head/neck was also found as a significant risk factor causing injuries in English rugby (Fuller et al., 2010). Tackle injuries were most often caused by impact with another player rather than impact with the ground in a study done in New Zealand (Wilson et al., 1999). This study also found that the majority of tackle injuries were associated with stopping tackles

to the trunk which were from the front (63%), rather than from the side or behind. In Scotland a study found that forceful or crunching tackles resulting in injury mostly occurred head-on or within the tackled player's side vision (Garraway et al., 1999). The laws of the game and guidance on reducing the risks associated with tackles emphasise the importance of avoiding tackles above the line of the shoulder and head/neck contact. The challenge for ball carriers and tacklers to achieve this consistently is, however, complex. RugbySmart and SharkSmart injury prevention programmes comment that the best way for ball carriers to reduce tackle injuries is to avoid big hit tackles and tackles at speed, and to keep the head/neck in the right position (Fuller et al., 2010). A study done in South Africa found that some tacklers got injured when they connected the ground or the thigh of an opposing player (Milburn, 1995). Another two cases of tackle injuries studied found that a player got injured when he dove head first into the ground or connected with his opponent's thigh. They also commented on injuries sustained by tacklers when they miss a tackle and hit the ground (Milburn, 1995).

2.4.2.3 *Speed of the ball carrier and tackler in the collision area*

A study done in England showed that high-speed going into the tackle and high impact forces were identified as significant risk factors in the tackle causing injuries (Fuller et al., 2010). The ball carrier and tackler were injured in tackles in similar proportions in both RIPP and New Zealand Rugby Football Union (NZRFU) video tackle incidents in a study done in New Zealand (Wilson et al., 1999). Both players were most often in motion in the tackle at the time of injury with approximately 70% of injuries occurring when the injured player was running or diving/falling to the ground (Wilson et al., 1999). A study done in Scotland found that either the tackling or tackled player was sprinting or running in most injury episodes (Garraway et al., 1999). One third of these injuries occurred in differential speed tackles, when one player was travelling much faster than the other at impact. The player with the lower momentum was injured in 80% of these cases (Garraway et al., 1999). A study done in Australia found that ball carriers were injured in 76% of tackle related injuries, though the mechanism was not clear in most cases (Milburn, 1995). In the United Kingdom it was also found that ball carriers were more prone to getting injured in the tackle with 13 injuries occurring and only four of these tackles were illegal tackles (Milburn, 1995). Another study done in the Cape Province in South Africa found that the majority of spinal cord injuries in the tackle were to ball carriers (Milburn, 1995).

2.4.3 Effect of the tackle on injury in different levels of rugby

2.4.3.1 School, youth and amateur rugby

In 2008 English youth community rugby most injuries occurred in the tackle (59%) (Haseler et al., 2010). At school and senior club rugby level the majority of match injury episodes were associated with tackling (40%) or with being tackled (24%) (Lee and Garraway, 1996). During the 2008 and 2010 U-20 Junior World Championships most injuries were caused by the tackle (45.1%) (Fuller and Molloy, 2011). Tackling was the most common mechanism of injury (74.5%) at a sevens tournament held by American Amateur Rugby in 2011 (Lopez et al., 2012).

2.4.3.2 Senior professional rugby

Over a three year period in English professional rugby match concussions were most commonly associated with tackling head-on (28%) and being tackled head-on (19%) (Kemp et al., 2008). The injury statistics of three teams competing in the 2010 Currie Cup showed that the tackle was the phase that accounted for the greatest amount of injuries (60%) (Redhead et al., 2011). The Bulls Super Rugby squad (38%), Lions Super Rugby squad (33%), Cheetahs Super Rugby squad (43%) and the Sharks Super Rugby squad (63%) had the most injuries caused by the tackle during the 2010 Super 14 competition (Redhead and Viljoen, 2011). This percentage was much higher than any other phase of play that caused injuries mentioned in paragraph 2.2.5.

2.4.3.3 Senior international rugby

During the 2006 Women's Rugby World Cup 63.6% of injuries occurred during the tackle (Shick et al., 2008). The tackle was also the cause of most injuries during the 2010 Women's World Cup (Taylor et al., 2011). At the 2007 Rugby World Cup most injuries were sustained in the tackle during matches and in full-contact skills activities during training (Fuller et al., 2007). It is clear out of above mentioned results that the tackle causes a lot of injuries at senior provincial and international levels of rugby.

2.4.4 Mechanisms and biomechanics of the tackle

Tackling is the act of bringing a player to the ground when he is carrying the ball. It is an important but potentially dangerous phase in rugby. There are different mechanical aspects to the tackle that should be mastered in order to perform an effective and injury free tackle (NZ Rugby, 2012).

The key factors in making a good injury free tackle are timing, momentum, and head and body position (NZ Rugby, 2012). The tackler must try to make most contact with the ball carrier with his shoulder and have his head in the right side on position. These tackles are relatively safe (Quarrie et al., 2007).

The most common types of tackle are the side on leg tackle and the front on ball and all tackle (NZ Rugby, 2012). The side on tackle is usually a leg tackle and can be made from both sides by the tackler on the ball carrier or from behind the ball carrier. The front on tackle is normally a chest high ball and all tackle and is made straight from the front on the ball carrier (Quarrie et al., 2007). The front on tackle is usually a high impact tackle because of the momentum involved in the collision. In all tackles leg drive, head and body position of the tackler and body position of the ball carrier after receiving the tackle are important. There can be one, two or more tacklers involved in a tackle that makes the impact forces even higher (NZ Rugby, 2012). The speed at which the tackle takes place also determines the impact of the forces involved in the tackle. This is usually associated with the phase of play. Tackles made around the ruck and maul area, the so called channel one area are usually at slower speeds than tackles made in the channel two or wider areas (further away from the set phase) (Posthumus and Viljoen, 2008).

2.4.5 Associated factors

Factors associated with injuries in the tackle are level of play, player position, level of coaching, player conditioning, weather conditions, type of surface, the number of players involved in the tackle and psychological factors (NZ Rugby, 2012).

2.4.5.1 *Level of play*

The level of play in rugby union influences the tackle through the speed at which the tackle takes place. At levels like Super rugby, Test rugby and Heineken Cup the speed of most tackles would be faster than schoolboy rugby, university rugby or lower level provincial rugby like the Vodacom Cup or Currie Cup (IRB, 2012). Literature shows that high speeds going into the tackle and high impact force had a significantly higher risk for injury in English Premiership rugby (Fuller et al., 2010). Whereas in English youth community rugby the speed in collisions were lower than professional rugby and although the tackle was still the main phase responsible for injury, this was because of other factors such as level of coaching and tackle technique (Haseler et al., 2010). Another study in Australia found an increase in the proportion of active shoulder tackles from younger than 15 years (13%) to elite (31%). Tackle characteristics differed between levels of play. Younger players engaged in more passive tackles and tended to stay on their feet more than experienced players. Younger than 15 year rugby players had a significantly lower risk of tackle game injury compared with elite players (McIntosh et al., 2010).

2.4.5.2 *Player position*

Backs tend to be more exposed to high speed tackles than forwards (Fuller et al., 2010). In the English Premiership midfield backs were much more prone to injury when tackling than other players ($p < 0.01$) (Fuller et al., 2010). The reason for this finding could be that more tackles occur in this area of play or the speed of the collision in midfield. A study done on international players in New Zealand rugby found a vast difference between the number of tackles players in different positions made and received. The study found that inside and midfield backs made a lot more tackles than outside backs. It was however not clearly stated which position received the most tackles. This study stated that this difference in contact events could contribute to a higher risk for injury and injury occurrence (Quarrie et al., 2012).

2.4.5.3 *Level of coaching*

At higher levels of rugby the coaching is of a higher standard and the technique of players in the tackle is better than players at club or school level (IRB, 2012). Most literature studied emphasise the fact that coaching should focus on improving certain aspects of the tackle to reduce injuries (Fuller et al., 2010; Wilson et al., 1999). Higher levels of rugby are usually associated with better quality of coaching.

A study was done in South Africa to review the literature on tackle injury mechanisms and events associated with increased risk of injury during the tackle and identify strategies that can be coached during training and executed by players during a match to reduce the risk of injury. Coaches equipped with a better understanding of injury mechanisms and a thorough knowledge of a safe and effective technique in the tackle have a major role in preventing or reducing tackle injuries (Hendricks and Lambert, 2010). Another study done among junior rugby players commented on the fact that players, coaches and administrators need to find the most suitable balance between injury prevention and performance during training within their team setting. This process may be facilitated by modifying the current equipment and training drills used to train the tackle, and the time of season during which tackle technique training occurs. Equally important, players should learn proper tackle technique at a younger age, with the importance of safety emphasised from all information sources. The tackle is the game event in rugby union most associated with injury (Hendricks et al., 2012).

2.4.5.4 *Player conditioning*

Top level rugby players are conditioned in such a way that they are powerful enough to take the contact and impact of the tackle without getting injured (Noakes and Du Plessis, 1996). Conditioning should focus on specific tackle drills at a high speed during training to improve tackle specific fitness and technique. These drills should be aimed at improving the player's technique in high speed, high impact tackles and also maintaining the technique when fatigue sets in the last quarter of the game (SA Rugby, 2012).

2.4.5.5 Weather conditions and type of surface

Different weather conditions can play a role in the way tackles are made and influence tackle injuries. The type of surface can have an influence on tackle injuries if it is a hard or slippery surface compared to the normal dry soft surface (NZ Rugby, 2012). A study done in English premiership rugby showed that the incidence of anterior cruciate ligament injuries was nearly four times higher on artificial surfaces than on grass (Fuller et al., 2010). A study was done in New Zealand that found seasonal changes for ground hardness and a tendency for injuries to occur early in the season; there was an overall 2% weekly decrease in injuries as the season progressed. Although the contribution of ground hardness to injury incidence was not statistically significant, match ground and injury incidence were highly correlated, confirming a seasonal bias, which may confound the relationship of injury to ground condition (Takemura et al., 2007).

2.4.5.6 Number of players involved in the tackle

The number of players completing the tackle can have an influence on tackle injuries (Fuller et al., 2010). In the early eighties a study found that a rugby player who is simultaneously tackled by 2 opponents is more susceptible to cervical spinal and spinal cord injury than the player tackled by a single opponent. Two illustrative case reports confirmed this (Scher, 1983). In Ireland a study found that two cases of acetabular fractures over a six-month period as a result of a tackle needed open reductions and internal fixations. This creates concern that these high-energy injuries may become more frequent as rugby continues to adopt advanced training regimens. Protective equipment is unlikely to reduce the forces imparted across the hip joint; however, limiting 'the tackle' to only two players may well reduce the likelihood of this life-altering injury (Good et al., 2011). In Australia a study found there was a greater risk of game injury associated with two or more tacklers involved in the tackle event, and the greatest risk was associated with simultaneous contact by tacklers, after adjusting for level of play (McIntosh et al., 2010). Another tackle that has contributed to head and neck injury but is not covered under the law is where the second or third tackler comes in late to assist with the tackle. The second tackler comes in high on most occasions, which makes it dangerous (Milburn, 1995).

2.4.5.7 Psychological factors

Psychological factors like motivation, stress and pressure to perform can contribute to injuries in the tackle. Few researchers have tested the mechanisms proposed to explain how psychosocial factors influence the likelihood of injury. An elevated stress response, particularly increased muscle tension, narrowing of the visual field, and increased distractibility, all place individuals at greater risk for injuries (Williams and Anderson, 1998).

A study done on football players revealed that changes in proximity-to-goal of one-versus-one football dyads influenced the decision-making behaviour and intentionality of players in relation to the ball. Therefore, field location, specifically proximity-to-goal, can be considered a primary task constraint that poses implications for representative design in team games practice. Subsequently, analysis of player-to-ball relationships revealed emergent coordination tendencies of performers in one-versus-one sub-phases of association football, reflecting how the unique task constraints of team games shape performance (Headrick et al., 2012).

A study on risk compensation, motivation and biomechanical factors as cause of injury in competitive sport created a model that outlines a biomechanical basis to the concept and implies that injury risk compensation theories must also consider motivation and explain how the compensation re-establishes the biomechanical requisites for injury. Figure 2.2 shows a schematic model of injury. The model would also be coupled to similar models representing other competitors in team sports. The \pm symbol indicates that training or a biomechanical response during an event may increase or decrease the injury tolerance level, for example, micro trauma (McIntosh, 2005).

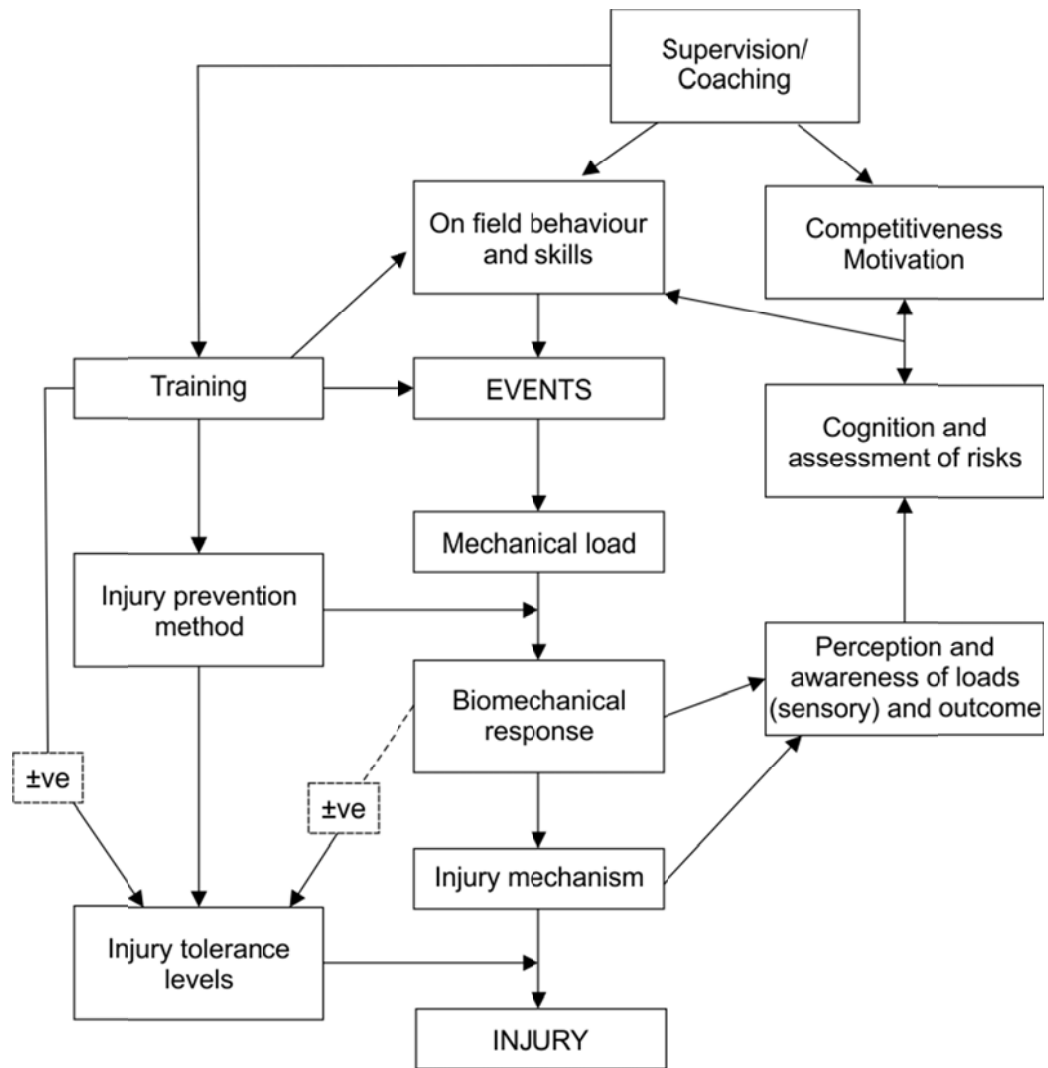


Figure 2.2: Schematic Model of Injury

2.4.6 Rules of the tackle

The IRB rules regarding the tackle in rugby union are presented in Table 2.1.

Table 2.1 Rules of the tackle (IRB, 2012)

<p>Tackle: The ball carrier brought to ground</p> <p>A tackle occurs when the ball carrier is held by one or more opponents and is brought to ground. A ball carrier who is not held, is not a tackled player and a tackle has not taken place. Opposition players who hold the ball carrier and bring him to ground and who also go to ground are known as tacklers. Opposition players who hold the ball carrier but don't go to ground are not tacklers.</p>
<p>Where can a tackle take place?</p> <p>A tackle can only take place in the field of play</p>
<p>Tackle: The ball carrier brought to ground</p> <p>When the ball carrier is held by one opponent and a team-mate of the ball carrier binds on to that ball carrier, a maul has been formed and a tackle cannot take place. If the ball carrier has one knee or both knees on the ground, that player has been 'brought to ground'. If the ball carrier is sitting on the ground, or on top of another player on the ground the ball carrier has been 'brought to ground'.</p>
<p>Tackler</p> <p>When a player tackles an opponent and they both go to ground, the tackler must immediately release the tackled player. The tackler must immediately get up or move away from the tackled player and from the ball at once. The tackler must get up before playing the ball and then may play the ball from any direction.</p>
<p>The tackled player</p> <p>A tackled player must not lie on, over, or near the ball to prevent opponents from gaining possession of it, and must try to make the ball available immediately so that play can continue. A tackled player must immediately pass the ball or release it. That player must also get up or move away from it at once.</p>
<p>Tackle: Ball carrier brought to ground</p> <p>A tackled player may release the ball by putting it on the ground in any direction, provided this is done immediately. A tackled player may release the ball by pushing it along the ground in any direction except forward, provided this is done immediately. If opposition players who are on their feet attempt to play the ball, the tackled player must release the ball. If a tackled player's momentum carries the player into the in-goal, the player can score a try or make a touchdown. If a player is tackled near the goal line, that player may immediately reach out and ground the ball on or over the goal line to score a try or make a touchdown.</p>

Table 2.1 Rules of the tackle (IRB, 2012) (continued)

Other players

After a tackle, all other players must be on their feet when they play the ball. Players are on their feet if no other part of their body is supported by the ground or players on the ground. After a tackle any players on their feet may attempt to gain possession by taking the ball from the ball carrier's possession. Players in opposition to the ball carrier who remain on their feet who bring the ball carrier to ground so that the player is tackled must release the ball and the ball carrier. Those players may then play the ball providing they are on their feet and do so from behind the ball and from directly behind the tackled player or a tackler closest to those players' goal line. At a tackle or near to a tackle, other players who play the ball must do so from behind the ball and from directly behind the tackled player or the tackler closest to those players' goal line. Any player who gains possession of the ball at the tackle must play the ball immediately by moving away or passing or kicking the ball. Any player who first gains possession of the ball must not go to the ground at the tackle or near to it unless tackled by an opposition player. Any player who first gains possession of the ball at the tackle or near to it may be tackled by an opposition player providing that player does so from behind the ball and from directly behind the tackled player or the tackler closest to that player's goal line. After a tackle, any player lying on the ground must not prevent an opponent from getting possession of the ball. After a tackle, any player on the ground must not tackle an opponent or try to tackle an opponent. When a tackled player reaches out to ground the ball on or over the goal line to score a try, an opponent may pull the ball from the player's possession, but must not kick or attempt to kick the ball.

Forbidden practices

No player may prevent the tackled player from passing the ball. No player may prevent the tackled player from releasing the ball and getting up or moving away from it. No player may fall on or over the players lying on the ground after a tackle with the ball between or near to them. Players on their feet must not charge or obstruct an opponent who is not near the ball. Danger may arise if a tackled player fails to release the ball or move away from it immediately, or if that player is prevented from so doing. If either of these happens the referee awards a penalty kick immediately.

Doubt about failure to comply

If the ball becomes unplayable at a tackle and there is doubt about which player did not conform to Law, the referee orders a scrum immediately with the throw-in by the team that was moving forward prior to the stoppage or, if no team was moving forward, by the attacking team (IRB rules of rugby, Law 15).

2.4.7 Prevention of tackle injuries

Worldwide there has been much emphasis on ways to prevent tackle injuries in rugby union. The major rugby playing countries have prevention programmes and initiatives like South African Boksmart, Australian Smartrugby, New Zealand RugbySmart and the IRB Rugby Ready programmes. These programmes are aimed at educating and empowering players and officials at all levels of rugby to help make rugby and the tackle safer (IRB, 2012).

Coaching the correct tackling techniques at different levels of the game plays a part in limiting injuries. The IRB and other governing bodies have put a lot of emphasis on educating coaches through coaching courses and other tools put in place (IRB, 2012).

The rules of rugby have changed a lot the last few years. This was done by the IRB to make the tackle safer for both ball carrier and tackler as stated earlier (Quarrie et al., 2008). Examples are the restriction of the height of a tackle and more severe penalties on dangerous and illegal tackles. Education of referees and making sure there are enough proper referees in the game are very important. The IRB and other governing bodies do a lot of research on injuries in the tackle and mechanisms that cause these injuries. However, the nature and occurrence of the tackle situation still makes it something to be studied to make the game safer.

2.5 CONCLUSION

From all information gathered and literature studied it is clear that the tackle is still the biggest cause of injury in rugby union. The fact that so many tackles occur during a rugby game contribute a lot to this statistic. There are still many voids in available research on tackle safety in rugby union.

The governing bodies spend a lot of time and money on studying the tackle and injuries caused. Most studies found in the literature study the incidence and nature of tackle injuries. There are, however, very few studies that focus on studying the mechanism of injuries in the tackle. No studies on the mechanism of injury in the tackle at Super rugby level could be found in my literature search.

Therefore studying the mechanism of injury in the tackle at Super 14 level done in this study could make a big contribution to decreasing injuries and making the game of rugby we love so dearly, safer. The aim of the study is therefore to investigate the incidence and mechanism of injuries associated with the tackle.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The aim of this study was to investigate biomechanical aspects of the tackle in professional rugby to identify possible mechanisms of injury in the tackle.

3.2 STUDY DESIGN

A retrospective descriptive study was undertaken to investigate mechanisms of injury in the tackle.

3.3 STUDY PARTICIPANTS

Players of the Cheetahs Super 14 Rugby Union franchise who participated in the first six games of the 2007 Super 14 competition were used.

3.4 DEFINITIONS

3.4.1 Tackle

A tackle occurs when the ball carrier is held by one or more opponents and is brought to ground. A ball carrier who is not held, is not a tackled player and a tackle has not taken place. Opposition players who hold the ball carrier and bring him to ground and who also go to ground are known as tacklers. Opposition players who hold the ball carrier but don't go to ground are not tacklers.

A tackle can only take place in the field of play. When the ball carrier is held by one opponent and a team-mate of the ball carrier binds on to that ball carrier, a maul has been formed and a tackle cannot take place (IRB, 2012)

3.4.2 Injury

An injury is defined as 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,

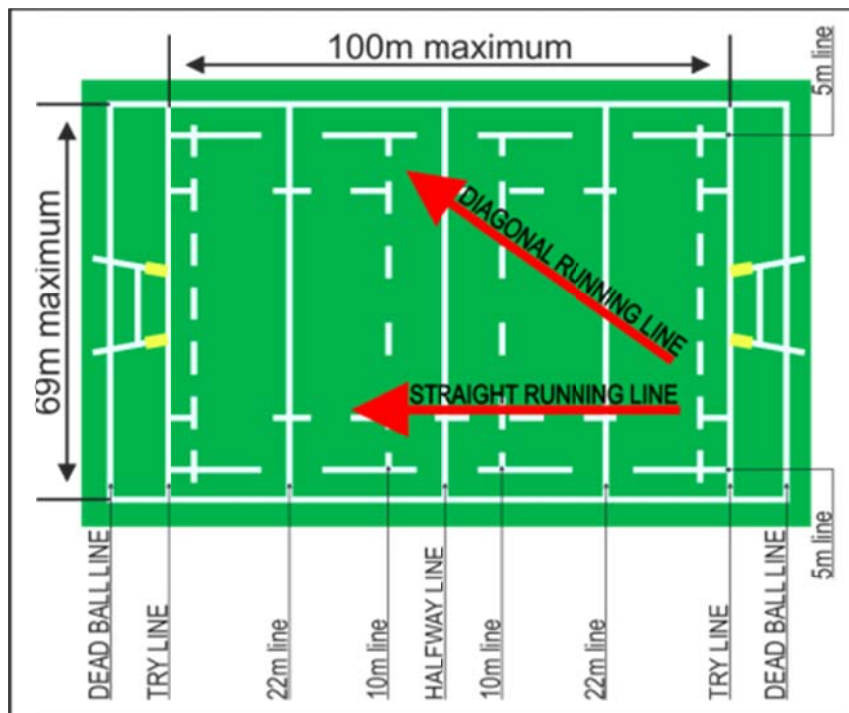
irrespective of the need for medical attention or time-loss from rugby activities. An injury that results in a player receiving medical attention is referred to as a *medical attention* injury and an injury that results in a player being unable to take a full part in future rugby training or match play as a *time-loss* injury. In this study *time-loss* injuries were used to describe and define injuries that occurred (Fuller et al., 2007).

3.5 MEASUREMENT

Video material with various camera angles of six games in the 2007 Super 14 was made available by the video analyst of the Cheetahs Rugby Team. Video material from all six rugby matches was studied and , with specific focus on the tackle phases.

The following aspects of all tackles were studied:

1. Whether a tackle was made or received by the team.
2. The running line of the ball carrier in relative relation to the length of the field. This was estimated and classified as either straight or diagonal as shown in figure 3.1.



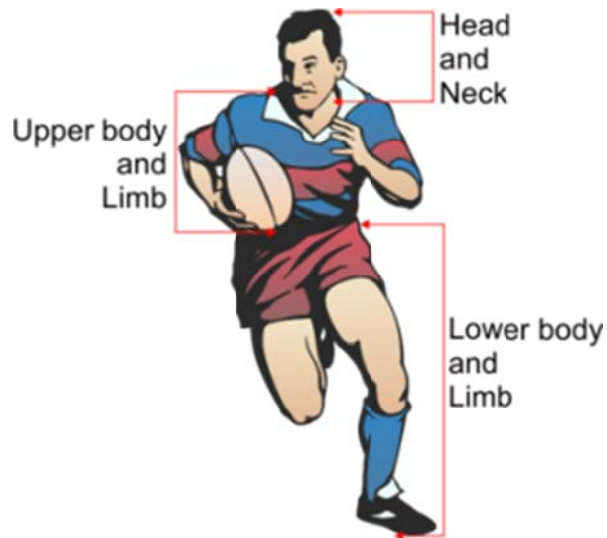
3. The angle from which the tackle was made relative to the ball carrier: Defined as side on (Angle one, Figure 3.2) and front on (Angle two, Figure 3.3) tackles. These directions are decided on in relation to the direction the ball carrier was running at that instance and was only an estimate. In double tackles (Figure 3.4) where two players carried out a tackle on one ball carrier, the angle noted first in the results was the angle at which the first tackler made contact with the ball carrier and the second angle was the angle of the second tackler during contact with the ball carrier. Where three or four tacklers completed the tackle the same principles were used.



le



4. The part of the body of the ball carrier/tackler hit in the tackle: multiple (more than two different parts of the body hit), upper body and limb, lower body and limb, head and neck as shown in Figure 3.5.



5. The approximate speed at which the ball carrier was moving: A slow jog was defined as being “slow”, a submaximal run was defined as being “medium” and a sprint was defined as being “fast” speed.
6. The approximate speed at which the tackler was moving: A slow jog was defined as being “slow”, a sub maximal run was defined as being “medium” and a sprint was defined as being “fast” speed.

The combined impact vector speed between ball carrier and tackler was determined and defined as follow where **BC** is ball carrier and **T** is tackler:

Slow $Slow_{(BC)} + Slow_{(T)}$

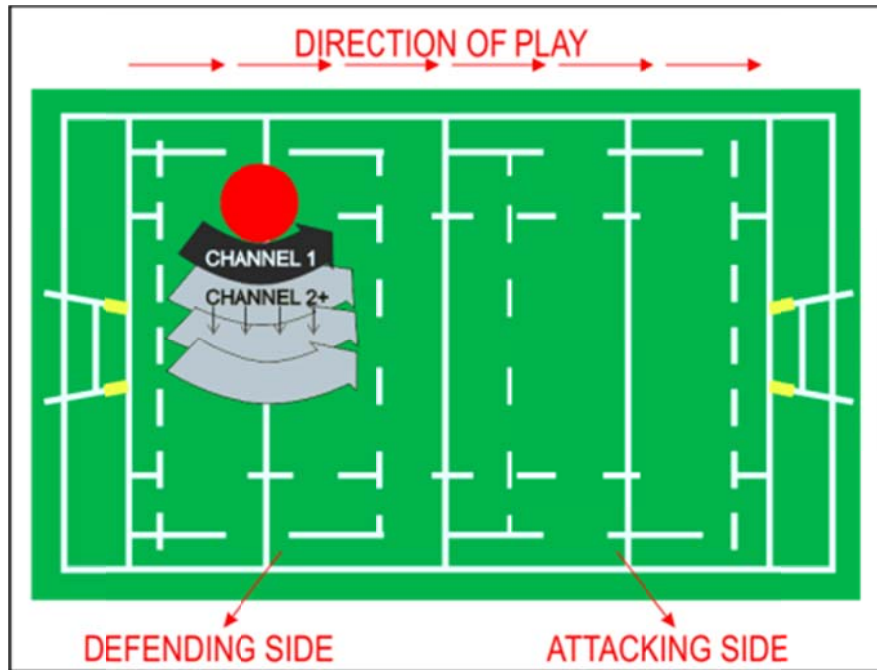
Slow-medium $Slow_{(BC)} + Medium_{(T)}$ or $Medium_{(BC)} + Slow_{(T)}$

Medium $Medium_{(BC)} + Medium_{(T)}$ or $Slow_{(BC)} + Fast_{(T)}$ or $Fast_{(BC)} + Slow_{(T)}$

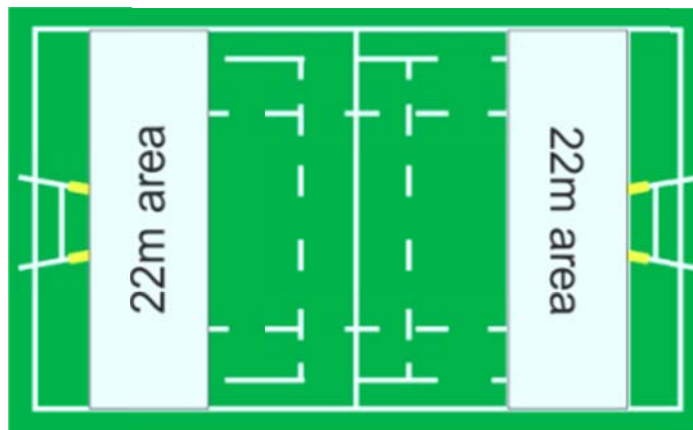
Medium-Fast $Medium_{(BC)} + Fast_{(T)}$ or $Fast_{(BC)} + Medium_{(T)}$

Fast $Fast_{(BC)} + Fast_{(T)}$

7. The phase of play when the tackle took place: Channel one and Channel two+. Channel one is defined as the area around the ruck and maul, scrum, line out and the first channel of play next to it. Channel two+ is defined as all channels wider than Channel one as shown in Figure 3.6.



8. The part of the field where the tackle was made: 0-22m or 22-22m. Where injuries occurred between the 0-22m line, we differentiated between the attacking and defending 0-22m area depending on the direction of play. (Figure 3.7)



as

9. The number of players making the tackle (bringing the ball carrier to the ground).

Each tackle was documented according to the nine aspects mentioned above. The tackles that caused injuries were noted on the standardised tackle data form created by the South African Rugby Union (Appendix A). Data on injuries that occurred in the tackles and when the injured players returned to play were obtained from injury data on the players. Injury data was also captured on the standardised tackle data form (Appendix A).

3.6 MEASUREMENT AND METHODOLOGY ERRORS

The following potential measurement and methodology errors were considered:

3.6.1 Random error

- Inter observer variation
This error was minimised by using only one analyst
- Intra observer variation
The minimisation of this mistake was challenging because of the complexity of biomechanics of the tackle, with many factors changing in each tackle. Intra-observer variation was minimised by repeated analysis of each tackle by the same analyst. This possible error should be kept in mind during analyses and when the report is written.

3.6.2 Systematic error

- General biases
This measurement error was minimised due to the fact that the same factors of every tackle were studied repeatedly. The human error and biases were therefore minimised.

3.6.3 Sample size

- Because of the relative infrequency of injuries per total exposure time to rugby, many player hours needed to be in order to increase the statistical strength of data. Constraints in this regard were availability of experts on video analysis and availability of video material.

3.6.4. Level of technical analysis

- In order to gain maximal insight into the vector forces and speeds involved in the tackle, sophisticated equipment and expertise is required. Because of unavailability of such resources, analysis of these factors was limited to what could be done with available resources.

3.7 PILOT STUDY

The pilot study was done on the 2005 Currie Cup final between the Cheetahs and the Blue Bulls. Every tackle in this game was studied to test the effectiveness of the injury data form and the different aspects of the tackle situation studied. After the pilot study no adjustments were made to the final method of data capturing and analysis. This match was not included in the study because it was played in a different competition and level of rugby.

3.8 DATA ANALYSES

The data for each tackle was captured in electronic format on the standard injury data form and by the Department of Biostatistics at the University of the Free State. Results were summarised according to frequency and percentages. The relation between variables was summarised by relative risks with a 95% confidence interval. Where statistical significance could not be reached, practical significance was calculated. According to Jansen (2011), practical significance is an acceptable outcome of research, especially where the practical application of the outcome of research could have major implications for the treatment of an ailment. Furthermore, Hopkins (2001) argued that the value of certain research outcomes, especially in the sport sciences, can be enhanced by the use of probabilities. In sciences where there is much value in probabilities of an effect being clinically beneficial, trivial or harmful, this type of practical significance should be used to

express results, rather than the traditional statistical significance or p-value. This notion is applicable in this study. Practical significance was calculated by the odds ratio (OR). Odds ratios are used to compare the relative odds of the occurrence of the outcome of interest (event or result), given exposure to the variable of interest. The odds ratio can also be used to determine whether a particular exposure is a risk factor for a particular outcome, and to compare the magnitude of various risk factors for that outcome (Szumilas, 2010). The interpretation of the odds ratio can be done according to the following statements:

- OR=1 Exposure does not affect odds of outcome
- OR>1 Exposure associated with higher odds of outcome
- OR<1 Exposure associated with lower odds of outcome

The calculation of the odds ratio in table format is shown in Table 3.1:

Table 3.1 Odds ratio calculation

	Scenario 1	Scenario 2
Event Happens	a	B
Event does not happen	c	D

The calculation expressed algebraically = $(a/b)/(c/d)$ or: = $(a \times d)/(b \times c)$

Given the algebraic rule of cross products, the second formula will produce the same result as the other two formulae for odds ratio and is the more commonly used formula (Bland and Altman, 2000).

Conclusions were made from the data, including injury rates per tackles made, relation between the nature of the tackle and injuries, speed of the tackler and ball carrier in relation to the occurrence of injuries and the relation between the phase of play and injuries. Correlations between variables and injury risk were pursued.

3.9 IMPLEMENTATION OF FINDINGS

The study identified the mechanism of injuries in the tackle in professional rugby. From this certain recommendations can be made for further studies to help decrease the incidence of injuries in the tackle and to make the tackle safer.

3.10 ETHICAL ASPECTS

The study was approved by the Ethics Committee of the University of the Free State (Ethics Approval number ECUFS 200/6). The Free State Rugby Union gave permission for the video and injury data to be used and names of all players injured in tackles stayed confidential (Appendix B).

CHAPTER 4

RESULTS

4.1 INTRODUCTION

Video material from six Super 14 rugby matches involving the Cheetahs was studied. The number of tackles resulting in injury to a Cheetah player was reported and further associated factors explored by determining differences using 95% confidence intervals. Significance was set at $p = 0.05$ and calculated from the proportional number of injuries from each category relative to the total number of tackles made. Because of small numbers recorded in the study, statistical significance was difficult to reach. Because of the practical nature of the study, practical significance in terms of effect size, determined by the odds ratio (OR), was additionally used to interpret the results and make recommendations where applicable.

4.2 PLAYING TIME AND NUMBER OF TACKLES

Four hundred and eighty minutes of rugby were studied, accounting to 7200 player minutes during which 744 tackles occurred (0.1 tackles per player minute on average). From the 744 tackles that were made, 20 (2.7%) of these tackles resulted in injury, accounting to 167 tackle injuries per 1000 player match hours. The results are reported in more detail in paragraph 4.3.

4.3 ASSOCIATED FACTORS OF TACKLES RESULTING IN INJURY

4.3.1 Injuries received by tackler or ball carrier

Table 4.1: Number of tackles made and received resulting in injury

	N	Non-injuries n (%)	Injuries n (%)	Odds Ratio
Tackles made (tackler)	404	398 (98.5)	6 (1.5)	2.8
Tackles received (ball carrier)	340	326 (95.9)	14 (4.1)	
Total	744	724 (97.3)	20 (2.7)	

$p = 0.153$

From Table 4.1 it can be seen that 404 tackles were made while 340 tackles were received. Proportionate to the total number of injuries (n = 20), more ball carrier injuries occurred (n = 14, 70.0%) compared to tackler injuries (n = 6, 30.0%). There was no difference in the injury rate (p = 0.153) when comparing the tackles made or received. However, the odds ratio between the number of injuries sustained by the ball carrier as opposed to the tackler is 2.8, which is of practical significance. From this odds ratio it can be inferred that the ball carrier has a 2.8 better chance to be injured than the tackler, or OR=2.8.

4.3.2. Injuries caused by number of tacklers involved in a tackle

Table 4.2: Number of tacklers involved in performing the tackles

Tacklers involved	N	Non-injuries n (%)	Ball carrier injuries n (%)	Tackler injuries n (%)	Odds Ratio
1	493	478 (97.0)	10 (2.0)	5 (1.0)	0.6
2	235	230 (97.9)	4 (1.7)	1 (0.4)	
3	15	15 (100.0)	0 (0.0)	0 (0.0)	
4	1	1 (100)	0 (0.0)	0 (0.0)	
Total	744	724 (97.3)	14 (1.9)	6 (0.8)	

p = 0.762

From Table 4.2 it can be seen that the majority of tackles (n = 493, 66.3%) involved one tackler, while 235 (31.6%) involved two tacklers. Only 15 (2.0%) tackles involved three tacklers, while one (0.1%) tackle was performed where four tacklers were involved. From the 20 tackles which resulted in injury, 10 (50.0%) of the injuries were sustained by the ball carrier when being tackled by a single tackler, while 5 (25%) of the injuries were sustained by the tacklers performing a solo tackle. Where two tacklers were involved, four (20.0%) ball carriers and one (5.0%) tackler of the 20 players injured sustained injuries. No injuries were recorded where more than two tacklers were involved. There were no statistically significant differences (p = 0.762) in the injury rates when comparing the number of tacklers involved in the tackles. No practically significant odds ratios were found in injuries by numbers of tacklers. The odds ratio of getting injured in single versus multiple tackles were equal (OR=0.6).

4.3.3 Direction of tackler impact relative to ball carrier

Table 4.3: General direction of tackler impact relative to the running line of the ball carrier

Type of tackle	N	Non-injuries n (%)	Ball carrier injuries n (%)	Tackler injuries n (%)	Odds Ratio
Single Side-on	305	299 (98.0)	4 (1.3)	2 (0.7)	1.8 (in favour of single front-on)
Single Front-on	258	249 (96.5)	6 (2.3)	3 (1.2)	
Multiple Side-on first	77	74 (96.1)	3 (3.9)	0 (0.0)	1.5 (in favour of multiple front-on)
Multiple All side-on	48	48 (100.0)	0 (0.0)	0 (0.0)	
Multiple Front-on first	55	53 (96.4)	1 (1.8)	1 (1.8)	
Multiple All front-on	1	1 (100.0)	0 (0.0)	0 (0.0)	
Total	744	724 (97.3)	14 (1.9)	6 (0.8)	

p = 0.106

Relative to the running line of the ball carrier, most of the tackles were performed by a single tackler from the side (Table 4.3.3, n = 305), followed by single tacklers from the front (n = 258). One hundred and eighty one (24.3%) of the total number of tackles (n = 744) involved more than one tackler, of which the majority (72.9%) tackled the ball carrier from different directions. Most of these multiple tackles had a primary impact direction from the side, but the odds ratio (OR 1.5) implies that multiple front-on tackles have a greater injury risk.

Proportional to the 20 injuries that occurred, four ball carriers were injured (20%) when being tackled by a single tackler from the side, while six ball carriers were injured (30%) when being tackled by a single tackler from the front. Two single tacklers (10.0%) were injured when tackling the ball carrier from the side, while three single tacklers (15.0%) were injured when tackling the ball carrier from the front. If one looks at the difference in number of injuries resulting from any single tackle (ball carrier or tackler injured), differentiating between front-on tackles and side-on tackles, the odds ratio is 1.80. This indicates that single front-on tackles show a tendency to cause more injuries than single side-on tackles. When multiple tacklers were involved with a primary impact from the side, three ball carriers (15%) were

injured without any injuries being sustained by the tacklers. Of the multiple tackles which had a primary impact direction from the front, one ball carrier (5.0%) and one tackler (5.0%) were injured. All tackles which resulted in injury consistently displayed a situation where the ball carrier was running straight forward in line with the length of the field when being tackled.

A number of interesting trends were observed which are mentioned here. Due to low numbers, these were not regarded as practically or statistically significant. Forty eight tackles involved more than one tackler where all tacklers impacted the ball carrier from the side, while only a single tackle was performed where more than one tackler were involved where all the tacklers impacted the ball carrier from the front. None of the tackles where multiple tacklers were involved, all coming from the same direction, resulted in injury. There were no statistical differences in the injury rates when comparing the different combinations of number of tacklers involved and their general impact direction during the tackle.

4.3.4 Combined impact vector speed within the tackle

Table 4.4: Combined impact vector speed between ball carrier and tackler

General speed	n	Non-injuries n (%)	Ball carrier injuries n (%)	Tackler injuries n (%)	Odds Ratio
Slow	67	65 (97.0)	0 (0.0)	2 (3.0)	
Slow-Medium	324	319 (98.5)	5 (1.5)	0 (0.0)	0.5 (S:SM)
Medium	228	220 (96.5)	5 (2.2)	3 (1.3)	2.3 (SM:M)
Medium-Fast	105	101 (96.2)	3 (2.9)	1 (0.9)	1 (M:MF)
Fast	19	18 (94.7)	1 (5.3)	0 (0.0)	1.4 (MF:F)
Total	743	723 (97.3)	14 (1.9)	6 (0.8)	

p = 0.297

Ball carrier speed unknown for one non-injury tackle. Combined impact vector speed between ball carrier and tackler defined as: **Slow** = $Slow_{(BC)} + Slow_{(T)}$; **Slow-medium** = $Slow_{(BC)} + Medium_{(T)}$ or $Medium_{(BC)} + Slow_{(T)}$; **Medium** = $Medium_{(BC)} + Medium_{(T)}$ or $Slow_{(BC)} + Fast_{(T)}$ or $Fast_{(BC)} + Slow_{(T)}$; **Medium-Fast** = $Medium_{(BC)} + Fast_{(T)}$ or $Fast_{(BC)} + Medium_{(T)}$; **Fast** = $Fast_{(BC)} + Fast_{(T)}$ where **BC** is ball carrier and **T** is tackler (See section 3.5).

From Table 4.4 it is seen that most tackles had a combined slow-medium impact vector speed (n = 234, 43.6%), followed by a combined medium impact vector speed (n = 228, 30.7%) between the ball carrier and tackler. Only 19 (2.6%) tackles occurred when both the ball carrier and tackler were sprinting, resulting in a fast

combined impact vector speed where one would expect most injuries to occur. However, only a single injury (5.0%) was sustained in this condition.

Looking at the 20 injuries which were sustained, two (10.0%) tacklers were injured in a slow impact vector tackler. A slow-medium combined impact vector speed resulted in 5 (25.0%) ball carrier injuries. Most injuries (n = 8, 40.0%) occurred in a medium speed tackle, of which 5 (25.0%) ball carriers and 3 (15.0%) tacklers were injured. Three ball carriers (15.0%) and one tackler (5.0%) sustained injuries in a medium-fast combined impact vector speed tackle. Relative to the total number of tackles made (n = 743), no statistical difference (p = 0.297) in injury rates were found between the different impact vector speeds within the tackles. The odds ratio for slow-medium to medium speed tackles is 2.3, and for medium-fast to fast tackles 1.4. These OR results imply that faster tackle speeds increase the risk for injury. No practical significance was found for slow to slow-medium and medium to medium-fast tackles.

4.3.5 Field position where tackle occurred

Table 4.5: Field position of ball carrier or tackler

Field position	n	Non-injuries n (%)	Ball carrier injuries n (%)	Tackler injuries n (%)	Odds Ratio
Tackles received					
Defending 22m	16	16 (100.0)	0 (0.0)	n/a	1.7
Midfield	272	264 (97.0)	8 (3.0)	n/a	
Attacking 22m	124	118 (95.2)	6 (4.8)	n/a	
Tackles made					
Defending 22m	107	106 (99.1)	n/a	1 (0.9)	29
Midfield	202	202 (100.0)	n/a	0 (0.0)	
Attacking 22m	23	18 (78.3)	n/a	5 (21.7)	
Total	744	724 (97.3)	14 (1.9)	6 (0.8)	

p = 0.048

From Table 4.5 it can be seen that despite the fact that the majority of tackles occurred in the midfield (n = 474, 63.7%), less than half (n = 8, 40%) of the injuries were sustained in this field position. All injuries occurring in the midfield were sustained by ball carriers, none by tacklers. When focussing on the remaining 12 injuries that were sustained outside of the midfield, it is clear that the vast majority (11 out of the 12, 55% of the total 20 injuries) of injuries were sustained in the attacking zone, while only a single injury was documented in the defending zone. Relative to the total number of tackles made (n = 744), significantly more injuries (p = 0.048) were sustained by tacklers performing a tackle in the attacking 22m compared to the other field positions.

The statistical significance is supported by the result of the odds ratio calculation for ball carrier injuries. The chances for the ball carrier getting injured in the tackle in the attacking 22m area are 1.7 times more than when tackled in the midfield or the defending 22m area of the field.

This number increases even more when one looks at the tackler injuries and the position on the field where the injuries were sustained. The odds ratio for the tackler to be injured in the attacking 22m area is 29, meaning the tackler has a really good chance to be injured when tackling in the attacking 22m area. This is also quite clear when one looks at the tackles with resulting injuries and field position in isolation. This is shown in Table 4.6

Table 4.6: Summary: Tackle according to Position on Field

Summary: Tackles according to Position on Field		
Tackles received		
Field position	Ball carrier injuries	
Defending 22m	0	n/a
Midfield	8	n/a
Attacking 22m	6	n/a
Tackles made		
Field position		Tackler injuries
Defending 22m	n/a	1
Midfield	n/a	0
Attacking 22m	n/a	5
Total	14	6
Percentage of tackles:	Ball carrier injuries	Tackler injuries
Attacking 22m	43% (OR=1.7)	83% (OR=29)
Midfield	57%	0%
Defending 22m	0%	17%

4.3.6 Game situation where tackles occurred

Table 4.7: Game situation where tackles occurred

Game situation	N	Non-injuries n (%)	Ball carrier injuries n (%)	Tackler injuries n (%)	Odds Ratio
Channel 1	122	119 (97.6)	1 (0.8)	2 (1.6)	0.9
Channel 2+	622	605 (97.3)	13 (2.1)	4 (0.6)	
Total	744	724 (97.3)	14 (1.9)	6 (0.8)	

p = 1.000

A minor proportion of tackles occurred during Channel 1 play (n = 122, 16.4%). Most of the tackles occurred in Channel 2+ (n = 622, 83.6%) which resulted to the vast majority of tackles occurring in this game situation. Seventeen (85.0%) of the 20 injuries were sustained during Channel 2+ play, of which 13 (65.0%) ball carriers and 4 (20.0%) tacklers were injured. Three players were injured in Channel 1 play, consisting of one ball carrier (5.0%) and two tacklers (10.0%). It may be of interest for coaches to note that most tackles occur in Channel 2+, and consequently more injuries (n=17, 85%) take place in the tackle in that area, but no statistical ($p=1.0$) or practical significance (OR=0.9) could be determined.

4.4 TACKLE INJURY PROFILES

Table 4.8: Nature and severity of injuries (n = 20)

Ball carrier or Tackler	Severity of injury	Tacklers involved	Impact region	Body part injured	Nature of injury
Ball carrier	Severe	1	UB	Shoulder	Dislocation
Ball carrier	Minimal	2	LB	Pelvis	Contusion
Ball carrier	Minimal	1	LL	Calve	Contusion
Ball carrier	Minimal	1	LL	Knee	Contusion
Ball carrier	Minimal	1	LL	Knee	Contusion
Ball carrier	Minimal	2	LL	Knee	Contusion
Ball carrier	Minimal	2	UB	Neck	Muscle strain
Ball carrier	Mild	1	LL	Ankle	Ligament sprain
Ball carrier	Mild	1	LB	Pelvis	Neuropraxia
Ball carrier	Mild	1	LL	Quadriceps	Contusion
Ball carrier	Mild	1	UB	Nose	Contusion
Ball carrier	Mild	2	UB	Ribs	Contusion
Ball carrier	Mild	1	UB	Shoulder	Ligament sprain
Ball carrier	Mild	1	UB	Shoulder	Ligament sprain
Tackler	Minimal	1	LL	Quadriceps	Contusion
Tackler	Minimal	1	LL	Ribs	Contusion
Tackler	Minimal	1	UB	Neck	Muscle strain
Tackler	Mild	1	UB	Shoulder	Ligament sprain
Tackler	Mild	2	UB	Shoulder	Ligament sprain
Tackler	Mild	1	UB	Shoulder	Ligament sprain

LL = Lower Limb, LB = Lower Body, UB = Upper Body (See Section 3.5)

In addition to confirming that 70% of injuries were incurred by the ball carrier, Table 4.8 shows that there were 8 lower limb and lower body injuries and 6 upper body injuries. The most severe injury was a ball carrier shoulder dislocation. Tables 4.9 and 4.10 summarise the important data from table 4.8. Tables 4.8, 4.9 and 4.10 are descriptive tables only applicable to the injuries recorded, therefore odds ratios and p-values were not calculated.

Table 4.9: Nature of injuries (n = 20)

Nature of Injury	Amount of Injuries (n = 20)	Percentage of Total Injuries
Contusion	10	50%
Ligament sprain	7	35%
Neuropraxia	1	5%
Muscle strain	2	10%

An important finding regarding the nature of injury when looking only at the injuries incurred was the overwhelming amount of contusions. Of the 4 types of twenty injuries found, 50% were contusions, while ligament sprains (35%), neuropraxia (5%) and muscle strains (10%) were 50% in total. Despite the fact that no statistical of practical significance could be reached, contusions may be preventable.

Table 4.10: Severity of injuries – ball carrier and tackler (n = 20)

Severity of Injury	Ball Carrier (n = 14)	Tackler (n = 6)
Minimal	6	3
Mild	7	3
Severe	1	0
Percentage of total injuries	70%	30%

According to table 4.10 it is clear that the ball carrier was injured 40% more than the tackler. The only severe injury was also found in the ball carrier group. From table 4.8 we can see that contusions amounted to 8 of the 14 injuries incurred by ball carriers, with only 2 incidences of contusions in tacklers. The ratio of injuries for ball carrier to tackler is 7 : 3. This indicates that there is a higher possibility for the ball carrier to be injured in the tackle.

4.5 CONCLUSION

This chapter presented the results of injuries sustained in the tackle by one team in 6 professional rugby matches. It was statistically and practically significant that most of the injuries were sustained by tacklers in the attacking 22m zone of the field. Statistical significance could not be reached in other variables measured, probably because of the small number of injuries recorded. Practically significant odds ratios (OR) indicated high odds of ball carriers getting injured as opposed to tacklers. Faster tackle speeds (medium and fast) were found to imply a higher risk for injury. A tendency was found that single front-on tackles had better odds of causing injury than single side-on tackles. Interesting trends were observed, which may be of practical significance and can guide future research and recommendations.

The results are discussed according to existing literature and recommendations made in Chapter Five.

CHAPTER 5

DISCUSSION OF RESULTS

5.1 INTRODUCTION

In this chapter the results of the study are discussed according to available literature, trends identified and recommendations offered to reduce injuries sustained in the rugby tackle.

5.2 METHODOLOGY

The study was a retrospective descriptive study of all tackles in six Super Rugby matches, attempting to identify factors associated with injuries in the tackle. The biggest limitation of this study was the limited number of games and tackles. The low number of injuries that occurred in the tackles studied made it difficult to recognise trends and obtain statistically significant results. However, a number of aspects of the tackle which were studied showed practically significant odds ratios and interesting trends, which offer valuable information for rugby physicians, injury prevention initiatives, as well as for future research.

5.3 PLAYING TIME AND NUMBER OF TACKLES

A total of 744 tackles were recorded in six matches, 480 playing minutes, at an average of 124 tackles per 80 minutes of play. This compares well to the average total of tackles for a side during a Super Rugby match. The number of tackles in this study compares well with other games played at this level, as reported to be between 150 and 220 tackles per game (Vaz et al., 2010). The incidence of injuries in this study was 167 tackle injuries per 1000 player match hours. This figure represents the highest injury rate in the tackle recorded to date. A study done in New Zealand found injury rates of 35 injuries per 1000 player-hours for ball carriers and 42 injuries per 1000 player-hours to tacklers in 434 matches in professional competitions in which New Zealand participated from 2003 to 2005. (Quarrie et al., 2008). The incidence of all injuries during the 2008 Super 14 competition was 96.3 injuries per player-match hours, which was also lower than the injury rate found in this study (Fuller et al., 2008). In the 1999 Super 12 competition, the overall incidence of injuries was 55.4 injuries/1,000 player game hours, and 4.3 injuries/1,000 player training hours. (Holtzhausen et al., 2006).

Reasons for the high rate of injuries in the tackle may include the rigorous collection of data, where all injuries according to the RICG definition were included in the study. It may also reflect the high intensity of rugby in the Super Rugby competition. It has been shown that higher levels of play account for higher injury rates (Fuller et al., 2008). Another factor which undoubtedly contributed to increased tackle rates and consequent injury rates sustained in the tackle is the changes which took place in the game over the last 12 years since the commencement of professional rugby union. The ball is in play for much longer now than ever before, creating more opportunities for tackles to occur. In the Rugby World Cup (RWC) the time of ball in play, where tackles occur, has increased from 33% in 1995 to 44% in 2011, creating much more opportunity for tackles to occur. The speed of the game also increased considerably – a recognised contributing factor to injuries in the tackle (IRB, 2011). The increased incidence of injuries in the tackle in professional rugby is an important finding to alert policy makers and medical professionals in rugby of a potential increased risk of injuries in the tackle.

5.4 ASSOCIATED FACTORS OF TACKLES RESULTING IN INJURY

5.4.1 Injuries received by tackler or ball carrier

In this study, tackles received caused substantially more injuries than tackles made. Of the 404 tackles that were made, 1.5% of tackles resulted in injuries. Of the 340 tackles which ball carriers received (receivers of the tackle), 2.7% of tackles recorded resulted in injury. Seventy per cent of tackle injuries recorded were to ball carriers, while only 30% of tackle injuries were sustained by tacklers. Statistical significance could not be reached with the data, because of the relatively low number of injuries recorded ($p=0.153$). However, the odds ratio (OR) between the numbers of injuries sustained by the ball carrier as opposed to the tackler is 2.8, which is of practical significance. The OR is interpreted as the ball carrier having a 2.8 times higher chance (odds) of getting injured in a tackle than a tackler.

Existing literature indicates that ball carriers are more prone to injury because of tackles to the head and neck (Fuller et al., 2010; Quarrie and Hopkins, 2008); chest high ball-and-all tackles with head to torso collision (Garraway et al., 1999; Quarrie et al., 2007), or tackles within the side-vision of the ball carrier (Garraway et al., 1999). Tacklers and ball carriers were mostly at equal risk of injury in a study on injuries in professional rugby in New Zealand (Quarrie et al., 2008). Similar results

were reported in video analysis of injuries in the Rugby Injury Prevention Program (RIPP) of the New Zealand Rugby Football Union (Wilson et al., 1999). A study done in South Africa found that some tacklers got injured when they connected the ground or the thigh of an opposing player (Milburn, 1995). It is clear from these results that more emphasis should be placed on protecting ball carriers from injuries in the tackle situation. The literature is ambiguous on injuries to the ball carrier being caused more by contact with the tackler or other players (Wilson et al., 1999), or by falling and hitting the ground (Milburn, 1995). Further research on the cause of tackle injuries to the ball carrier in Super Rugby is advised, especially seen in the context of the disturbingly high tackle injury rate recorded in this study.

5.4.2 Field position where tackle occurred

Injuries sustained in the tackle in the attacking 22m area were significantly more than in any other position on the field ($p=0.048$). Eleven out of 12 injuries that occurred in the 22m area was in the attacking 22m area. Six of these injuries were sustained by ball carriers and five sustained by tacklers. This represents a very high percentage of injuries in this area (55% of total tackle injuries recorded) and is the most significant finding of this study. The incidence of injuries in the attacking 22m area is also of practical significance (OR = 1.7). Even more significant is the finding that tacklers in the attacking zone, or the defending party when the other team is attacking, have an OR of 29.4, or a 29.4 times increased chance of getting injured than the ball carrier. This finding indicates a different dynamic in the attacking 22m, which warrants further investigation. No studies could be found in the literature where the incidence of tackle injuries in the attacking zone was reported.

It is well known anecdotally that the intensity of play is higher in the attacking zone. Game plans often include specific high intensity attacking moves to cross the opposition goal line. The nature of the game is that the attacking side wants to score a try at all cost and the defending side wants to protect their goal line. Higher intensity of play with increased stress, motivation and pressure have been shown to cause narrowed vision fields and increased muscle tension which can increase injury risk (Williams and Anderson, 1998). A study done in football found that coordination and skill level of players change in relation to the pressure of a game situation and proximity to the goal area, which supports the notion of increased risk for sustaining injuries under pressure (Headrick et al., 2012). The injury model of McIntosh (2005) clearly indicates that altered levels of competitiveness and

motivation influence cognition and assessment of risk by players, which in turn influence on-field behaviour and skills, ultimately affecting injury risk.

A comprehensive literature search and an enquiry to the South African Rugby Union (SARU) referees department could not source statistics on possible altered game statistics, increased intensity, foul play, tackle infringements, penalty count or other factors which may indicate variables that can contribute to the high incidence of injuries in the attacking zone, or give an indication of altered level of play, mind-set or concentration level in the attacking 22m zone. It is therefore recommended from the findings of this study that play in the attacking 22m zone and factors that may be associated with increased risk of tackle injuries in this zone be investigated in detail.

5.4.3 Game situation where tackles occurred

Most tackles occurred in open play in the outfield. Of the 744 tackles studied, 122 occurred close to the set piece (Channel one) where 2.4% of tackles resulted in injury, and 622 occurred in the wider running channels (Channel 2+) where 2.7% of tackles resulted in injury. No statistically significant difference could be determined regarding the relative risk of injury between Zone 1 and Zone 2+ ($p=1.000$). No significant odds ratio could be determined either. However, of the 20 injuries that were sustained, 17 (85%) occurred in channel 2+, and only three (15%) in Channel 1. Even though this finding is not an indication of relative risk compared to Channel 1 but merely a reflection of the fact that most tackles occur in Channel 2+, it is of much practical value for coaches to select Channel 2+ a focus area for coaching tackle and falling techniques. A further interesting finding was that 13 of the 17 (76%) tackle injuries in Channel 2+ were sustained by ball carriers. In fact, if relative risk is disregarded and a coach wants to know which players are most likely to be injured, it is of practical value to know that 65% of all tackle injuries recorded in this study were sustained by ball carriers in Channel 2+. This data is supported by Milburn (1995), who reported a number of studies. In England a study found that midfield backs were significantly more prone to injuries than any other player, this was the result of high speed tackles in open play – the equivalent of Channel 2+. The risk of tackle injuries occurring in Channel one was not significant (Fuller et al., 2010). A study done in Australia found that ball carriers were injured in 76% of tackle related injuries. In the United Kingdom it was also found that ball carriers were more prone to getting injured in the tackle. A study done in the Cape Province

in South Africa found that the majority of spinal cord injuries in the tackle were to ball carriers (Milburn, 1995).

Even though neither statistical significance nor a significant odds ratio could be shown for relative injury risk between play around the set phases and open play, practical interpretation of the data shows a trend which correlates with findings of other studies. A case can therefore be made from these results and the literature that there is a higher risk of tackle injury in open play further away from the set phases are. Injuries are more likely to occur in ball carriers in this area.

5.4.4 Injuries caused by number of tacklers involved in a tackle

This study recorded no statistical difference between the risks of injury in single (one tackler) or multiple (more than one tackler) tackles. The OR of getting injured in a single tackle versus a multiple tackle is equal (OR=1). These findings are in contrast with much of the existing literature which often indicates multiple tackles as higher risk situations.

Examples of studies which showed that tackles by multiple tacklers result in a higher injury risk include the study where a greater risk of injury in the tackle were where two or more tacklers were involved in the tackle event and the greatest risk was associated with simultaneous contact by tacklers (McIntosh et al., 2010). Furthermore, in the early eighties a study found that a rugby player who is simultaneously tackled by 2 opponents is more susceptible to cervical spinal and spinal cord injury than the player tackled by a single opponent. Two illustrative case reports confirmed this (Scher, 1983). Another type of tackle that has contributed to head and neck injury but is not covered under the law is one where the second or third tackler comes in late to assist with the tackle. The second tackler comes in high on most occasions, which makes it dangerous (Milburn, 1995). The results of this study could however be influenced by the greater occurrence of single tackles occurring during the games that were studied. It is therefore not possible to make definite recommendations from these results. More player hours and tackles need to be studied before recommendations in this regard can be made.

5.4.5 Direction of tackler impact and combined vector speed of the tackle

5.4.5.1 General direction of tackler impact relative to the running line of the ball carrier

Considering single tackles, this study found a significant odds ratio (OR=1.8) of higher chance of injury in front-on tackles as opposed to side-on tackles. This finding supports much of the relevant literature. A study in New Zealand found that the majority of tackle injuries were associated with stopping tackles to the trunk which were from the front (63%), rather than from the side or behind (Wilson et al., 1999). In Scotland a study found that forceful or crunching tackles resulting in injury mostly occurred head on or within the tackled player's side vision (Garraway et al., 1999). One study commented on stopping tackles from the front (Angle two, 90 degrees) being responsible for more injuries compared to tackles from the side (Angle one, 45 degrees) or behind (Wilson et al., 1999). The analysis of the direction of the tackle in multiple tackles indicates a similar scenario. A significant odds ratio of 1.5 indicates a 1.5x higher relative risk of injuries in multiple tackles when the first contact is front-on, compared to side-on first tackles.

These results add to the growing body of evidence that front-on tackles hold higher risk for injury than tackles from other directions.

5.4.5.2 Combined impact vector speed within the tackle

In general, higher odds ratios for injuries were found at higher vectors of collision. There is an OR of 2.3 of getting injured when the collision is at medium speed compared to slow-medium speed. An OR of 1.4 times higher risk of injury was calculated when the collision is fast, as opposed to medium-fast. Even though statistical significance was not demonstrated, this trend is keeping with existing literature.

There is convincing literature indicating that increased impact vectors are associated with increased risk of tackle injuries (Fuller et al., 2010; Garraway et al., 1999). High speeds by both the tackler and the ball carrier before going into the tackle caused the most injuries in the tackles studied in professional rugby in England (Fuller et al., 2010). It has been established that the risk of injury is higher when the tackler entered the tackle situation at a high speed (Fuller et al., 2010). A study done in New Zealand concluded that the risk for injury is higher when the tackler is

in motion during the tackle (Wilson et al., 1999). A study done in Scotland found that either the tackling or tackled player was sprinting or running in most injury episodes (Garraway et al., 1999). One third of these injuries occurred in differential speed tackles, when one player was travelling much faster than the other at impact. The player with the lower momentum was injured in 80% of these cases (Garraway et al., 1999).

In this study, limiting factors in examining the effect of vector impact speed was firstly the fact that speeds were only estimated due to the lack of appropriate equipment. . The combined vector speeds in the tackle need to be studied in more numbers, in a lot more detail, with more sophisticated measuring tools to make recommendations about this factor in limiting tackle injuries. Secondly, the number of tackles included in the study was not sufficient to reach definite conclusions where multiple variables are considered. It is possibly not useful to include the investigation of such variables in this type of descriptive research.

5.5 TACKLE INJURY PROFILES

This section reported descriptive data on types of injury, severity of injuries, injured body part, and the nature of injuries sustained in the tackle in this study. Because of low numbers, statistical or practical significance were not calculated on the data. Furthermore, comparison of this type of data in the literature is much confounded by methods of data collection, injury definition, and interpretation of other variables, making comparison and pooling of data difficult.

5.5.1 Contact area in the tackle

The lower limb area (10) were hit most in the tackle situation, followed by the upper body (6), lower limb/upper body (3) and lower body/upper body (1) combinations. It is clear out of the results that the body part hit in the tackle was very seldom the body part that sustained the injury. This might be because a lot of injuries sustained by ball carriers occur to parts of the body when they hit the ground or another player after a tackle (Noakes and Du Plessis, 1996). Tacklers on the other hand usually get injured because of wrong technique in the tackle, where the head and neck area might be in the wrong position during impact (Noakes and Du Plessis, 1996). A study done in South Africa found that some tacklers got injured when they connected the ground or the thigh of an opposing player (Milburn, 1995). Another

two cases of tackle injuries studied found that a player got injured when diving head first into the ground or connecting with his opponent's thigh. The study also reported injuries sustained by tacklers when they miss a tackle and hit the ground (Milburn, 1995). In professional rugby in New Zealand in 2008 ball carriers were most at risk for injuries in tackles to the head-neck region and tacklers were mostly at injury risk when making low tackles, with contact to the head and shoulder (Quarrie et al., 2008). A study done in England also found this to be true with $p < 0.01$ when contact to the head and neck area were made (Fuller et al., 2010). In New Zealand during the late nineties tackle injuries were mostly associated with stopping tackles to the trunk area made from front on (Wilson et al., 1999). A large increase in the number of chest high, ball-and-all tackles has been documented in the 10 years before 2007. This type of tackle is now associated with the highest incidence of injuries and puts the tackling player at risk of a head on torso collision and spinal injury (Quarrie et al., 2007).

5.5.2 Injured body part

The most common injury location was the shoulder (30%). The second most common was the knee (15%). Neck (10%), ribs (10%), quadriceps muscle (10%) and the pelvis (10%) were the next most common injuries. The nose (5%), calve (5%) and ankle (5%) made up for the rest of the 20 injuries. This could be classified further into upper body (55%) and lower body (45%) injuries. Analysis of more tackle injuries need to be done to reach conclusions regarding the body part injured in the tackle.

5.5.3 Severity of injuries

A traumatic shoulder dislocation was the only severe tackle injury recorded in this study (5% of injuries). with the rest of the injuries resulting in seven or less playing days missed, made up of nine minimal injuries (45%) and ten mild injuries (50%), resulting in 257 player days missed in six matches. The severity of injuries sustained by ball carriers and tacklers were similar. These results are similar to other studies done on the same level of rugby, where the majority of injuries were minimal or mild (Fuller et al., 2010; Quarrie et al., 2008).

5.5.4 Type of injuries

Fifty per cent of tackle injuries resulted in contusions. Ligament injuries (35%), muscle strains (10%) and neuropraxia (5%) made up the balance of types of injuries recorded. It is interesting to note that injuries from tackles resulted in a higher percentage of contusions when compared to statistics on types of injuries in rugby in general, where musculo-tendinous injuries and ligament sprains were often the most common injuries recorded (Fuller et al., 2008; Holtzhausen et al., 2006). Interestingly, two other teams in the Super 14 competition also reported relatively high numbers of contusions (Redhead et al., 2011). This similarity may reflect on the type of rugby played in this competition. Even without statistical significance, a trend of a high rate of contusion injuries has been shown. It may be of practical value if contusion injuries can be prevented or reduced in severity by protective clothing. Further research in this regard is recommended to verify the trend and reach more definite conclusions.

5.6 LIMITATIONS OF THE STUDY

Even though a number of interesting findings and trends were reported in this study, a number of limitations to the methodology and execution of the study were recognised, resulting in relatively poor strength of evidence of the findings.

Great care was taken to limit different types of bias in collection and analysis of the data. The main limitation of the study was the relatively low number of match hours and tackles that were studied. The statistically rare occurrence of injuries in the tackle demands many more hours to be studied in order to reach definite conclusions. This study was limited to six matches because of unavoidable practical circumstances. The second important limitation of the study was the relative lack of resources to analyse speeds, forces and vectors involved in the tackle. An attempt was made to estimate and stratify speeds and vectors, with little success. In fact, many findings in this study with any value, could have been obtained without video-analysis, but only required routine injury surveillance.

5.7 CONCLUSIONS

The aim of this study was to investigate biomechanical aspects of the tackle in professional rugby to identify possible mechanisms of injury in the tackle. Despite the limitations of the study, interesting findings were reported.

5.7.1 Strong evidence

Strong evidence, as defined by direct comparison of findings with the literature, or with statistical significance with a 95% confidence interval, was reported in this study in the following instances:

This study recorded the highest incidence of injuries in the tackle ever recorded. The implied increase in tackle injuries may be ascribed to a number of factors, including increased speed and intensity of professional rugby, or longer periods of ball in play. The trend of increasing incidence of tackle injuries should be monitored closely and to eventually reduce the risk of injuries in the tackle.

The study recorded a significantly higher incidence of tackle injuries in the attacking 22m zone. To reach statistical significance with such low numbers of data, as is the case here, implies particularly strong evidence. To the researcher's knowledge, it is the first time that this finding has been reported in the literature. A further unique finding of the study is the high odds ratio of injuries to tacklers when defending their goal line in this zone, which is contrary to the general trend of higher injury risk to ball carriers. Anecdotal evidence indicates a higher intensity of play in the attacking zone. According to the literature described in the study, higher intensity of sport can ultimately lead to decreased cognitive functioning, which, in turn, can increase risk of injury. It is emphatically recommended that a detailed analysis of play in the attacking 22m zone is undertaken to investigate possible causative factors for injury.

5.7.2 Weaker evidence

In order to quantify relative risk in the clinical and sports environment, where practical value or significance can be attributed to findings without reaching statistical significance, odds ratios were calculated for relative risk of injury under different circumstances. This is presented as weaker statistical evidence, but nevertheless important to stakeholders.

The odds ratio for injury to ball carriers in the tackle was significantly higher than to tacklers. This finding correlates well with existing literature. Contrary to this, the high odds for injury to tacklers in the attacking 22m area has been described, emphasising the novelty of identifying the attacking 22m area as a unique zone in terms of injury risk. In view of the high incidence of tackle injuries recorded in the Super 14 competition, it is recommended once more to analyse existing literature and new data to determine preventable causes of injuries to ball carriers.

The high odds ratio of injury in front-on tackles compared to other directions of vector force, has practical significance, especially when added to the existing evidence in this regard. Evidence of the dangers of front-on tackles is ample. Research should now be focused detailed analysis of mechanisms and causes of front-on tackles, specifically to identify preventable factors.

Further evidence by means of practical significance was provided in this study that higher vector forces, or speeds in the tackle carry increased risk of injury. This finding is also in keeping with the existing literature, highlighting the need for further investigation into the mechanisms of higher speed tackles, also to identify preventable factors

5.7.3 Trends

A number of interesting trends were identified in the results of the study, which were neither statistically significant nor displayed significant odds ratios. For rugby physicians and researchers alike, however, it makes for interesting reading and may be of value in planning injury prevention strategies and guide future research. These are:

- By far the most tackle injuries (85% of all injuries recorded) occurred in open running, at least one channel away from the set piece (Channel 2+). The reasons for that are mainly that most tackles occur in that phase of play, and that the highest speeds in the game – a known risk factor for tackle injuries – occur there. It stands to reason, therefore, that if aspects of the tackle to investigate an identify preventative factors are selected, identification and modification of factors associated with tackle injuries in open play will be the most advantageous.

- Fifty per cent of all tackle injuries were contusions. This is notably higher than the incidence of contusions in injuries caused in other phases of play. Contusions are caused by high impact contact, either between players in the tackle, a third person, or the ground. The types of contact that causes injury should be investigated. Tackle technique, falling technique or protective gear may play a role in decreasing these injuries or decreasing their severity.

In conclusion, the researcher wishes to emphasise two important learning experiences from this study. Firstly, even though video analysis, requiring much technical resources, was used as tool to collect and measure data, most of the important findings of this study could have been made by routine injury surveillance. The message is that technical analysis is probably valuable, but given the time, effort and money it requires, it should rather be attempted with highly sophisticated tools and expertise. The follow-up on this study, for example to investigate the precise vectors and biomechanical mechanisms of tackle injuries need to be done with such resources. Routine injury surveillance by means of recording match statistics and injury data remains a key component of injury prevention protocols. The second learning experience to emphasise is that statistical significance in injury data has an important place, but much useful and practically significant findings are made by different means of data analysis, such as measurement of effect size and calculation of odds ratios.

The aim of this study was to investigate biomechanical aspects of the tackle in professional rugby to identify possible mechanisms of injury in the tackle. Even though not many biomechanical aspects associated with injury could be identified with strong evidence, novel findings were made. The highest incidence of tackle injuries recorded in the literature was recorded in this study. The attacking 22m area was identified for the first time as a unique area in rugby, where not only the incidence of injuries is significantly higher than elsewhere on the field, but that the pattern of injuries is different.

The study therefore made a meaningful contribution to the understanding of tackle injuries and will be used as a basis for further investigation into injury prevention in rugby.

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SARU: STANDARDISED TACKLE DATA FORM

Injury Surveillance Study Injury Report Form			
TEAM:	Player name:	Date of injury:	Date returned from injury No. of matches missed
1. ACTIVITY at TIME of INJURY (Complete <i>either</i> the match <i>or</i> the training section):			
Match <i>Time of injury</i>	Warm-up <input type="checkbox"/> 0 - 20 mins <input type="checkbox"/> 21 - 40+ mins <input type="checkbox"/> 41 - 60 mins <input type="checkbox"/> 61 - 80+ mins <input type="checkbox"/> Cool-down <input type="checkbox"/>		
Event causing Injury (Tick one box only)	Collision <input type="checkbox"/> Ruck <input type="checkbox"/> Tackled <input type="checkbox"/> Tackling <input type="checkbox"/> Lineout <input type="checkbox"/> Kicking <input type="checkbox"/>	Maul <input type="checkbox"/> Collapsed maul <input type="checkbox"/> Scrum <input type="checkbox"/> Collapsed scrum <input type="checkbox"/> Running <input type="checkbox"/>	Other (describe) <input style="width: 100%;" type="text"/>
Playing position at time of injury: <input style="width: 100%;" type="text"/>		Player: Started game <input type="checkbox"/> Replacement <input type="checkbox"/>	
Was the player using the following items when injured? (tick ALL applicable)			
Gum shield <input type="checkbox"/> Shoulder pads <input type="checkbox"/> Head guard <input type="checkbox"/>			
2. CLASSIFICATION of INJURY (Refer to Guidance Information provided for body location and type of injury categories)			
Was the injury? Acute <input type="checkbox"/> Gradual onset <input type="checkbox"/>	Was player removed from play? Immediately <input type="checkbox"/> Later <input type="checkbox"/> Not at all <input type="checkbox"/>		
Body location: <input style="width: 100%;" type="text"/>	Type of injury: <input style="width: 100%;" type="text"/>	Side of body: left <input type="checkbox"/> right <input type="checkbox"/> Bilateral <input type="checkbox"/> N/A <input type="checkbox"/>	
Orchard code: <input style="width: 100%;" type="text"/>	If coding is unclear, describe injury: <input style="width: 100%;" type="text"/>		
Were diagnostic investigations used? Yes <input type="checkbox"/> No <input type="checkbox"/> If YES, please specify: <input style="width: 100%;" type="text"/>			
Were invasive procedures used? Yes <input type="checkbox"/> No <input type="checkbox"/> If YES, please specify: Suturing <input type="checkbox"/> Surgery <input type="checkbox"/> Steroid injection <input type="checkbox"/> Other <input type="checkbox"/>			
Is this injury a recurrence (see definition)? Yes <input type="checkbox"/> No <input type="checkbox"/> Date player returned from previous injury: <input style="width: 100%;" type="text"/>			

APPENDIX B

PERMISSION LETTER: FREE STATE RUGBY UNION

CONSENT FORM

I, Harold Verster, ID 4912225024084, Chief executive officer of the Cheetahs Rugby Union, give hereby permission for the use of video footage of Cheetah players during the first six games of the 2007 Super 14 competition to be analysed for research purposes.

Kind regards

Signed at BROEFONTEIN on the 28TH day of JANUARIE 2008


Signature