The epidemiology of hostel rugby injuries at Stellenbosch University

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DECLARATION

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own original work, that I am the authorship owner thereof (unless to the extent explicitly otherwise stated) and that I have not previously submitted it in its entirety or in part for obtaining any qualification.

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DEDICATION

I would like to dedicate this to my mother, Barbara Barrett, the most amazing mom a daughter could ever ask for. Although the content of his thesis may not be your typical bed time reading, I would like you to know that your never-ending support and unconditional love has motivated me to finish my degrees. Life may have been unbelievably tough at times but you always put your children first and for that I am truly grateful. In the past you have wondered where my determination comes from and I can honestly say it's from you and for you. Despite your small size, you are by far the strongest woman I know. I strive to succeed in everything I do as a way to honour you. I love you with all my heart.

"All that I am or hope to be, I owe to my angel mother"

~Abraham Lincoln

SUMMARY

The contact nature of rugby means that players are at a high risk of injury (Quarrie & Hopkins, 2008). Almost every area of the body is at risk of injury and severity of injury ranges from mild to catastrophic. Injury data pertaining to South African university hostel level players have, however, not been investigated previously. Injuries may have a negative impact on the future opportunities in work and sport for these students. Knowledge of the nature and prevalence of injuries amongst these players will facilitate the development of preventative strategies to mitigate the occurrence of injuries.

The aim of this study was to describe the nature and prevalence of hostel rugby injuries sustained during matches at Stellenbosch University during the 2011 to 2013 seasons.

A retrospective cohort study design was used. The data concerning injuries that occurred during ‘hostel’ rugby matches during 2011 and 2013 were captured on a modified BOKSMART injury surveillance form and entered into an electronic database for analysis (Fuller *et al.*, 2007c). In addition, match fixture data was obtained from the MATIES Rugby Club to enable the reporting of data per 1000 hours of match play.

During 2011 - 2013 hostel seasons, there were 335 injuries which correlated to an injury rate of 17.5/1000 playing hours. Two hundred and thirty three (233) time-loss injuries and 102 medical attention injuries were reported. The head (24%), face (23%), shoulder (13%) and knee (10%) were the body parts most affected and the tackle was the phase of play where most injuries occurred (n = 199; 59.4%). The most common injuries were lacerations (23.6%), joint injuries (16.1%), concussions (15.5%) and ligament injuries (11.9%). Forwards sustained more injuries compared to backs (172 vs 160) and the specific positions that proved most vulnerable were the flanks, centres, left wings, hookers and fullbacks. Most injuries were of moderate severity (resulting in 8-28 days missed) which could have a significant impact in an academic environment. Hostel players may be at higher risk due to long mid-season breaks and lack of conditioning programs in their respective teams (Kaplan *et al.*, 2008).

Hostel players have a similar injury prevalence rate when compared to school boy players and a lower rate when compared to club, provincial and national players (Palmer-Green, *et*

al., 2013; Fuller *et al.*, 2013). They are, however, a distinctive population who are affected by a range of unique risk factors such as lack of conditioning and academic pressure. There is a definite need for prevention strategies in this division of players because injuries may have an effect on their academic performances which in turn may affect their future careers.

OPSOMMING

Die kontak aard van rugby lei tot 'n hoë risiko van besering (Quarrie & Hopkins, 2008). Byna elke deel van die liggaam het ‘n risiko vir besering en die erns van die besering wissel van matig tot katastrofies. Beseringsdata met betrekking tot koshuisliga spelers aan ‘n Suid-Afrikaanse universiteit is nog nie voorheen bestudeer nie. Beserings kan 'n negatiewe impak op die toekomstige geleenthede vir ‘n student hê. Kennis van die aard en die voorkoms van beserings onder hierdie spelers sal die ontwikkeling van voorkomende strategieë fasiliteer en moontlik die voorkoms van beserings verminder.

Die doel van hierdie studie was om die aard en voorkoms van koshuisliga rugbybeserings tydens wedstryde aan die Universiteit Stellenbosch vanaf 2011 tot 2013 te beskryf.

'n Retrospektiewe kohort studie ontwerp is gebruik. Beserings wat tydens koshuisliga rugbywedstryde in 2011, 2012 en 2013 plaasgevind het is op 'n aangepaste BOKSMART beseringsvorm aangedui en is by wyse van ‘n elektroniese databasis geanaliseer (Fuller *et al.*, 2007c). Daarbenewens is inligting rondom wedstryde vanaf die Maties-rugbyklub verkry om die beskrywing van data per 1000 wedstrydure moontlik te maak.

Gedurende die 2011 - 2013 koshuisliga seisoene was die beseringskoers 17.5/1000 speelure. Een honderd nege en sestig (169) beserings het speeltyd ingekort en 84 beserings het mediese aandag vereis. Die kop (24%), gesig (23%), skouer (13%) en knie (10%) was die liggaamsdele wat die meeste geraak is en die meeste beserings het tydens duikslae plaasgevind (199; 59.4%). Die mees algemene beserings was laserasies (23.6%), gewrigsbeserings (16.1%), harsingskudding (15.5%), en ligamentbeserings (11.9%). Voorspelers (172) het meer beserings opgedoen as agterspelers (160) en die spesifieke posisies wat mees kwesbaar was, was die flanke, senters, linkervleuels, hakers en heelagters. Die meeste beserings was van matige erns (8-28 dae speeltyd gemis) wat 'n beduidende impak in 'n akademiese omgewing kan hê. Koshuislliga spelers mag ‘n hoër risiko vir beserings hê as gevolg van die lang mid-seisoen breek en die gebrek aan kondisioneringsprogramme in hul onderskeie spanne (Kaplan *et al.*, 2008).

Koshuisliga spelers het 'n soortgelyke besering voorkomssyfer as skoolseunspelers en 'n laer koers as klub, provinsiale en nasionale spelers (Palmer-Green *et al.*, 2013; Fuller *et al.*,

2012). Hulle is egter 'n eiesoortige populasie wat deur ‘n verskeidenheid unieke risikofaktore geraak word, byvoorbeeld die gebrek aan kondisionering en akademiese druk. Daar is 'n besliste behoefte aan voorkomingstrategieë vir hierdie vlak spelers, aangesien beserings 'n invloed op hul akademiese prestasie kan hê en uiteindelik hul toekomstige loopbane nadelig kan beïnvloed.

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LIST OF ABBREVIATIONS

ACC	Accident Compensation Corporation
ACL	Anterior Cruciate Ligament
FIFA	Fédération Internationale de Football Association
GPS	Global positioning system
IRB	International Rugby Board
RICG	Rugby Injury Consensus Group
SARU	South African Rugby Union
SCI	Spinal cord injury
SD	Standard Deviation
TRIPP	Translating Research into Injury Prevention Practice
UEFA	Union of European Football Associations
WR	World Rugby

APPENDIX

CHAPTER ONE

INTRODUCTION AND PROBLEM STATEMENT

1.1 Introduction

Rugby union (hereafter referred to as rugby) is a popular, full contact sport with almost 200 countries affiliated with the International Rugby Board (IRB) (now World Rugby) (Schneiders *et al.,* 2009). According to Palmer-Green *et al.* (2013), rugby is second only to football with regards to participation rates around the world. Each team has 15 players on the field for the duration of the game with seven (sometimes eight) substitutes being allowed. It is characterised by short, intermittent bouts of high intensity activity separated by periods of jogging or standing. At senior level, the game is played for two forty minute halves with a ten minute interval (Brown *et al.,* 2012). It includes four main phases of play, namely, the tackle, ruck and maul, set pieces (scrum and lineout) and open play (Kaplan *et al.,* 2008).

Rugby demands a high level of conditioning and technical skill ability from the players due to the intensity and physicality of the game (Sedeaud *et al.,* 2012; Noakes & du Plessis, 1996). It includes open skills due to the dynamic unpredictable environment which is ever changing. With most injuries occurring in the second half of the game, good fitness levels are a vital component to every rugby team's program (Dallalana *et al.,* 2007; Bathgate *et al.,* 2002). Whilst certain characteristics are suited for different positions, the main aspects of a well-rounded rugby player include a balance of strength, endurance, speed, power, agility and flexibility. As with every sport, even though a player may be well conditioned, injuries still occur in rugby (Fuller *et al.* 2013).

Considering that rugby is a full contact sport, injury rates are generally very high when compared to other sports (Trewartha *et al.,* 2014). Overall injury rates for rugby were 69/1000 playing hours whilst other sports like soccer and cricket reported much lower injury rates (28/1000 playing hours and 3.7/1000 playing hours respectively) (Patricios, 2014). The overall injury rate of professional rugby players was reported as 91/1000 playing hours (MacQueen & Dexter, 2013), whilst studies on adolescent rugby have reported injury rates between 27.5 and 129.8/ 1000 playing hours (Bleakely *et al.,* 2011). Sporting codes similar to rugby, such as rugby league, have reported similarly high injury rates. Gabbett (2008) reported an injury rate of 56.8/1000 playing hours in junior rugby league matches over 4 seasons.

Posthumus and Viljoen (2008) found that there are several areas of play, including the tackle, that are responsible for the majority of injuries in rugby, namely, taking the ball into contact, the lineout and the ruck and maul. However, the general consensus is that tackles are responsible for most injuries (Roberts *et al.*, 2014; Usman *et al.*, 2011; Schneiders *et al.*, 2009). Although contact with other players (tackles) has the highest injury rate, the most common contact experienced by the players is making contact with the ground (Van Rooyen, 2008).

Injuries, especially musculoskeletal injuries, are common in rugby due to the high intensity and contact nature of the game (Bleakely *et al.*, 2011; Quarrie & Hopkins, 2008). The most common areas of musculoskeletal injury are the shoulder, knee, thigh, ankle and head (Brooks & Kemp, 2008). The New Zealand National Accident Compensation Corporation collected rugby injury data from across New Zealand over the period ranging from 1999 to 2007. They concluded that the most common injuries that needed medical attention were soft tissue injuries and the most common injury site was the knee (King *et al.*, 2009). Despite certain body sites and types of injuries being more common to injury, the cause of these injuries differs due to the dynamic nature of the game.

Professionalism in rugby has brought about changes in the game itself as well as the players involved. The players have become more competitive for places in the team due to the financial gains and pride for representing their province, club or country. This has brought about abundant research and a focus on the science of physical conditioning and peak performance (Quarrie *et al.*, 2013; Smart *et al.*, 2013; Austin *et al.*, 2011; Brooks *et al.*, 2005). The demands of the game include a massive increase in the amount of rucks in a typical match (62.4 rucks in 1988 vs 134.4 rucks in 2002) (Sedeaud *et al.*, 2012). Fuller *et al.* (2007b) reported 142.6 rucks over two seasons (2003/2004 and 2005/2006) in 13 English Premiership teams. The size of players has increased over time due to the improved training methods as well as the change in demands of the game. Seven's rugby players are typically smaller than fifteen's players because of the very high intensity of the game. Although they need to be physical to dominate the one on one tackles, there are very few rucks during the match and much more running. Research has actually shown that the longer the team has possession of the ball, the less likely they are to score (Higham *et al.*, 2014).

Smart *et al.* (2013) analysed the anthropometric characteristics of players as well as the physiological demands for each position. The results showed that props were the heaviest and strongest out of the 15 players and the outside backs were the fastest players. This relates to their positional demands on the field, with props having to compete in close contact events such as scrums, lineouts, rucks and mauls and backs having more space available to them as they need to break through defence lines (Smart *et al.*, 2013). Another factor to consider would be that the style of play of younger, hostel players is different to that of more senior players. According to de Beer and Bhatia (2009), younger rugby players have become more aggressive and competitive, but the musculoskeletal structures of players may not have fully developed as yet which may place them at a higher risk for injury.

In a literature review by Kaplan *et al.* (2008), all levels of play were analysed in the more prominent rugby playing nations and it was found that players with the highest injury rates were hookers and props involved in the scrum, as well as centres and flankers who are involved in contact at a high speed and had high tackle rates. In addition, fullbacks are responsible for solid last defence tackling on wings and are often on the injury list (Kaplan *et al.*, 2008). In the 2007 IRB Rugby World Cup (RWC), the injury rates were relatively similar between forwards and backs during training and matches (in training: forwards 84/1000 playing hours; backs 83.7/ 1000 playing hours; matches: forwards 3.5/ 1000 playing hours; backs 3.6/ 1000 playing hours). In the 2011 RWC, the forwards had an injury rate of 2.7/1000 playing hours and the backs 1.7/1000 playing hours during training. During matches, the results were reversed, with the backs having a higher injury rate than forwards (93.8/1000 playing hours compared to 85.0/1000 playing hours, respectively). The lower limbs were found to be the most affected area during matches (31.6%) and in training (51.4%). The tackle was the area of play which caused the most injuries in backs (45.2%) and forwards (43.6%) (Fuller *et al.*, 2012; Fuller *et al.*, 2008).

The stage of the rugby season has also been found to influence the injury incidence rates of all players, regardless of their positional duties. The early half of the season proved to be the time in which most injuries occurred in training, whilst the latter stage of the season saw more match playing injuries (Roberts *et al.*, 2013). In the university setting, the season is influenced by university holidays and intense exam periods where prolonged rest periods or high stress levels may have an impact on the risk of injury. Van Niekerk and Lynch (2012) found that high anxiety levels are associated with a higher risk for injuries, specifically the shoulder.

During matches, the research depicts contradicting results with regards to injury rates. Nicol *et al.* (2011) found that most injuries occurred in the first half of a match which may be due to players running at a higher speed and providing higher impact forces. Dallalana *et al.* (2007) found more injuries occurred in the second half of the match which may be due to players fatigue levels increasing after forty minutes of play. Although the timing of injuries during the season or match is important aspects of injury surveillance, another vital factor is the activity the player was involved in at that specific time during the match (running, tackling etc).

The contact situation in rugby is one of the aspects of the game that produces the highest injury rates and research show the tackle specifically causes most injuries (Bleakley *et al.*, 2011; Brooks & Kemp, 2008; Fuller *et al.,* 2008; Holtzhausen *et al.*, 2006; Best *et al.,* 2005). Viljoen and Patricios (2012) claimed that the tackle and the scrum contributed to 78% of all serious and catastrophic head, neck and spine injuries. With tackles occurring approximately 221 times in a game and rucks 142.5 times, Fuller *et al.* (2008b) concluded that these events were responsible for the most injuries, as well as the greatest loss in playing time.

Coaching techniques as well as basic medical care have been introduced via rugby specific educational programs like Rugby Smart in New Zealand and Boksmart in South Africa which aim to provide coaches, referees, players and administrators with the knowledge, skills and leadership abilities to ensure that safety and best practice principles are incorporated into all aspects of contact rugby. The education of coaches and players in these rugby specific educational programs has helped reduce the incidence of injury (Quarrie *et al.,* 2007; Gianotti *et al.,* 2007). Quarrie *et al.* (2007) and Gianotti *et al.* (2009) evaluated injury incidence before and after the implementation of Rugby Smart and found a decrease in injuries in New Zealand rugby, as well as an increase in safe behaviour in the contact situations of tackle, scrum and ruck technique. Boksmart is the South African equivalent to Rugby Smart and is currently being evaluated by an expert in collaboration with the University of Cape Town's Research Unit for Exercise Science and Sport Medicine (Viljoen & Patricios, 2012). They have followed a similar principle of Rugby Smart by acknowledging a major problem, identifying risk factors, developing strategies to target the problem, implementing these initiatives and putting independent processes in place to evaluate the success of the programme. One of the major challenges is implementing realistic prevention strategies that will bring about positive behavioural changes to attempt to reduce injuries amongst players (Viljoen & Patricios, 2012).

Hostel rugby at university level does not have the same training regime as amateur club rugby, provincial or international rugby. The players are generally social players which means they are involved in limited gymnasium and field conditioning and technical sessions outside of matches played once a week. Repetitive training brings about sport- specific adaptations which enable players and athletes to perform the physical and technical skills needed in their chosen sport. The lack of physical conditioning in hostel rugby players puts them at a higher risk for injury as they may be unable to cope with the stressors and impacts on their body.

Knowledge of injury data allows for the identification of risk areas. The areas can be addressed through education and technical training to mitigate risk and reduce injury. Knowledge regarding injury rates at university is limited. It is not known if injury rates are disproportionally higher compared with other levels of play and whether the specific risk areas are different. Hence, suitable education and technical training, or structural changes to mitigate injury risk cannot be instituted.

1.2 Aim of the study

The aim of this study was to describe the epidemiology of injuries sustained during hostel rugby matches at a university from 2011 to 2013.

1.2 Objectives

- To determine the prevalence of injuries in hostel rugby union players at a university across three seasons.
- To compare injury statistics between the Varsity Cup and hostel league.
- To determine the severity of the injury as well as the anatomical location of the injuries.
- To determine which playing positions are most affected and which phase of play these injuries occurred at.
- To determine whether incidence rates of hostel players at a tertiary level differ from other levels such as high school players, Varsity Cup players and senior professional players.

- To determine whether there are any trends in the injury data in relation to the academic calendar.

1.4 Population

All registered male rugby union players at Stellenbosch University who represented residence rugby teams were included in the study. The players participating in the study were 18 years and older. The players were from forty four hostel teams from sixteen residences. There are five divisions in the hostel rugby set up with the first division being the strongest team in each residence.

1.5 Motivation for the study

Injury statistics have been collected at schools, clubs, provincial and national rugby matches but there has been no research done at university level. To date, there is also no clear picture as to whether there are any changes to injury prevalence rates according to the academic calendar. High stress levels around exam time and long university holidays may create an increased risk for injury.

Attending a university requires a certain level of intellectual capability and injuries may have an adverse effect on an individual's academic performance. Injuries like concussion have a direct impact on a student's performance at university. In addition to this, orthopaedic injuries could also have an indirect impact on academic performance and possible employability in the future. University holidays and exams may have an impact on the players' performances and risk of injury due to prolonged periods of rest and high stress levels. University teams are not professional teams which mean they are not as conditioned as provincial or national players. This may well lead to a higher risk for injury in comparison to other players.

Injury surveillance allows for the identification of possible preventable causes of injury in sport. If risk factors are reduced, less injuries are likely to occur which makes more players available to play. An injury cause players to miss training and matches which in turn affects the team's performance. A study done in the UEFA (Union of European Football Associations) Champions League spanning across 11 seasons found that a lower injury burden and a higher match availability was associated with a higher final ranking in the league (Hagglund *et al.*, 2013). In a literature review by Abernethey and Bleakley (2007) it was shown that injuries may also have an impact on future participation in sport. It was reported that 8% of children in Ireland drop out of sport every year due to injury. Orchard *et al.* (2013) performed a very large injury surveillance study on Australian football league players over a 21year period. The results of this study highlighted several common injuries, which brought about several rule changes in the game in order to increase player safety.

The majority of research has been done on professional players and teams; however, they form the minority of the rugby playing population. For instance, in New Zealand, 0.2% of the rugby playing population is professional players (Schneiders *et al.*, 2009). More research needs to be done on the social and amateur players to make appropriate conclusions as to what can be done to prevent injuries in these rugby populations. Professional players have quick access to medical treatment and there is a minimal financial burden placed on the player as the union covers the cost. Social players, such as hostel players, do not have this luxury which may mean they go untreated when injured or their injuries do not heal as well as they should if they were to have full time medical support.

Long-term consequences of major injuries have been investigated and it has been suggested that an individual's job options may be limited which will then affect personal income. Furthermore, personal medical costs are increased as they may need medication or surgeries. Quarrie *et al.* (2002) reported that cervical spine injuries sustained by rugby players may results in death in 5-10% of cases. O'Rourke *et al.* (2007) reported that in general, players who retire from professional rugby are bound to have arthritis or limited joint mobility. Meir *et al.* (1997) investigated the consequences of injuries in rugby league and they found that there are several detrimental effects that may impact on a player, namely, job limitations, reduced income earning potential, and increased personal medical costs.

The effect of concussions has been assessed at college level in several studies and the results generally show that short and long term effects of concussions may become troublesome for players (Hollis *et al.*, 2009; Moser *et al.*, 2005). Moser *et al.* (2005) found that post-concussion symptoms may last up to 1 month after the initial injury. The symptoms include impaired performance on tests of attention, concentration, processing speed, and mental flexibility. They also made an interesting conclusion in that there is no difference in the cognitive performance of athletes who have had 2 or more previous concussions and those who have sustained a concussion in the previous week. Roux *et al.* (1987) investigated the concussion rates in high school rugby players and found that approximately 50% of players had suffered an average of two concussions each during their rugby playing careers at school level. Being diagnosed with a concussion does not necessarily mean that players will take a break from their sport as shown by Sye *et al.* (2006). They reported that only 45% of players who sustained a concussion actually waited for clearance from a medical professional before they returned to play. This places players at a higher risk for a reoccurrence (Brown *et al.*, 2013).

Viljoen and Patricios (2012) found that the tackle and the scrum have resulted in a large number of permanent injuries in rugby, which included neurological deficits, quadriplegia or death. Some of the more common conditions included arthritis, chronic back pain, restricted joint mobility and chronically stiff fingers. Conditions such as osteoarthritis and back pain may inhibit the quality of life as well as affect future career options. Joint replacement/ reconstruction surgery may be necessary at later stages which are a large medical cost and there is a lengthy rehabilitation period where they are unable to work. The level of play and the playing position may have an effect on the long term consequences of major injuries, but further investigation into this matter is needed. Based on the possible deleterious effects of injuries on the academic performance and future employment opportunities of students, it is of paramount importance that the prevention of injuries at this level be prioritised. The implementation of effective preventative strategies can only be achieved through a thorough understanding of the current situation.

Risk factors that affect hostel players may be divided into intrinsic and extrinsic risk factors. Intrinsic factors are related to the physiological and psychosocial characteristics of each individual player, whilst extrinsic factors are factors that may affect the player from the outside such as the environment, the opposition players and protective equipment. Cunniffe *et al.* (2009) have further divided risk factors into modifiable and non-modifiable risk factors, which are explained simply as risk factors that can be affected by prevention programs (modifiable) and those that cannot (non-modifiable). The focus of this study was to identify as many risk factors as possible surrounding hostel rugby so as to provide a foundation from which prevention programs can be developed. These programs will attempt to impact the modifiable risk factors.

Injury surveillance is important in order to assess whether there are any causal links between risk factors and injuries (Schneiders *et al.*, 2009). This study will create a relevant injury database identifying the risk factors to which university level rugby players are exposed to. Possible prevention strategies can then be proposed and further research can be done on the effects of these strategies. Injury incidence has been shown to increase as the level of play increases (Fuller *et al.*, 2008b).

1.6 Terminology

1.6.1 Injury definition

There is an abundance of research done on rugby injuries but the wide variation of definitions and methodologies make it difficult to compare results and the value of individual studies has limited value. The Rugby Injury Consensus Group (RICG) has been established in 2007 by the IRB in order to reach an agreement on the appropriate definitions and methodologies in an attempt to standardise the recording of injuries and reporting of studies in rugby union (Fuller *et al.*, 2007c). The consensus statement was used in this study to make the results comparable to similar studies completed after 2007.

1.6.2 Injury

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 and that was sustained by a player during a rugby match or rugby training, irrespective of the need for medical attention or time-loss from rugby activities. An injury that results in a player receiving medical attention is referred to as a *medical attention injury* and an injury that results in a player being unable to take full part in future rugby training or match play as a *time loss injury* (Fuller *et al.*, 2007c).

In rugby union, non-fatal catastrophic injuries are of particular interest and therefore a third subgroup of reportable injuries was added by the RICG:

A brain or spinal cord injury that results in permanent (>12 months) severe functional disability is referred to as a *non-fatal catastrophic injury*.

1.6.3 Recurrent injury

A recurrent injury is an injury of the same type and at the same site as an index injury (first-time injury) and occurs after a player's full return from the index injury. A recurrent injury occurring within 2 months of a player's return to full participation is referred to as an "early recurrence"; and one occurring 2 to 12 months after a player's return to full participation as a "late recurrence"; and one more than 12 months after a player's return to full participation as a "delayed recurrence" (Fuller *et al.*, 2007c).

1.6.4. Injury severity

Injury severity is defined as 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 were 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.*, 2007c).

1.6.5 Match exposure

Match exposure is defined as play between teams from different clubs (in this case, residence teams). Total match exposure calculations was done using the following formula: $N_MP_MD_M/60$ where N_M is the number of matches played, P_M is the number of players per team and D_M is the duration of the match in minutes (Fuller *et al.*, 2007c).

1.7 Structure of the thesis

Chapter One: Introduction and problem statement: The chapter provides a background to the game of rugby as well as a background on the prevalence and nature of rugby injuries. It also highlights that there is limited research available regarding rugby injuries within the amateur hostel teams.

Chapter Two: Theoretical background. The purpose of this chapter is to summarise the rugby injury research currently available. It also discussed the potential risk factors that may cause injuries.

Chapter Three: Methodology: The chapter describes the method in which the research was conducted and presented. The data capture guidelines that were followed were according to the consensus statement produced by the Rugby Injury Consensus Group (Appendix C) (Fuller *et al.*, 2007c).

Chapter Four: Results: The chapter reports the results obtained from the current study.

Chapter Five: Discussion: The chapter discusses the results found in the current study. The results were compared to previous literature.

Chapter Six: Conclusion, limitations and future research: In summary, through injury surveillance, rugby injuries in the hostel league were assessed and risk factors were identified. This allows for future research to be done on this specific rugby population, especially in the direction of implementing appropriate prevention strategies.

Chapter Seven: References

CHAPTER TWO

THEORETICAL BACKGROUND

2.1 Introduction

This chapter is an account of the current literature regarding rugby injuries. It will also focus specifically on the nature and incidence of rugby injuries whilst explaining various risk factors and current prevention strategies. The nature of injuries refers to the type of injury and what area of the body is affected. The incidence of injuries refers to the rate of the injuries over a specified period of time.

Injuries have a detrimental effect on players' ability to play, study or work (Bailey *et al.*, 2010; Abernathy & McAuley, 2003). Lee *et al.* (2001) claimed that injury was the main reason for players discontinuing rugby. Forty three percent of 911 Scottish Rugby Union club players who stopped playing rugby were injured within a month of their retirement during the 1996/7 season. Ten percent of the players who returned to play participated in a lower league compared to the league they were in prior to their injury. The most common injuries that lead to retirement were dislocation, strain, or sprain injuries to the knee (35% of all injuries), back (14%), shoulder (9%), neck (8%), ankle and foot (8%), and hip and thigh (6%) (Lee *et al.*, 2001).

Rugby injuries may have a negative impact on employment opportunities, family life and health of the player (Fong *et al.*, 2009). Viljoen and Patricios (2012) reported that osteoarthritis and back pain due to previous rugby injuries may inhibit quality of life and also affect career options. Depending on the severity, injuries may hamper a player's performance or exclude them from participation entirely and this may have a negative effect on the team. Minor injuries, such as lacerations and bruises, may have a minimal effect on the player after the game, however, more severe injuries such as concussions, fractures and torn ligaments may impair their ability to perform effectively at their job and other daily activities (Maffuli *et al.* 2010). This study focuses specifically on students at a university who are involved in attending classes and studying for exams. It is postulated that a moderate to severe injury could reduce their ability to perform their academic duties and therefore hamper their progress in their studies. This may cause extra stress on the student, as well as an added financial burden if they end up repeating subjects because of their injuries. A study done in Ireland found that over 80% of sports related injuries in secondary school students required more than analgesics and advice in order to return to their sport (Abernathy & McAuley, 2003). This means extra visits to specialist physicians, physiotherapists, biokineticists or occupational therapists which increases the cost as well as possibly taking away time from class and work in order to attend the sessions.

2.2 Injury surveillance

Injury surveillance is important in order to assess whether there are any causal links between risk factors and injuries (Schneiders *et al.,* 2009; Finch, 2006; McIntosh, 2005). From this information, informed decisions can be made on possible law changes, prevention strategies and coach education programmes.

Prior to 2007, significant findings and interstudy comparisons in rugby injury data were difficult to perform and analyse due to there being no consensus on injury definitions, research methodologies and reporting of results (Bleakely *et al.,* 2011; Bailey *et al.,* 2010; Hermanus *et al.*, 2010; Fuller *et al.,* 2007c). Brooks *et al.* (2005a) found a seemingly high rate of injury in the England rugby team prior and during the 2003 RWC, but attributed this to the very broad definition of injury . This is one example of how non-uniform definitions confounded, and lessen the comparability, of research results.

Within cricket and football recognised injury definitions and injury surveillance methodologies exist which has shown to be successfully implemented (Fuller *et al.,* 2006; Orchard *et al*., 2005)**.** In 2007 the Medical Advisory Committee of the IRB established the Rugby Injury Consensus Group (RICG) and through a process of lengthy discussions and consultations, adapted the football proposal into a rugby union specific consensus statement (Fuller *et al.*, 2007c). This statement produced standardized definitions and methodologies in reporting rugby injuries which allows more accurate trend analysis and comparisons between studies. More detailed information regarding the methods of the RICG's consensus statement will be provided in the Methodology chapter of this thesis.

2.3 Sports injuries

Sport has the advantage of improving physical health and fitness, but injuries are an unfortunate drawback associated with almost every sporting code. Ample research has been done on sporting injuries worldwide in order to assess injuries common to the sport and identify the associated risk factors (Orchard *et al.,* 2013; Orchard *et al.,* 2009; Gabbett, 2008; Hoskins *et al.,* 2006; Junge *et al.,* 2004). This section will highlight previous injury surveillance research from other sports to demonstrate what has been done in various sports. It will also provide a basis for comparison to rugby which will be done more thoroughly later.

Injury surveillance has been done during international soccer events such as the Fédération Internationale de Football Association (FIFA) World Cup and UEFA European Championships. They reported injury surveillance rates of 50.7, 45.9 and 40.1/1000 player hours during the 2002, 2006 and 2010 FIFA World Cups, respectively. The most prevalent injuries were thigh strains and ankle sprains (Dvorak *et al.*, 2011).

Dick *et al. (*2007) examined the injury rates in women's lacrosse at a university level and reported an injury rate of 7.15/1000 player hours. Despite lacrosse being classified as a non-contact sport, the concussion rate in particular was high in comparison to other non-contact sport which was suggested to be due to the nature of the game which includes contact with other players as well as contact between sticks and players. The lower limb was particularly vulnerable in lacrosse, especially ankle sprains (22.6%), internal derangements of the knee (14%) and upper leg muscle strains (7.2%). Of particular importance, 22% of all the injuries were to the head and neck, with concussions making up 9.8% of these injuries.

The typical injury profile in cricket differs to rugby due to the different demands of the game. Research shows that most injuries in cricket are sustained by bowlers (40-45%), fielders (including the wicket keeper) (25-33%) and batsmen (17-21%) (Stretch & Trella, 2012). There was also a difference in injury profile between the types of bowlers, with fast bowlers being more susceptible to lumbar spine, lower limb and shoulder injuries due to the high impact at the crease during the fast bowling action. Spin bowlers, however, use their hands and fingers to affect their bowling action so their most common area of injury during bowling is the fingers (Orchard *et al.*, 2009). A recent study done on 5 international teams in the International Cricket Council (ICC) Cricket World Cup found an injury incidence rate of 3.7/1000 player days, with the rates between bowlers and batsmen being relatively similar (3.3 and 2.2/100 player days, respectively) (Ranson *et al.*, 2013).

2.4 Background on rugby union

Around the world, there are more than 150 countries across 5 continents which are involved in rugby (MacQueen & Dexter, 2010). It is estimated that over 5 million people play the game (Robertson *et al.*, 2014). In South Africa there are approximately 651 146 rugby players who participate at school and club levels (Brown *et al.*, 2013). At senior level, the game is made up of two halves not more than 40 minutes each with not more than a 15 minute interval. At U19 level, each half is 35 minutes, from U16 down to U13, halves are 25 minutes and U12 down to U9 play 20 minutes a half (IRB, 2015). Hostel teams play 25 minutes a half from divisions 2 and below, while division 1 teams play 30 minutes per half. Fifteen players from each team compete against each other to try and score the most points by the end of the game. Seven replacements (sometimes 8 in some competitions) due to injury or tactical purposes are allowed at any time during the match (Quarrie & Hopkins, 2008). During the game, there are four main phases of play, namely, the tackle, ruck and maul, set pieces (scrums and lineouts), and open (or general) play (Kaplan *et al.*, 2008). These phases are further expanded as follows:

"A tackle in rugby is defined as a player being brought to the ground by an opposing player. A ruck occurs when the ball is on the ground and players from the opposing team fight for possession. Mauls are characterized by a ball carrier being held by opposing players, with other players joining the tackle. Scrums occur after infringements and are an organized way for teams to form opposing tunnels. When the scrum is set to begin, the ball is placed in the created tunnel and the teams push each other in attempts to gain possession. Lineouts occur if the ball has left the field of play. Players are lifted in the air in order to attempt to catch the ball." (Kaplan *et al.*, 2008).

2.5 Rugby injuries

Considering that rugby is a full contact sport, it is not surprising that many injuries occur during training or in a game. Injury rates vary according to level of play, with most injuries occurring in professional divisions (68-218 injuries/ 1000 playing hours), followed by senior amateur levels (15-74 injuries/ 1000 playing hours) and school boys (7.0–28 injuries/ 1000 playing hours) (Brooks & Kemp, 2008).

Research over the years have shown that the rate of injuries has progressively increased over time (Brooks & Kemp, 2008; Quarrie & Hopkins, 2007; Quarrie *et al.*, 2007; Bathgate *et al.*, 2002, Garraway *et al.*, 2000). Some of the reasons for this are the increase in professionalism of the game, the higher speed and intensity of play, overtraining, an increase in the body size of players, changes in positional demands as well as an increase in the time which the ball is in play (Sedeuad *et al.*, 2012; Kaplan *et al.*, 2008). The amount of injuries during matches has increased almost two-fold after professionalism of rugby union occurred in 1995 (Alentorn-Geli *et al.*, 2009) due to the games becoming much faster and more physical (Hendricks, 2014). In the 2012 Super Rugby tournament, 25% of the South African players sustained more than one injury (Schwellnus *et al.*, 2014).

The professionalism of rugby has had an effect on coaches and support staff as well. With more money involved, especially when a team is successful, coaches have been afforded more time and resources from their respective unions in order to encourage match-winning performances (Hendricks & Lambert, 2010). Coaches have been able to improve on aspects such as "fitness conditioning, strength and power training, periodization, different ruck and scrum techniques, game strategies, and running lines" which has an effect on the players and the style of game played (Hendricks & Lambert, 2010).

Quarrie *et al.* (2007) found that with the increase in professionalism, several phases of the game have also increased, namely, the time the ball is in play (19%), the number of tries (72%), as well as the number of tackles (51%) and rucks (63%). However, the number of kicks, mauls, scrums and lineouts has decreased significantly. Several law changes have resulted in a transformation in the style of play and by improving the continuity of the game the spectator value has also increased.

2.6 Anatomical locations of injuries

Injuries can occur in almost every area of the body and although there is variation in the research, many authors have highlighted the most common areas (Roberts *et al.*, 2014; Hillhouse, 2014). Most injury research shows that the lower body is most affected by injuries in rugby (Palmer-Green *et al.*, 2013; Williams *et al.*, 2013; Brooks & Kemp, 2008; Brooks *et al.*, 2005; McIntosh, 2005; Bathgate *et al.*, 2002). Brooks and Kemp (2008) found that forward players were more prone to upper body injuries, whilst backs were more prone to lower body injuries. During a tackle the ball-carrier's lower limbs are more susceptible to injury, whilst in the case of the tackler the head is most susceptible (McIntosh *et al.*, 2010b; Carter & Muller, 2008).

Yard and Comstock (2006) performed a longitudinal analysis of all men and women rugby players in the USA (approximately 236 539 players) who presented at hospital emergency departments between 1978 until 2004 in the USA. From 1978 to 2004 most frequently injured sites were the face (20.5%), shoulder (14.1%), head (11.5%) and ankle (9.1%). According to Brooks and Kemp (2008), most rugby literature report the most common areas of injury as being the shoulder, knee, thigh, ankle and head. Brooks *et al.* (2005) found thigh hematomas to be the most common injury in English Premiership rugby, whilst Palmer-Green *et al.* (2013) reported a broader variation in school and academy players which included the ankle, shoulder and knee. According to Van Niekerk and Lynch (2012), shoulder injuries generally make up 6-19% of joint injuries. Brooks *et al.* (2006) reported a hamstring injury rate of 5.6/1000 playing hours in English Premiership Clubs, which is almost double that of semi-professional soccer (3.0/1000 playing hours).

2.7 Phase of play

Injuries can occur in almost every phase of the game, including tackles, rucks, scrums, lineouts and general play. More injuries occur during uncontrolled play such as tackles, whereas set pieces like scrums and lineouts produce fewer injuries (Kaplan *et al.*, 2008). Fuller *et al.* (2007) ranked phases of play according to their risk for injury and found collisions (when the tackler does not use their arm[s] when attempting to stop the ball-carrier) and scrums had the highest risk, followed by tackles and mauls and then lineouts.

Some researchers have divided the injuries according to the phase of play the players were involved in when they were injured. Research shows that at a senior or elite level and depending on the level of play, tackles generally make up the majority of injuries (24-58%), followed by ruck (6–17%), maul (12–16%), collision (8–9%) and scrum (2–8%) (Fuller *et al.*, 2007b; Quarrie *et al.*, 2007). The phases of play have changed over time as the game has evolved with more tackles and rucks and less set pieces occurring but when comparing the phases with their propensity to cause injury, tackles and scrums have the highest risk (Brooks & Kemp, 2008). Williams and McKibbon (1987) analysed spinal injuries in Welsh clubs for over 20 years and found that 40% of the injuries occurred in scrums, with tackles and rucks/mauls making up 30% each.

2.7.1 Scrums

According to IRB laws, a scrum is a method of restarting play after a minor infringement has occurred. A scrum is formed in the field of play when eight players from each team, bound together in three rows for each team, close up with their opponents so that the heads of the front rows are interlocked. This creates a tunnel into which a scrum half throws the ball so that front row players can compete for possession by hooking the ball with either of their feet.

In most research, scrums are the phase of play with the highest incidence of catastrophic neck injuries (Berry *et al.*, 2006). Although spinal cord injuries (SCI's) seemingly occur rarely, they are considered to be the most common causes of morbidity and mortality in rugby (Hermanus *et al.*, 2010). Fuller *et al.* (2007b) found that scrums had a 60% higher injury risk in comparison to tackles when a catastrophic neck injury occurs. Hendricks *et al.* (2014) found that in South Africa, from 2008 to 2013, 33% of all catastrophic injuries occurred in the scrum. Similarly, Berry *et al.* (2006) also found scrums to cause the highest number of spinal cord injuries (SCI's) in rugby in New South Wales from 1986 to 2003. However, more recently, it seems the tackle is responsible for more catastrophic neck injuries (Patricios, 2014; Brown *et al.*, 2013; Kuster *et al.*, 2012; Dunn & van der Spuy, 2010; MacQueen & Dexter, 2010; Shelly *et al.*, 2006). The anatomical design of the cervical vertebra makes this area particularly vulnerable to injury. The area consists of small vertebral bodies, oblique articular facets, weak muscle protection and increased mobility (Shelly *et al.*, 2006). Hermanus *et al.* (2010) reported similar results in a retrospective study done in South Africa from 1980-2007 with 37% of the SCI injuries occurring in club players and 33% in school players.

The scrum is a set piece with several phases controlled by the referee, although the same cannot be said of tackles. Prior to the recent law changes in the scrum engagement sequence, the impact force between the front rows in a typical scrum was extremely high and produced a large amount of injuries (Gianotti *et al.*, 2008; Fuller *et al.*, 2007b). In the 1970s there was an increase in deliberate collapsing of scrums and rucks which resulted in an unnecessarily large pile-up of players that put the players under a higher risk of SCI's (Williams & McKibben, 1987). In this era, the occurrence of SCI's in scrums ranged from 35% to 44% of all rugby injuries in the greater rugby union nations such as New Zealand, England and South Africa (Silver, 1984; Burry & Gowland, 1981; Scher, 1977). SCI rates have increased in South Africa specifically and rugby remains the sport responsible for the highest amount of SCI's across all sport in SA. The SCI rate in SA is, however, lower than that of Australia and New Zealand (Hermanus *et al.*, 2010). The recent law changes involving the scrum engagement sequence ("crouch-bind-set" instead of "crouch-touch-set") has been shown to reduce the risk of injury during scrummaging by decreasing the impact forces on the engagement, as well as improving the stability of the set piece (Cazzola *et al.*, 2014). These law changes are probably responsible for the decreased number of injuries during this phase of play.

The two most common mechanisms of injury within the scrum occur during the scrum engagement and the scrum collapse (Kuster *et al.*, 2012; MacQueen & Dexter, 2010). Scrum engagement and collapse place excessive stress on the heads and necks of the front row players with the most common resulting injury being facet dislocations of the motion segments between C4/5 and C5/6 (Kuster *et al.*, 2012). Brown *et al.* (2013) reported that of all the scrum injuries at all levels of play in South Africa during 2008 to 2011, 56% occurred during the scrum engagement and 39% occurred when the scrum collapsed. Taylor *et al.* (2014) analysed English professional rugby over a season (2011-2012) and found that 31% of scrums result in a collapse and the injury rate is double in a collapse as opposed to a typical scrum (8.6% vs. 4.1%). Roberts *et al.* (2014) reported a much lower collapse rate (5%) in English community-level rugby matches over 3 seasons, but found the incidence rate was four times greater than non-collapsed scrums and six times more severe. The abovementioned evidence therefore reflects the recent law changes, as well as continued focus from the IRB and referees to reduce scrum collapses.

Hyperflexion (with or without rotation) and hyperextension are the two main mechanisms of injury to the cervical vertebra (Kuster *et al.*, 2014; Naish *et al.*, 2013, Fuller *et al.*, 2007b; Quarrie *et al.*, 2002). Hyperflexion occurs when *"a force is exerted through the vertex of the head and transmitted through the skull to the cervical vertebrae"* (Shelly, 2006). This causes the vertebra to be crushed and posterior protrusion or dislocation of the vertebral disc and body (most commonly C4-C5 or C5-C6) may occur. Hyperflexion normally occurs when a scrum has collapsed and the forward pack continues to push forward while the front row's heads are trapped against the ground (Kuster *et al.*, 2012; Shelly *et al.*, 2006).

During a scrum engagement, the most typical injury of the neck is hyperextension (MacQueen & Dexter, 2010). When the front rows charge into each other on the scrum engagement and the players' heads are not aligned correctly, hyperextension of the cervical vertebra may occur. The spinal cord is at risk of being seriously damaged when this occurs because hyperextension causes narrowing of the spinal canal. The posterior portions of the vertebra may fracture and impingement may occur (MacQueen & Dexter, 2010). Kuster *et al.*

(2012) recently argued that "buckling" of the cervical vertebra was the main mechanism of SCI's rather than hyperflexion or hyperextension. Buckling occurs when the cervical vertebra undergoes flexion in one area and extension in another when it is placed under extreme axial compression. According to Browne (2006), spear tackles in children younger than 15 years old who presented at the Children's Hospital in Westemead, Sydney, between 2000 and 2003 are responsible for approximately one third of the SCI injuries caused by hyperextension in rugby. Patricios (2014) reported that SCI's have a significant impact on physical, emotional and financial well-being due to the severity of the injury.

2.7.2 Lineouts

A lineout is a method of restarting play once the ball has left the field of play and the forwards from each team stand in two parallel lines to compete for the ball. They do this by lifting their teammates into the air as the hooker throws the ball from the touchline. The main mechanism of injury during the lineout is when the jumper (the player being lifted) falls from a significant height, either because he was dropped by his teammates or pulled down by the opposition (MacQueen & Dexter, 2010; Fuller *et al.*, 2007b). Posthumus and Viljoen (2008) found cervical and lumbar facet joint injuries to be prevalent in lineouts due to players being lifted and dropped without control of the supporting players. Robertson *et al.* (2014) reported a high number of clavicle fractures amongst locks who were dropped in the lineout.

According to Fuller *et al.* (2007b) the risk of injury during a lineout is very low when compared to other phases of play. There is minimal research which reports injuries specific to the lineout and those that do, find few to no injuries during this phase of play (Bathgate *et al.*, 2002, Hughes & Fricker, 1994). Fuller *et al.* (2009) reported injury rates in the lineout across several competitions (English Premiership, 2007 RWC, Super 14 and Vodacom Cup) and found lineouts to have the lowest injury rates compared to all other phases of play (0.8, 0.8, 0.7 and 3.1/1000 playing hours, respectively). Similarly, Fuller *et al.* (2007b) found a very low injury rate (0.9/1000 playing hours) during lineouts in 13 English Premiership clubs over two seasons. Interestingly, a study by Sankey *et al.* (2008) was performed on 12 English Premiership clubs over two seasons and they reported that 40% of ankle injuries that occurred during the matches occurred during the lineout.

2.7.3 Tackle

A tackle as defined by the IRB is *"when a ball carrier (a player carrying the ball) is held by one or more opponents and is brought to ground. The opposition player that goes to ground with the ball carrier is referred to as the tackler*" (IRB, 2015). Players tackle the ball carrier with the intention of preventing the attacking team from gaining territory or scoring points (Hendricks & Lamert, 2010). For the purposes of research, especially injury surveillance research, tackles have been categorised into the direction in which the tackler made contact with the ball carrier and in what manner this contact was made. Hendricks and Lambert (2014) have classified the tackles as follows:

Table 2.1: Types of tackles and definitions (Hendricks & Lambert, 2014)

Type of tackle:	Definition:
Arm tackle	The tackler impedes/stop the ball-carrier by using the upper limbs
Collision tackle	Tackler impedes/stops ball-carrier without the use of arm(s)
Jersey tackle	Tackler holds the jersey of the ball-carrier
Lift tackle	Raises ball-carrier's hips above the ball-carriers head
Shoulder tackle	Tackler impedes/stops ball-carrier with shoulder as the first point of contact followed by the use of his arm(s)
Smother tackle	Tackler uses chest and wraps both arms around ball-carrier
Tap tackle	Tackler trips ball-carrier using a hand on either lower limb (below the knee) of the ball-carrier
Situational tackle	Tackler assesses the situation and attempts a tackle
Goal line tackle	Tackler defends his goal-line

The number of tackles in a game rose substantially once rugby became professional (Hendricks & Lambert, 2014). As mentioned previously tackles have one of the highest injury rates in rugby (Fuller *et al.*, 2013; Palmer-Green *et al.*, 2013; Fuller *et al.*, 2011; Usman *et al.*, 2011; Headey *et al.*, 2007). Some research is contradictory as to which player carries the highest injury risk; the tackler or the player being tackled. Most research points to the latter as having the most risk (Schneiders *et al.*, 2009; Kaplan *et al.*, 2008; Brooks *et al.*, 2005).

Ball carriers who are tackled from the side had higher injury rates (51%) compared to being tackled front-on (34%) (Brooks *et al.,* 2005). Roberts *et al.* (2014) found that the ball carrier had a higher injury rate (4.8/1000 playing hours) compared to the tackler (3.6/1000 playing hours) in English community rugby. Best *et al.* (2005) found that more injuries occurred when being tackled (21%) as opposed to tackling (10%) during the 2003 RWC. McIntosh *et al.* (2010b) found a significantly higher injury rate when two tacklers were involved. Other forms of tackling could also be injurious. McIntosh *et al.* (2010b) highlighted the ankle tap as a type of tackle that causes a high number of injuries. An ankle tap is when a player dives and taps the ball carrier's ankle or foot which causes them to fall. If the ankle tap is successful the ball carrier trips and falls at high speed which is potentially very injurious.

Various risk factors for tackle injuries have been proposed in the research. According to Hendricks and Lambert (2010), the ball carrier is most at risk for injury when they are tackled very low or high, if the tackler loads their body weight onto the ball carrier, or from being tackled from behind. On the other hand, tacklers are most at risk for injury when they attempt to tackle too low and make contact with the ball carrier's moving legs. McIntosh *et al.* (2010b) highlighted the speed of the players, head/ neck contact as well as front-on tackles and side-on tackles as risk factors for tackle injuries (McIntosh *et al.,* 2010b). Quarrie and Hopkins (2008) highlighted the difference in direction and application of the transfer of energy as being the main factor for these differences. They found that sprinting produced three to five times more injuries than low speed movement. According to Usman *et al.* (2011) the shoulder force vector exerted by the tackler, which is a combination of the line of action and the magnitude of the impact, determines whether they knock the ball-carrier backwards, lift them or if they themselves get knocked backwards, which may have an effect on whether the ball carrier or tackler sustains an injury. Brooks *et al.* (2005) found that tacklers migh higher injury rates when making a head-on tackle (56%) as opposed to side-on tackles (38%).

Usman *et al.* (2011) reported 195 tackles per game in non-professional divisions and between 142 and 166 tackles per hour in professional matches. This is a significant number and it is understandable why so many injuries occur in this phase of play. Fuller *et al.* (2007b) also found a high number of tackle events in English Premiership club matches with an average of 221 per game.

Good technique dictates that a tackle be executed by using the shoulder, neck and arm region. However, this means that there is a significant force placed on this area when a player tackles another player or when they make contact with the ground (Ogaki *et al.*, 2014). De Beer and Bhatia (2009) have categorized various shoulder injuries specific to rugby according to the type of injury and have explained the mechanisms associated with these injuries. Commonly, shoulder injuries associated with the tackle occur at the acromioclavicular (AC) joint, the rotator cuff muscles, the glenohumeral joint as well as the soft tissue around the joint. The shoulder is particularly vulnerable because of its construction. In addition, the movements and forces that cause injuries to the shoulder are very common movements performed in accordance to the demands of the game. Tackling requires the player to lead with the shoulder and make contact with another player with the arm outstretched. Being tackled often causes the player to land directly on the shoulder causing anything from mild bruising to fractures and dislocations of shoulder joints. With respect to the shoulder, Brooks and Kemp (2008) noted that tackles were responsible for the most common high risk injuries such as dislocation and "episodes of shoulder instability". In addition, according to Brooks and Kemp (2008), the tackle was also responsible for other serious injuries such as anterior cruciate ligament (ACL) injuries, medial collateral ligament (MCL) injuries, chondral or meniscal injuries of the knee and concussions.

As mentioned previously, the tackle has been shown to be responsible for most SCI's (Brown *et al.*, 2013; Kuster *et al.*, 2012; Dunn & van der Spuy, 2010; MacQueen & Dexter, 2010; Shelly *et al.*, 2006). According to Hermanus *et al.* (2010) 45% of SCI's occurred during the tackle (28% whilst being tackled) and 37% occurred in the scrum. Hyperflexion of the neck is the main mechanism for cervical spine injuries in tackles and often causes fracture dislocations of C4-C5 or C5-C6 (MacQueen & Dexter, 2010; Shelly *et al.*, 2006; Scher, 1998). According to McIntosh *et al.* (2010b), high and spear tackles are responsible for catastophic cervical spine injuries and SCI's. A spear tackle is "when the ball carrier is inverted and driven head first into the ground" (McIntosh *et al.*, 2010b). Spinal injuries are an unfortunate and tragic occurrence on the rugby field. There is also a difference in incidence rates between levels of play with Hermanus *et al.* (2010) reported similar results in a retrospective study done in South Africa from 1980-2007 with 37% of the SCI injuries being club players and 33% being school players.

2.7.4 Rucks and mauls

A ruck is defined as a phase of play where one or more players from each team, who are on their feet, in physical contact, close around the ball on the ground (IRB, 2015). There are a substantial number of rucks that occur during the game as teams generally set these phases of play up in order to protect the ball after their player has been tackled. According to Fuller *et al.* (2007b), the number of rucks is second to tackles with 142.5 rucks per match in the English Premiership club season. Brooks and Kemp (2008) reported that the number of rucks has increased by 63% since the professionalism of rugby, which supports the notion that teams train and plan ruck plays in order to protect the ball as much as possible. Conversely, Kraak and Welman (2014) reported that the top three teams in the 2010 Six Nations Championship set up less rucks when compared to the bottom three teams. A suggestion into the style of play can be made in that more skilful teams are able to pass the ball around successfully, whereas the lower skilled teams prefer to keep the ball close and set up a slower game.

A maul occurs when a player who is carrying the ball is held by one or more opponents, and one or more of the ball carrier's team mates bind on the ball carrier (IRB, 2015). Mauls are a method of maintaining possession of the ball whilst gaining territory and the general trend by teams is to set up the maul from a lineout, especially near the goal line. The number of mauls has decreased by 25% since the introduction of professionalism of rugby (Brooks & Kemp, 2008); however, more recently, teams, like the more physical Springboks, have placed a lot of emphasis on maul formation and effectiveness because it is difficult to defend against. Injury risk increases when the maul is collapsed, as shown by Fuller *et al.* (2007b), with 12 out of the 21 maul injuries in English Premiership club rugby occurring when the maul collapsed.

2.7.5 Foul play

According to the IRB definition foul play is *"anything a player does within the playing enclosure that is against the letter and spirit of the laws of the game. It includes obstruction, unfair play, repeated infringements, dangerous play and misconduct which are prejudicial to the game"* (IRB, 2015). In recent years, the IRB have been very strict regarding scrum and tackle regulations due to the high injury rate involved in these phases of play (Gianotti *et al.*, 2008).

Several types of tackles have been highlighted as high injury risk, namely high and dangerous tackles and spear/tip tackles. High tackles occur when the tackler tackles the ball carrier above the line of the shoulders. The spear tackle occurs when *"the ball carrier is inverted and driven head first into the ground"* which puts the tackled player in a vulnerable position (IRB, 2015). It has been an area of great concern for the IRB and referees and has since been banned due to its propensity to cause severe injuries (Noakes & Draper, 2007). One would assume that most injuries are caused due to illegal tackles such as those mentioned above, but research actually shows that tackles to the lower limbs may cause more injuries (Fuller *et al.*, 2010). However, this may also be due to the higher occurrence of low tackles in comparison to high tackles.

Brooks *et al.* (2005) found that only 6% of injuries in 12 English Premiership clubs across two seasons were due to foul play. Hermanus *et al.* (2010) investigated SCI's and found that 16% of these injuries were due to foul play. Dunn and Van der Spuy (2010) found an even higher injury rate (39%) of spinal cord injuries due to foul play across all levels of rugby in the Western Cape from 2003-2008. Kemp *et al.* (2008) found that foul play caused 17% of all the match injuries in 13 English Premiership Clubs across 3 seasons.

2.7.6 General play

During general play, players execute physical movements such as running with and without the ball, sidestepping opponents and kicking the ball. During these actions the muscles and joints are under variable stresses. Roberts *et al.* (2013) found that running had the highest injury rate within the non-contact injuries, followed by twisting/turning actions that contributed to injuries.

Hamstring injuries are the most common muscle strains in many sports and the mechanism of injury as well as the risk factors has been thoroughly debated in the research (Mendiguchia *et al.*, 2012; Brooks *et al.*, 2006). Brooks *et al.* (2006) analyzed hamstring injuries in 546 players from 12 English Premiership rugby clubs over the 2002 to 2004 seasons and found that 122 of those players sustained at least one hamstring injury. Most hamstring injuries occurred during running and kicking, with the kicking injuries being more severe. The mechanism of injury includes *"sprinting, high-intensity running, stopping, starting, quick changes of direction, and kicking"* (IRB, 2015). Backs are more prone to hamstring injuries because of their positional demands, which means they perform more sprinting and experience higher running loads (Roberts *et al.*, 2014).

Another common non-contact injury occurring in general play is lateral ankle sprains which are caused by a quick change of direction when running with or without the ball (Brooks & Kemp, 2008). Sankey *et al.* (2008) estimated that between 8-20% of all injuries in rugby union are ankle injuries. The researchers assessed 12 English Premiership Clubs over 2 seasons and found that 52% of ankle injuries are caused in contact situations and 35% are non-contact injuries. The majority of the injuries were lateral ankle sprains and Achilles tendon pathologies.

2.8 Types of injuries

2.8.1 Fractures

Fractures are unfortunate injuries that occur in rugby due to the high force contact situations, such as tackles, which overloads the capacity of the bones. In a recent study by Robertson *et al.* (2014), rugby ranked second highest in terms of the frequency of fractures in sport. The study assessed the number of fractures in all rugby union matches during the 2007/2008 season in Edinburgh, Mid and East Lothian populations and found that there were 120 upper limb fractures and 25 lower limb fractures. The tackle was responsible for all lower limb fractures and the tackled player was found to be the most vulnerable. An interesting finding was that low-level amateur rugby was associated with 40% of all of the rugby-related fractures, followed by school level rugby (33%), high level amateur level (15%), social (6%), professional (4%) and semi-professional rugby (3%).

Lark and McCarthy (2010) have highlighted injuries such as “stingers” and “burners” as a cause for transient neuropraxia, which reduces the cervical range of motion (especially lateral flexion) and places the player at an increased risk of injury. Robertson *et al.* (2014) found that players with previous fracture injuries had symptoms of fracture site pain (72%), stiffness of an adjacent joint (45%) and weakness of grip (27%). Some also experienced persisting symptoms (32%), for up to 4 years post-injury. Despite these problems, only 11 of the players’ symptoms had an effect on their ability to play. Forty two percent (42%) of players that did not return to rugby post-injury cited fear of re-fracture as the reason for not playing anymore.

2.8.2 Musculotendinous, joint and ligament injuries

Soft tissue injuries, which include musculotendinous and joint ligament injuries, tend to be some of the most prevalent injuries in rugby, with soft tissue injuries accounting for up to 50% of all injuries (Schneiders *et al.,* 2009; Kaplan *et al.*, 2008; Bathgate *et al.*, 2002). These injuries may either be caused by contact or non-contact mechanisms.

Fuller *et al.* (2008) found that the most common injuries during the 2007 RWC were lower limb muscle and ligament injuries. Brooks *et al.* (2005) found that muscle and tendon injuries (50%), as well as joint and ligament injuries (41%) made up the bulk of the injuries within the England squad during and prior to the 2003 RWC.

Previous muscle, ligament or tendon injuries may cause a degenerative condition later in life. Athletes who have had meniscal lesions or ACL replacements are at greater risk for developing osteoarthritis (Maffuli *et al.*, 2010).

2.8.3 Head injuries

Lacerations, epistaxis (nose bleeds) and concussions are very common injuries on the rugby field, especially considering there is a high rate of collisions with solid objects, such as studs of boots, elbows, knees, and heads of players (Schneiders *et al.*, 2009; Brooks & Kemp, 2008). In previous research, lacerations were included within the head injuries despite their mild severity. More recently, however, they have been excluded from injury analysis because minimal to no playing time was lost by players due to these types of injuries. Best *et al.* (2005) reported that 42% of all the injuries during the 2003 RWC were open wounds, lacerations or contusions, of which 92% of these were to the head and face.

Research describes the tackle as being the main cause of concussions in rugby (Patricios *et al.*, 2010; McIntosh & McCrory, 2005). Patricios *et al.* (2010) defined concussion as a *"trauma-induced change in mental state that may or may not involve loss of consciousness"*. Sye *et al.* (2006) reported that a player's memory and attention may be affected by concussions. Concussion rates may be seen to have increased over the years, but one must also take into account the increased awareness regarding concussions in sport. With there being a lot of attention on concussions by referees, medical professionals involved in rugby and rugby unions, regulations such as on-field concussion tests and concussion protocols have been introduced which may have led to many more concussions being identified (Schneider *et al.*, 2013).

The definition of concussion according to the consensus statement at the 4th International Conference on Concussion in Sport (2013):

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

1. Concussion may be caused either by a direct blow to the head, face, neck or elsewhere on the body with an ‘‘impulsive’ force transmitted to the head.

2. Concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously. However, in some cases, symptoms and signs may evolve over a number of minutes to hours.

3. Concussion may result in neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury and, as such, no abnormality is seen on standard structural neuroimaging studies.

4. Concussion results in a graded set of clinical symptoms that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course. However, it is important to note that in some cases symptoms may be prolonged” (McCrory *et al.*, 2013).

In the 2003 RWC only 2% of the total injuries reported were concussions (Best *et al.*, 2005). McIntosh *et al.* (2010a) reported 199 concussions amongst 1159 junior players over two seasons in New South Wales. Haseler *et al.* (2010) examined English community rugby and found a concussion rate of 1.8/1000 player hours. In New Zealand amateur rugby the rate was 11/1000 player hours which is significantly higher than previous studies done across the world (King *et al.*, 2013). Fuller *et al.* (2015) reported on concussion in major tournaments such as the Junior and Senior RWC as well as the 7‘s World Series between 2007 and 2013 and found that more concussions occurred in professional 7's matches as opposed to 15's matches. Shuttleworth-Edwards *et al.* (2008) found that the concussion rate was 4-14% in high school players and 3-23% in adult players.

Gardner *et al.* (2014) published a review of the current literature on concussions in rugby. Elite players had the lowest concussion rate (0.40/1000 playing hours), followed by women's rugby (0.55/1000 playing hours) and school boy rugby (0.62/1000 playing hours). Men's 7's rugby (3.01/1000 playing hours) and community level players (2.08/1000 playing hours) had the highest concussion rates.

Concussions during the tackle phase usually occur in head-on tackles and research by Kemp *et al.* (2008) shows that both the tackler and ball-carrier had a high rate of concussions (28% and 19%, respectively) and that midfield backs (centres) were the most prone to concussions. Fuller *et al.* (2010d) supported these findings that in general, centres were more prone to concussions in the tackle and hypothesized that this was due to them travelling at high speeds, high impact within tackles, head/neck contact between the ball carrier and tackler,or tackling the lower limbs of the ball carrier.

The prevalence of concussions has increased slightly over the years, however, the reasons for this may not necessarily be due to the game itself. There has been an increase in research into the occurrence and characteristics of concussions and on the improvement of the management of concussions which may have created a greater awareness. This means that team medical staff has tended to be overcautious and are better able to identify and manage players with concussions (Orchard *et al.*, 2013).

Concussions have short-term and long-term effects for players. Directly after the concussion, players may struggle with a range of physical, cognitive, emotional and sleep-related symptoms such as, headaches, dizziness, nausea, visual disturbances, amnesia, poor concentration, irritability, depression, fatigue and drowsiness (Patrizios *et al.*, 2010). Moser *et al.* (2005) reported that attention and concentration was significantly worse when compared to players without a concussion. What was interesting to note was players that had two or more previous concussions obtained similar results on the cognitive test involving attention, concentration, processing speed and mental flexibility, than those with a recent concussion.

If players are not assessed and monitored correctly or if they return too soon to playing after a concussion, they may be at risk of further complications (Patricios, 2014; Moser *et al.*, 2005). Second Impact Syndrome occurs if players return to play too soon following a minor concussion and receive a further blow to the head which causes diffuse cerebral edema (Patricios, 2014). This means that there is additional swelling and the brain may become unable to control blood inflow. The pressure within the cranial cavity increases substantially due to the increased cerebral blood flow. This may be a possible fatal condition as players may go in to cardiorespiratory failure (Moser *et al.*, 2005).

2.9 Injury severity

The severity of injuries in rugby ranges from very mild, to moderate, to severe, and even catastrophic depending on the number of training days missed. Brooks *et al.* (2005) found that at least 18% of the squad were unavailable due to injuries sustained during matches each week in the English Premiership seasons between 2002 and 2004. The same researchers also assessed training injuries and found a further 5% of players were unavailable to play due to injuries sustained during matches.

The rates of returning to play after an injury vary according to the competition levels. As the level becomes more professional so the return rate increases. Professional players had a 100% return rate to the same level of play in comparison to amateur and school boy players which were 78% and 93%, respectively (Robertson *et al.*, 2014). With that being said, the differences were not statistically significant but it can be suggested that professional players have better medical resources and more financial support in comparison to lower level players (Robertson *et al.*, 2014).

In previous research, injury severity has been found to differ between the upper body and lower body. Brooks and Kemp (2008) analysed the trends in rugby and found that lower limb injuries tended to result in the most number of days lost, whilst Brooks *et al.* (2005) found upper body injuries to be more severe resulting in more days lost than any other injuries. McIntosh (2005) reviewed the injury surveillance literature on junior rugby players at the University of New South Wales and found upper body injuries to be more severe.

Types of injuries require different periods of recovery, with fractures resulting in the most time lost (Robertson *et al.*, 2014). The researchers reported that it took a total of 12 months for all of the players to return to play after a fracture injury. The nature of a fracture means an increased recovery time due to the need for proper bone healing. ACL injuries in the knee have also been shown to have the highest injury severity. Dallalana *et al.* (2007) reported up to 255 days missed for players from 12 English Premiership clubs across 2 seasons that tore their ACL. Furthermore, 2 out of 3 players who retired from rugby after their injury suffered ACL tears. Other types of injuries that cause retirement are SCI's and other traumatic brain injuries. SCI's may have a low injury rate when compared to other types of injuries, but they are also responsible for most playing days missed as well as early retirement. A study done by Brooks *et al.* (2005) on 546 professional rugby players found that 4037 training and match hours were lost over 2 seasons due to SCI's out of a possible 16,782 hours during matches and 196,409 during training.

Abernethy and MacAuley (2003) measured the severity of the injuries of secondary school students at the emergency department in Ulster (Ireland). The authors estimated how much sports participation time would be lost due to the injury as a measure of the severity of the injury. Only 12% of the pupils returned to sport immediately, it took 71% of the pupils at least 3 weeks to return to sport and 2.7% of the pupils needed 8 weeks to return to sport, which is considerable. On the academic side, 41.3% of children presenting at the emergency department as a result of sporting injuries did not miss any days of school, however, 58.7% missed entire school days or part of the school day. Due to the fact that the injured players were still minors, there was a heavy reliance on parents and other family members to miss work to transport the children and take care of them.

2.10 Current magnitude

The level of play has a significant effect on injury incidence rates, with the professional contingent yielding the highest rates (Viljoen *et al*., 2009; Kaplan *et al.*, 2008; Brooks & Kemp, 2008). Viljoen *et al.* (2009) proposed that the reasons for the increased injury incidence rates among professional players were their increased size and speed, which resulted in higher impact forces between players during collisions. There are differences in the rugby playing populations in other divisions such as club and school levels. The following paragraphs describe the injury rates across the different levels of play.

2.10.1 Professional

Jakoet and Noakes (1997) analysed the 16 teams participating in the 1995 RWC and found a total of 70 injuries during the tournament which corresponds to an injury rate of 32/1000 player hours. During the 2003 RWC, there was a total of 189 injuries recorded over 48 matches which corresponded to 97.9/1000 player hours (Best *et al.*, 2005). The 2007 RWC injury surveillance study revealed a slightly lower injury incidence rate of 83.9/1000 player hours. This decrease could possibly be explained by an increased awareness of injury prevention as well as improvements in the conditioning programs of players. However, it may also be reflective of the standardisation of injury surveillance research in rugby proposed by RICG (Fuller *et al.*, 2007c). In the 1995 and 2003 tournaments, match-day laceration/blood injuries were included as injuries, whereas in the later tournaments, some were excluded due to more precise classifications (Fuller *et al.*, 2008). During the 2011 RWC a similar number of injuries to that observed in the 2007 RWC were reported and corresponded to a match incidence rate of 89.1/1000 player hours. The 2006 Women's RWC was the first study to report on injuries in women's international rugby and they found a significant injury rate of 45 injuries occurring during matches at the tournament which corresponds to 37.5/1000 player hours (Schick *et al.*, 2008).

In the 1995 RWC there was a significant difference in injury rate between the non-finalist teams and the finalist teams, with the final round matches producing more injuries (43/ 1000 player hours) compared to the preliminary matches (30/1000 player hours). The opposite was however true during the 2003 RWC with the 8 finalist teams experiencing a significantly lower injury rate than the 12 non-finalist teams (72.7/ 1000 player hours vs. 103.1/ 1000 player hours).

In the 1999 Super 12 competition, Holtzhausen *et al.* (2006) assessed three out of the four South African teams and found an injury rate of 55.4/1000 player hours over the 14 weeks. This correlates to 62 injuries in 48 players which are very high. During the 2012 Super Rugby tournament, the injury rate increased to 83.3/1000 playing hours (Schwellnus *et al.*, 2014). Bathgate *et al.* (2002) focused specifically on injury rates within the Australian Wallaby Team from 1994 to 2000 and found an injury rate of 67/1000 player hours which correlates to 143 injuries in 91 matches. What was interesting to note was the increase in injuries in the Australian Wallaby Team from 47/1000 player hours to 74/1000 player hours in the seasons before and after rugby became professional.

2.10.2 Amateur/Club

Roberts *et al.* (2014) examined the injury rates between semi-professional teams, amateur teams and recreational/social teams during 3 seasons (2009-2012) and found that the amateur teams had a lower injury rate (16.6/1000 player hours) in comparison to semi-professional teams (21.7/1000 player hours), but a higher injury rate than the recreational/ social teams (14.2/1000 player hours). They attributed differences in physical conditioning and skill ability as possible reasons for these differences.

2.10.3 Schools

Most research shows that injuries at school level are lower than senior rugby (Palmer-Green *et al.*, 2013; Haseler *et al.*, 2010; McIntosh *et al.*, 2010a). Brooks and Kemp (2008) found that junior players had similar injury rates when compared to senior players with the difference that they were more prone to upper limb injuries.

Abernethy and MacAuley (2003) examined injuries in 11 to 18-year olds who presented at the emergency department in Ulster (Ireland). Sports injuries represented over half of the total amount of injuries for this age group and rugby was the sport with the highest percentage of injuries (43%). Palmer-Green *et al.* (2013) found an injury rate of 35/ 1000 player hours across two seasons in seven schools in England. The majority of injuries occurred in the tackle (57%) and the lower limb was most affected.

McIntosh *et al.* (2010b) used video analysis to analyze tackle technique from junior to senior level players in 77 games from the Rugby Union Injury Surveillance Study cohort in Australia. They found that the older the player, the more active shoulder tackles and smother tackles (tackler engages the ball carrier with his arms wrapped around the ball carrier and traps the ball) occurred. Younger players tended to stay on their feet and engage in a more passive tackle (tackler's shoulder was the first point of contact, no leg drive is present, no forward momentum gained) (McIntosh *et al.*, 2010b). The authors also concluded that school boy rugby is much safer than senior rugby due to the difference in tackle technique.

2.10.4 Sevens rugby

Sevens rugby is a similar but faster format of the game of rugby. It is played on a standard 15-a-side rugby field, with seven players from 2 teams competing for two 7-minute halves (Fuller *et al.*, 2010c). Although the matches are shorter, sevens tournaments require that several matches be played on one day, so fatigue becomes a factor in a player's susceptibility for injury. Taylor *et al.* (2010) analysed the 2008/2009 IRB World Sevens Series and the IRB Sevens Rugby World Cup. They found an injury incidence rate of 106.2/1000 player hours which is significantly higher than in 15-a-side international tournaments. Lopez *et al.* (2012) analysed injuries in 4 amateur one day tournaments in the USA and found an injury rate of 55.4/1000 player hours. The most common injuries were ligament sprains and concussions. Other studies have been done on sevens rugby league tournaments in New Zealand and similar results and conclusions were found (King *et al.*, 2006). The research thus indicates that sevens rugby league reports more injuries in comparison to 15-a-side rugby. Possible reasons for this difference are that sevens is played at a higher intensity in comparison to 15-a-side and they also play several matches each day during 2/3 day tournaments, so fatigue may have a bigger effect.

2.10.5 Gender differences

Although there has been minimal research done on women's rugby, some comparisons may be drawn from the available literature. Peck *et al.* (2013) assessed the injury rates over 5 years between male and female American intercollegiate rugby players. It was found that the injury rate in men was 30% higher than in women and that the anatomical location of the injuries is different between the sexes. Women were 5.3 times more prone to ACL injury, whilst men were 2.5 times more likely to sustain a fracture. Another significant finding was the differences in the number of open wounds, with men having an injury rate of 6.6 times higher than women. One of the main reasons that had been proposed for the disparity in the data is due to the differences in the style of play. A reason specific to America is that the men may come from American football backgrounds where physical contact is also one of the main aspects of the game to which women may not be as experienced in.

2.10.6 Injury rates specific to South Africa

According to Posthumus and Viljoen (2008), rugby has a higher injury incidence rate (218 and 120/1000 player hours for international and club rugby, respectively) compared to other team sports in South Africa. Soccer and cricket hardly compare, with incidence rates of 42 and 26/1000 player hours, respectively.

Holtzhausen *et al.* (2006) reported a high injury rate (55.5/ 1000 player hours) amongst the South African players in the Super 12 competition. The results were similar to that of other international studies in that ligament sprains and musculotendinous injuries were the most common injuries. What was interesting to note was the pelvis and hip being named as the most common injury site (19.3%), followed by the knee and head (12.9%). In South Africa, it was found that the tackle and scrum are responsible for 78% of all serious and catastrophic head, neck and spine injuries (Viljoen & Patricios, 2012).

The nature of rugby injuries may differ across countries due to the diverse styles of play, especially between the Northern and Southern hemispheres. Each hemisphere may interpret the laws differently and weather and ground conditions may mean different game plans are adopted. English premiership clubs have a slightly higher injury rate of 91/ 1000 player hours over two seasons (Brooks *et al.*, 2005) compared to South African Super Rugby injury rates of 83.3/ 1000 playing hours (Schwellness *et al.*, 2014).

2.11 Risk factors

Several general risk factors have been identified in the literature that increases the risk for injury in rugby. These risk factors are age, skill, body mass index (BMI), playing experience, protective equipment (scrum caps/ shoulder pads/ mouthguards), previous injury, playing position and level of play/ competition (Brown *et al.*, 2012; Usman *et al.*, 2011). Further risk factors include the time within the match (first half/ second half) and the season, the environmental conditions in which the game is being played in and the psychological stress level of the players (Van Niekerk & Lynch, 2012; Fuller *et al.*, 2010; Dallalana *et al.*, 2007). Kaplan *et al.* (2008) reported that high forces experienced by players during physical contact will increase the risk for injury. However; the intensity of the physical contact as well as the speed of players will vary according to the level of players which therefore affects injury rates.

Since tackle situations lead to the highest injury rate, several authors have identified tackle-specific risk factors. Fuller *et al.* (2010d) emphasized "playing position; player's speed, impact force, head position, head/neck flexion and body region struck in the tackle; sequence, direction and type of tackle". Similar risk factors were noted by Usman *et al.* (2011). They also added level of play, number of tacklers and high tacklers as risk factors. McIntosh *et al.* (2010a) and Quarrie and Hopkins (2008) specified two risk factors for spinal injuries in rugby, namely tackles to the actual head/ neck region and double tackles.

2.11.1 Positional differences

Different playing positions demand diverse physiological and anthropometric characteristics from the players and also produce different types and number of injuries (Kaplan *et al.*, 2008). Forwards are generally heavier and stronger as they are involved in scrums and lineouts, as well as plenty of close range contact in the rucks and mauls (Kaplan *et al.*, 2008). Their increased size also allow for increased force generation and absorption of greater impacts (Sedeaud *et al.*, 2012). Backs tend to be more agile and fast because they are involved in more running and open play (Kaplan *et al.*, 2008). Brooks and Kemp (2008) suggested that forwards tend to sustain more upper body injuries, whilst backs sustain more lower body injuries.

There has been an increase in the size of players over time (Lombard *et al.* 2015; Quarrie & Hopkins, 2007; Brooks & Kemp, 2005). Even in the Craven Week teams (regional South African tournament for high school boys), there has been on average a 10kg increase in the body mass of the players since the tournament first began 40 years ago (Lambert *et al.*, 2010). Sedeaud *et al.* (2012) also described a steady increase in body mass and BMI from the 1987 RWC to the 2007 RWC (1.34 kg and 0.33 $kg.m^{-2}$ for forwards and 1.46 kg and 0.30 $kg.m^{-2}$ for backs, respectively). Significantly, the team with the larger players in the RWC won more games, especially the finals. Fuller *et al.* (2013) examined players in English Premiership Clubs from 2002 until 2011 and found that players are generally becoming heavier, taller and younger, with most significant changes in the props. This results in higher impact forces in contact situations. Similar results have been found by Junge *et al.* (2004) and Brown *et al.* (2012) when they analysed youth amateur rugby in New Zealand and South Africa, respectively.

Although most research has differentiated between the injury rates of forwards and backs, the overall margin is negligible (Schwellnus *et al.*, 2014; Schneiders *et al.*, 2009; Brooks & Kemp, 2008). Some studies, which have focused on smaller groups, have found differences in injury rates between forwards and backs; however, there is no consensus in the literature on this matter (Williams *et al.*, 2013; Fuller & Molloy, 2011; Schneiders *et al.*, 2009; Headey *et al.*, 2007). According to Swain *et al.* (2011) as cited in Naish *et al.* (2013), forwards are more prone to neck injuries than backs. More specifically, hookers and props have a higher neck injury rate (McIntosh *et al.*, 2010b; Quarrie *et al.*, 2002). In general, forwards make double as many tackles as backs do (Hendricks & Brown, 2010), which would place them at a higher risk for injury.

Brooks & Kemp (2008) examined the literature for recent trends in rugby across all levels and concluded that eightmen, locks, hookers, fullbacks, flyhalves and outside centres are the players with the highest injury rates. They also assessed the anatomical location of injuries when comparing backs to forwards and found that forwards acquire more head, shoulder, neck and knee injuries, whilst backs have more knee, ankle, thigh and shoulder injuries.

In a study by Smart *et al.* (2008), creatine kinase levels of 23 elite players were measured before and after 5 matches. Creatine kinase enters the blood from the cells if the plasma membrane has been damaged so it may indirectly indicate the level of muscle damage within the body (Takarada, 2003). The creatine kinase levels of forwards was almost triple that of backs so it can be assumed that that forwards took much more physical contact than the backs and they spent more time defending (Smart *et al.*, 2008).

In the 2007 RWC the injury incidence rates were relatively similar between forwards and backs during training and playing hours (forwards 84.0; backs 83.7 and forwards 3.5; backs 3.6/ 1000 player hours, respectively). The 2011 RWC saw the backs (93.8/1000 player hours) with a higher incidence rate than forwards (85.0/1000 player hours) during matches, whilst the opposite was true during training (forwards 2.7/1000 vs backs 1.7/1000 player hours, respectively (Kaplan *et al.*, 2008). Flankers who are most often involved in rucks and tackles compared to other forwards, as well as centres who are involved with high-speed tackling, are players highly susceptible to injury (Fuller *et al.*, 2010d; Kaplan *et al.*, 2008). Fullbacks are responsible for solid last defence tackling on wings and are also often on the injury list (Kaplan *et al.*, 2008). Bathgate *et al.* (2002) found flyhalves and locks had the highest overall injury rate, while Fuller *et al.* (2010) named midfield backs as the players with the highest overall injury rate. This was due to their positional demands of running at high speeds in open spaces which means high impact tackles.

Robertson *et al.* (2013) named scrumhalves, full backs and wingers as having the highest reported rates of fractures in rugby. They also reported that locks had particularly high rates of clavicle fractures due to being dropped in the lineouts.

There is not much literature on injuries in women's rugby. During the 2006 women's RWC, the injury rate was 10.0/ 1000 playing hours with most injuries occurring during tackles. The most affected area was the neck, knee, head/face and the most vulnerable positions were players in the front row. A study done in New Zealand as part of the Injury and Performance Project reported a significantly higher injury rate of 35.5/ 1000 player hours during the 2010 women's Rugby World Cup in London (Taylor *et al.*, 2011). In this instance, knee ligament injuries were the most common and the tackle was the most predominant mechanism of injury. The authors concluded that injury rates in women were significantly lower than in men at an international level.

2.11.2 Time in match

The time period in the game in which most injuries occur has been analysed and the general consensus across all levels of rugby was that most injuries occur in the second half of the game when the players are fatigued (Brooks *et al.*, 2006; Best *et al.*, 2005; Brooks *et al.*, 2005). Some researchers divided the matches into four quarters to get a more accurate timeline of the distribution of injuries. The results show that the highest amount of injuries occurred in the third quarter (Schneiders *et al.*, 2009; Best *et al.*, 2005; Bathgate *et al.*, 2002). Brooks *et al.* (2006) found that most hamstring injuries occur in the fourth quarter of the match. It was hypothesized that this may be due to the inability of the player to adapt to the intensity of play after the half-time break, or the muscles may have cooled down or the players are fatigued after playing 40 minutes of rugby (Schneiders *et al.*, 2009; Brooks *et al.*, 2006).

2.11.3 Time in season

The timing of injuries throughout the season has been analysed by several authors and the majority of the research shows that most injuries occur in the first half of the season (Roberts *et al.,* 2013; Schneiders *et al.,* 2009; Brooks *et al.,* 2005). Brooks *et al.* (2005) analysed training injuries over two seasons in 11 English Premiership clubs and found that most injuries (34%) occurred in the preseason period due to the sudden increase in training loads. The authors did, however, identify a trend that injuries increased as the season progressed although these differences were not statistically significant. The researchers found that the opposite was true when they assessed match injuries, with the injury rate being significantly lower during preseason matches as opposed to in-season matches.

Several factors which may explain these fluctuation include overtraining in the preseason, previous injuries, stress, strength imbalances, fatigue, poor flexibility, cross-pelvic posture (increased curve of lower back, forward tilt of pelvis, tight hip flexor muscles, weak abdominals and tight hamstrings), and poor lumbopelvic strength and stability (Van Niekerk & Lynch, 2012; Brooks *et al.*, 2006; Galambos *et al.*, 2005; Brooks *et al.*, 2005). Most spinal cord injuries occurred in the early half of the season and it was hypothesized to be due to the fact that the packs weren't familiar with each other during scrum time and this may contribute to collapsed scrums (Williams & McKibben, 1987).

2.11.4 Level of play

Injury incidence has been shown to increase as the level of play increases (Brooks *et al.,* 2012; Fuller *et al.*, 2008). Hermanus *et al.* (2010) explained this increase as a result of greater force production ability and the increased exposure to training and playing matches. Usman *et al.* (2011) found that as the level of play increases so does the speed, size and body mass of the players. Fuller *et al.* (2009) observed that RWC players and Super 14 players were of similar stature, although the Super 14 players were younger. Vodacom Cup players were found to be much smaller, lighter and younger when compared to more professional teams. The higher the level of play, the more pressure there is placed on winning and so levels of competitiveness and aggression increase as well as the amount of foul play.

There are more injuries in senior rugby when compared to school boy rugby (Palmer-Green *et al.,* 2013). This trend was amplified during the four SARU Youth Weeks in 2011. Brown *et al.* (2012) ran an injury surveillance project across the U13 (Craven Week), U16 (Grant Khomo Week), and U18 (Academy Week and Craven Week) tournaments. In the U13 Craven Week the overall incidence rate was 43.1/ 1000 player hours of which 15.3/ 1000 player hours were time-loss injuries. Injuries at the Grant Khomo U16 Week equalled 45.7/ 1000 player hours, with 19.8/ 1000 player hours being time-loss injuries. The U18 Academy Week reported 50.5 injuries/ 1000 player hours and 24.9/ 1000 player hours were time-loss injuries. Finally, the injury rate during the U18 Craven Week tournament was 49.5/ 1000 player hours with the time-loss injuries totalling 28.6/ 1000 player hours.

Fuller *et al.* (2009) compared the injury rates in the Super 14 and the Vodacom Cup competitions and found that the international tournament (Super 14) had a significantly higher injury rate (96.3/ 1000 player hours) than the domestic tournament (71.2/ 1000 player hours) (Vodacom Cup).

2.11.5 Conditioning level of players

Two distinct views about the role of conditioning in the incidence of injuries are eminent from the literature. The players' level of conditioning has either been seen as an essential component for success in major tournaments, or as a reason for the players being at an increased risk for injury. There is a fine balance between training for optimal performance on the rugby field and placing the players at an increased risk for injury, as Brooks *et al.* (2005) discovered during the 2003 RWC. They found that the taller, heavier forwards were more susceptible to injuries during endurance training on the field and subsequently most teams turned to cycling and rowing. This, however, does reduce the specificity of the training and should be properly managed to ensure optimal performance on the field.

Most training programs emphasize an increase in lean muscle mass in players in order to become more physically competitive on the field (Fuller *et al.*, 2013). The increased lean body mass is associated with an increase in strength and power of the players and may offer protection in tackles, collisions and overuse injuries. This also means the impact forces between players are increased which has been previously shown to be a risk factor for injuries (Fuller *et al.*, 2010d; Quarrie & Hopkins, 2008). The majority of training sessions generally consist of rugby specific skills and drills, but when the focus was changed to more physical conditioning, the players' risk for injury was reduced. Injury surveillance was done amongst the England rugby team prior to and during the 2003 RWC and they found a significant reduction in the injury rate after more than half of their preseason training load (52-55%) consisted of physical conditioning. They promoted "personalised conditioning training programmes" to help reduce the risk of injury in competitions.

An important component of a training program which has an effect on injury risk is training volume. Brooks *et al.* (2007) found that an increased training load is associated with more severe injuries despite no change in the injury rate, when compared to lower volume training loads. On the other hand, the lack of conditioning also places players at a higher risk for injury with research by Headey *et al.* (2007) finding that players with a BMI above 30.9 $kg.m^{-2}$ suffered the most severe injuries, especially shoulder injuries.

Sedeaud *et al.* (2012) suggested that the size of players can be considered a key to success when they found that teams that have won previous RWCs have been taller and heavier than their opposition. This may be due to an increased ability to compete and maintain possession due to physical dominance in contact situations and phase play. Most teams, especially the more professional teams, included fitness testing within a typical season. Whilst there are obvious benefits in obtaining objective information from each player, it can also place the players at a higher risk of injury if the protocols are not designed appropriately (Brooks *et al.*, 2005).

2.11.6 Previous injury

New injuries constitute the majority of incidents recorded in injury statistics (Fuller *et al.*, 2013). However, players who have been injured in previous matches or seasons are at a higher risk for re-injury compared to previously non-injured players (Williams *et al.*, 2013; Emery *et al.*, 2005). The severity of the injury, as well as the treatment plan that was implemented to manage the initial injury, plays a major role in the risk of re-injury. Roberts *et al.* (2013) found that out of all the injuries in the English community clubs during 2009 and 2012 (4625 matches), 18% of the injuries were reoccurrences of previous injuries. They also identified a trend that the number of recurring injuries increased as the level of play increased.

2.11.7 Environment

Although the current study did not assess the risk that the environmental conditions have on the injury rate, previous research has shown that it may have an effect. The two main focus points when discussing ground conditions with regards to sports injuries is ground hardness and traction. Ground hardness is the ability of the surface to absorb impact energy and is directly correlated to the soil moisture content (Petrass & Twomney, 2013). Ground traction is the type of grip the playing surface provides and is affected by the amount of grass cover on the pitch (Petrass & Twomney, 2013).

Petrass and Twomey (2013) performed a comprehensive assessment of research done on the relationship between ground conditions and the rate of sports injuries. Their findings show that harder/ drier grounds pose the highest injury risk. However, one major limitation in most studies was that the assessment of the ground conditions was done subjectively by researchers categorizing ground conditions as hard, muddy or soft. This method lowers the reliability and validity of the result and makes interstudy comparisons difficult. However, most research shows similar results, with more match injuries occurring when the grounds were harder and there was less rainfall (Gabbett *et al.*, 2007; Alsop*et al.*, 2005). Conversely, Chalmers *et al.* (2012) found a 10% increase in the injury rate in muddy conditions when compared to dry conditions. Interestingly, Fuller *et al.* (2010a) found no significant difference in injury rates between rugby played on grass and artificial turf. The researchers did note however that ACL injuries, although not statistically significant, were four times more likely to occur on artificial turf than on grass and called for further research to be done on this topic.

2.11.8 Psychological factors

Psychological factors have been found to have an impact on an athlete's ability to perform, as well as on their risk for injury (Van Niekerk & Lynch, 2012; Galambos *et al.*, 2005). More specifically, life stress has been shown to increase the risk for injury in sports (Caine *et al.*, 2008). A stress and injury model was designed by Andersen and Williams (1988) which states that when an athlete faces a potentially stressful situation, there is a stress response which is individualized according to several psychosocial factors. This stress response comprises of a cognitive appraisal of the demands, resources and consequences, followed by physiological reactions and attentional responses (Maddison & Prapaveddis, 2005). These physiological and attentional changes may include *"increased muscle tension, narrowing of the visual field, and increased distractibility, which may have a negative impact on the stress-injury response"* (Williams & Andersen, 2007). These changes may have an effect on the athlete's co-ordination and flexibility, as well as his ability to detect environmental cues.

There are three main factors that influence an athlete's response to stress, namely, personality, history of stressors and coping resources. These factors may work independently or in combination with each other when an athlete responds to a stressful situation. The athlete's susceptibility to injury is directly related to the extent to which these factors are present (Maddison & Prapaveddis, 2005).

Using the above-mentioned model, Lavalée and Flint (1996) investigated the effect of psychological factors such as stress, competitive anxiety and negative mood state on injury incidence and injury severity in 55 athletes (including 13 rugby players) from a major Canadian university. They found that competitive anxiety and general anxiety were related to injury frequency, and that anxiety, anger and total negative mood state were related to injury severity. Galambos *et al.* (2005) screened 854 athletes at the Queensland Academy of Sport and found a relationship between mood dimensions and orthopaedic incidents. In South Africa, Van Niekerk and Lynch (2012) investigated whether there was a relationship between anxiety and shoulder injuries in university and club rugby players. They found that players who had injured their shoulders previously had a significantly higher level of anxiety than players who were uninjured.

2.12 Injury prevention

Injury prevention is an important focus of most sports teams and coaches as the individual or team is more likely to perform better without injuries. Many prevention strategies, such as specific conditioning and rehabilitation programs and improved medical support have been successfully introduced in various sporting codes (Alentorn-Geli *et al.*, 2014; Herman *et al.*, 2012; Finch, 2011; Lim *et al.*, 2009).

Most research regarding rugby injuries has also suggested and called for preventative measures to help reduce the incidence of injuries in the game (Brooks & Kemp, 2011; Meir, *et al.*, 2007). The preventative measures include protective equipment, law changes, education in correct techniques and specific prevention programs which will be further discussed below.

2.12.1 Equipment

Headgear, mouth guards and shoulder pads have been introduced by large sporting manufacturers in order to assist in reducing injury rates in rugby. The efficacy of the equipment has been thoroughly tested, but its effects on injury prevention are somewhat contradictory (McIntosh *et al.*, 2009; Marshall *et al.*, 2005; Jones *et al.*, 2004).

In previous years, mouth guards were thought to reduce the risk of concussions, however, more recent research has shown that they are only effective in preventing dental and orofacial injuries (McCrory *et al.*, 2013; Quarrie *et al.*, 2007; Quarrie *et al.*, 2005). Brown *et al.* (2012) reported that 51% of all injured players at the SARU Youth Weeks were wearing a mouth guard. McIntosh *et al.* (2009) discussed an interesting phenomenon called "risk compensation" which describes the increase in reckless play due to the false belief that wearing headgear protects them from injury. The authors hypothesized that this phenomenon may actually cause an increase in injuries.

Shoulder pads worn by rugby players have been tested for their ability to absorb impact and reduce injuries and no results indicate a positive effect. According to Usman *et al.* (2011), shoulder pads are ineffective at reducing the impact force on the shoulders when making a tackle. The impact forces on the shoulder while wearing shoulder pads were measured at 1635 N compared to 1684 N when no shoulder pads were worn. With these results, it can be said that shoulder pads have very little ability to reduce the impact force on the shoulders. Other contact sports such as American Football have much more substantial protective equipment and injury research has shown that football has a lower injury rate when compared to rugby. Although these sports may differ in nature and tackling technique, it is an interesting correlation to make due to the fact that there are still high speed collisions between football players.

McGuine *et al.* (2013) conducted a major comparison between brands of headgear and mouth guards in American football players from 36 schools. The results showed that players wearing the generic mouth guards had a lower concussion incidence rate compared to players wearing the more expensive customized mouth guards and there was no significant difference between the concussion rates of players wearing old or new helmets.

Lincoln *et al.* (2011) found an increase in concussions over an 11 year period in 6 sports in American public schools, irrespective of whether the players wore a helmet or not. Nevertheless, in the sports where a helmet was worn, such as American football, lacrosse and baseball, concussion rates were double that of the non-helmeted sports (basketball, wrestling, football). Despite the steady increase in the number of concussions, protective equipment does seem to serve a purpose as shown in the comparison of injury rates between men and women lacrosse players where the nature of play, as well as the rules and protective equipment are different.

Although rugby and American football have different game structures, they are regarded as somewhat similar because they are both contact orientated sports with high injury rates. There is, however, a significant difference in the protective equipment between the two sports. All football players wear hard-shelled helmets and heavy padding on their shoulders and thighs, whilst rugby players may choose to wear slim, padded headgear or shoulder pads. Kaplan *et al.* (2008) attributes this difference to be one of the main reasons why rugby has a 3-fold higher injury rate compared to football.

2.12.2 Law changes

Although no research has been done on the most recent changes in rugby laws, especially revolving around the scrum sequence, available research has assessed the impact of law changes on injury rates. Several law changes have been implemented to increase the continuity and competitiveness of the game, while the development of player's physical attributes (strength, speed and power) has led players to become faster, stronger and more clinical in implementing these attributes. These changes may have had an effect on injury rates (Quarrie & Hopkins, 2008). A key factor affecting the decisions to make law changes lies in the IRB's attempts to reduce the incidence of injury. With the introduction of professionalization in 1995, the game became a product that could be marketed and sold. Hence a need arose to enhance audience satisfaction. Rule changes thus also attempted to improve the spectacle of the game and by doing so improve the product offered and increase the financial profit gained from it by unions and sponsors.

Law changes have also brought about a change in the style of play which has improved audience satisfaction, with faster, open attacking play being executed. Since the experimental law variations were introduced, such as the 5 m offside line at scrums and quick throw-ins being allowed, the slower set pieces such as scrums and lineouts have decreased significantly. Tackles, metres gained and penalties have increased significantly, whilst rucks won, defence being beaten and passes made have increased moderately (Van Den Berg & Malan, 2012). Overall, this means that the time the ball is in play has increased from 33% to 44% of a match (IRB, 2015). In research by Quarrie & Hopkins (2008) of the Bledisloe Cup matches between 1972 and 2004 the effects of professionalism and law changes were clearly shown. The time the ball was in play increased by 19% and the number of tries scored increased by 72%. The number of tackles and rucks increased significantly (51% and 63%, respectively), whilst the number of kicks during play, mauls, scrums and lineouts decreased (30%, 25%, 8% and 14%, respectively). Considering tackles have the highest injury rate, this change in the style of play may also mean an increase in injury risk due to the increased physical contact in tackles and rucks.

Tackles have been an area of focus for the IRB as they have attempted to reduce the amount of injuries which occur in this phase of play. Actions such as high tackles, late tackles, shoulder charges and lifting the player’s feet off the ground have been of particular concern for referees as they attempt to reduce the number of serious head or neck injuries in rugby (Fuller *et al.,* 2010d; Gianotti *et al.*, 2008). The role of the referee in a rugby match is to ensure the game is played according to the laws and to ensure the safety of the players. If the referee deals with foul play strictly, it can be assumed that players are less likely to infringe the laws again. Quarrie & Hopkins (2008) suggested a practical solution to reducing tackle injuries by proposing the introduction of a new law that lowers the height of the tackle because of the danger of high tackles and head to head contact. By lowering the maximum allowable tackle height from the shoulders to the axillae (armpits) there may be less head to head contact and neck injuries caused by swinging/ stiff arm tackles. The number of players involved in a tackle may also be a critical factor to consider. Good *et al.* (2011) reported a case study of two players who sustained acetabular fractures during tackles in rugby. One of the players was injured during a school match and the other during a club rugby match. The researchers suggested a law change to limit the number of tacklers in each tackle to two players (ball carrier and tackler only).

As mentioned previously, scrums are an area which causes more severe neck injuries so there has been a lot of focus on finding ways to improve this. A large emphasis has been on changing the engagement sequence which has slowed down the engagement as well as reduced the impact between the two front rows. Correct technique and experience are also important factors in reducing the risk for injury (Gianotti *et al.*, 2008).

The hostel league at Stellenbosch University has been an experimental law “test centre” over the years. Recent experimental laws which have been implemented include a dual referee system, a penalty kick in the middle of the 22m when a yellow card is given, the scrumhalf cannot pass the tunnel at a scrum and a quick throw in is allowed regardless of whether the ball has touched anything beyond the playing area. The laws attempt to improve the time the ball is in play as well as reduce foul play. These laws are specific to the hostel league so the style of play might be different to other leagues which in turn may have affect the injury rate.

2.13 Prevention strategies

2.13.1 General injury prevention models

The injury prevention model by Van Mechelen *et al.* (1992), used by most researchers today, was adapted from a standard public health prevention model and applied into the sport setting. This model has a simple four stage approach and was initially the most frequently used model in research.

The model begins by establishing the extent of the problem, then analysing the aetiology and mechanism of the injury; thereafter, preventative measures are introduced and then assessed for their effectiveness by repeating the first stage. Finch (2006) supports the model’s ability to collect evidence to build an injury database and identify causal risk factors, but the author sites several limitations as well. Limitations in the methodology (eg: retrospective interviews regarding previous injuries) in many studies reduce the integrity of the results. The most notable limitation, however, is the fact that most studies fail to move beyond stage 2, which is identifying the aetiology and mechanism of injuries. Appropriate and effective prevention measures need to be implemented in order for the model to achieve positive outcomes. The entire sporting community, including the athletes, coaches, administrators and sporting bodies, will need to accept, adopt and comply with the prevention model to facilitate beneficial results.

Finch (2006) expanded the previous model when he proposed the TRIPP (Translating Research into Injury Prevention Practice) model. The framework consists of:

a) a detailed understanding of the aetiology of injuries;
b) development of interventions to directly address the identified mechanisms of injury;
c) formal testing of these interventions under controlled conditions (i.e., efficacy research);
d) understanding of the sporting and individual athlete behaviours context in which the interventions are to be implemented;
e) potential modification of interventions to take this implementation context into account;
f) assessment of potential factors associated with the real-world introduction and application of safety measures to accompany the real-world "roll-out" of the interventions; and
g) formal evaluation of the effectiveness of injury prevention measures within the implementation context.

Below is a table which compares the Van Mechelen *et al.* (1992) four stage approach to that of the TRIPP model.

Table 2.2: A comparison between the TRIPP model and the Van Mechelen approach in preventing sports injuries (Finch, 2006)

Model Stage	**TRIPP**	**Van Mechelen *et al.* (1992) 4 stage approach**
1	Injury Surveillance	Establish extent of the problem
2	Establish aetiology and mechanisms of injury	Establish aetiology and mechanisms of injury
3	Develop preventative measures	Introduce preventive measures
4	"Ideal conditions"/scientific evaluation	Assess their effectiveness by repeating stage 1
5	Describe intervention context to inform implementation strategies	
6	Evaluate effectives of preventive measures in implementation context	

More recently, Verhagen and Van Mechelen (2010) have updated their systematic approach for preventing sports injuries as shown in Figure 2.

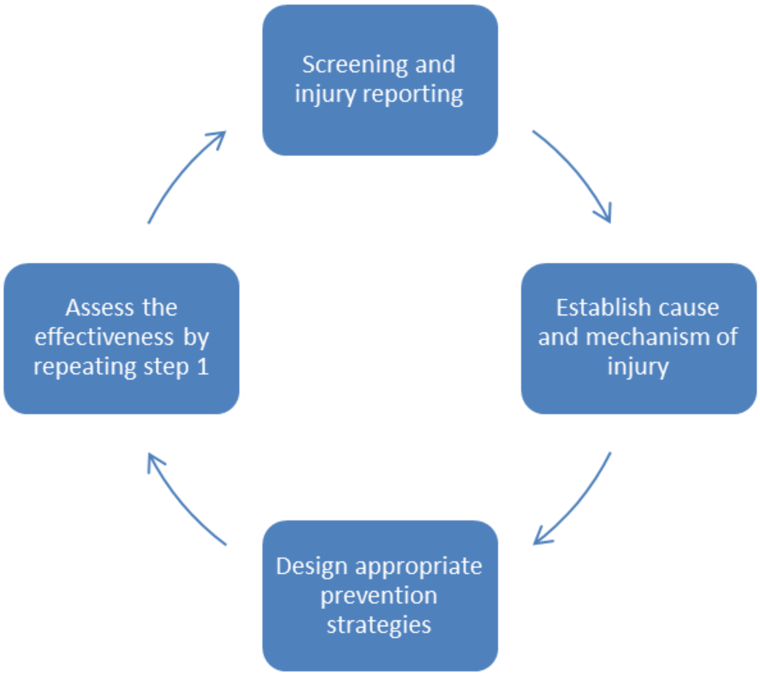


Figure 2.1 The Translating Research into Injury Prevention Practice (TRIPP) framework for research leading to real-world sports injury prevention (Finch, 2006).

Screening and injury reporting are the two important steps to begin with, followed by the establishment of the most common cause and mechanism of injuries. With the above information, the appropriate prevention strategies such as stretches for warm-up and cool-down sessions, appropriate physical conditioning, coaching and implementation of correct technique, education on hydration and nutrition, promotion of fair play, allowing protective equipment, making sure the training or match happens in a safe environment can be implemented to address the specific risk identified. Furthermore if injuries do occur, the correct treatment plan should be followed.

2.13.2 Rugby specific prevention strategies

Due to the high rates of injuries in rugby, most research has called for specific prevention programs (Fuller *et al.*, 2010d; Brooks *et al.*, 2006). Injury prevention programs, when implemented, have generally shown a decrease in the injury rate as they promote injury/ treatment awareness, improved education regarding conditioning and skill techniques. They also have an added advantage, especially in a South African setting, of providing jobs for course educators and trainers. They may also promote a stronger relationship between schools and clubs and their respective unions as there is increased communication and a feeling of support from the union. The possible disadvantages of the programs are that whether every player, team, coach or referee has access to the courses, expertise and equipment, as well as the necessary finances to implement such a program.

In New Zealand in 1995, "Tackling Rugby Injury" was one of the first rugby injury prevention programs implemented and the NZ Accident Compensation Corporation (ACC) reported a lower incidence of injury claims. RugbySmart has since been developed and implemented since 2001. Similarly, the Australian Rugby Union developed SmartRugby which runs on similar protocols of injury prevention. In Scotland, school boys who play in the front row need to complete a protocol of strength testing before they are allowed to participate in any games (Kuster *et al.*, 2012).

Rugby Ready was an initiative launched by the IRB in 2007 and focused on player welfare at all levels of the game. The BokSmart National Rugby Safety programme is the rugby injury prevention programme in South Africa and was launched in December 2007. Boksmart is an evidence-based approach to rugby safety and uses internationally accepted best practice standards in order to prevent injury and enhance performance across South Africa (Viljoen & Patricios, 2012). Although it is based on similar programmes in New Zealand (RugbySmart) and Australia (SmartRugby), it is tailor-made to suit the social-economic challenges and disparity in education in South Africa. The Boksmart programme requires all coaches and referees to be accredited otherwise they are unable to participate in any rugby. This accreditation needs to be refreshed every two years in order to align with updated protocols. The Boksmart programme consists of a DVD presentation which focuses on safety and first aid course specifically for rugby. It allows access to online educational resources as well as a toll-free Spineline number which assists in the management and transport of head, neck and spinal injuries sustained by players (Viljoen & Patricios, 2012). Along with nationwide programmes, several local unions have implemented injury prevention programmes within their local clubs and school as well. SharkSmart was based on the RugbySmart programme in New Zealand and has been running in Kwazulu-Natal since 2003.

2.14 Short and long-term effects of rugby injuries

Rugby injuries may cause symptoms such as pain and discomfort for a few hours to several days, depending on the severity of the injury. In the short term, university students may miss a day or two of class because of these symptoms which is manageable, although not ideal.

Injuries that are more severe may mean that students may not perform optimally or they may miss the test or exam completely which affects their academic performance.

Some rugby injuries can result in neurological deficits, quadriplegia or death. Posthumus and Viljoen (2008) found that of the 12-33% serious or catastrophic head, neck and spine injuries in South Africa, 40% were scrum injuries and 36% were tackle injuries resulted in permanent damage for the player. Scrum injuries may also lead to more long term effects, such as premature chronic degeneration of the cervical spine (Trewartha *et al.,* 2014).

In conclusion, rugby injuries are inevitable due to the contact nature of the game. It is important to analyse the epidemiology of the injuries in order to identify risk factors that affect the specific rugby population. Rugby injuries may have several negative effects on a player which may in turn affect them in the long term. Injury surveillance studies need to be done across all populations in order to identify relevant risk factors. From this information, appropriate risk factors can be developed in an attempt to reduce the injury rate and monitor the effectiveness of the prevention program.

2.15 Conclusion

Rugby injuries have been widely researched across many levels of the game. Research has shown that the higher the level of play, the higher the number of injuries. The phase of play responsible for the highest injury rate is the tackle. Rugby injuries affect all areas of the body and range from minor injuries to severe injuries. Previous injury, conditioning status, psychological factors and the environment have all been identified as risk factors for injuries. Prevention strategies have shown to have a positive effect on injury rates but continuous effort is needed.

CHAPTER THREE

METHODOLOGY

3.1 Study design

This study followed a retrospective cohort design that used a questionnaire-based data collection procedure. Injuries were captured during the university matches over three complete rugby seasons (2011, 2012, and 2013). An electronic database was then developed in 2013 and all injury data was entered into the database.

3.2 Study population

All registered male rugby union players at Stellenbosch University who represented residence rugby teams were included in the study. The players who participated in the study were aged 18 years and older. The players were from 40-42 residence rugby union teams and involved sixteen residences.

3.3 Ethical clearance

The study protocol was approved by the Ethics Committee for Human Research at Stellenbosch University (DESC-Barrett/2014) (Appendix A). The data on the database is password protected and may be used for future research by the University. Ethical clearance was obtained from Campus Health to access the players' medical records

3.4 Procedures

3.4.1 Data collection

Data were collected during every hostel rugby union matched played at the Stellenbosch University rugby fields, throughout the playing seasons from April 2011 until September 2013. Data collection commenced on the first round of hostel matches in April and involved all hostel teams registered in the university league. In 2012 and 2013, data was collected at the first year tournament held prior to the hostel league as well as during the university league. There were between 42-44 teams that participated each year in the leagues.

An injury data hardcopy was used to collect the data which included injury definitions from the consensus statement by Fuller *et al.* (2007c). The injury data capture forms were modified from the Boksmart Rugby Safety program (Appendix C). The number of matches played during the season was calculated in order to calculate the amount of playing hours per week so incidence rates could be determined. The academic calendar for the previous three years was obtained from the Registrar of Stellenbosch University and match records were accessed with regards to match fixtures.

3.4.3 Place of Study

Data were collected at the Stellenbosch University Rugby Medical Room during every rugby match played at the Stellenbosch University rugby fields. In addition, data were also collected from patient records at the Injury Clinic of Campus Health Services.

3.4.2 Data management

Injury data was collected by a qualified Biokineticist, or biokineticists in training. In case of the latter, the individuals were properly informed on the methods. After collecting injury data on a hardcopy during the matches it was entered into an electronic database. This electronic database was developed specifically for the purpose of this study so the injury data can be entered via internet access.

3.4.5 Delimitations

This study only involved male rugby union players, who were registered students and played for a university residence.

3.4.6 Statistical Analysis

Descriptive and inferential statistics regarding the number of observations per injuries, body region and injury mechanism were reported on a weekly basis. Means and standard deviations of the different types of injuries according to the body region (head and neck, trunk, arm, hip, thigh, knee, ankle and foot) were represented in incidence per 1000 playing hours (Fuller *et al.* 2007c). This data was used to create graphical representations. Inferential statistics (means and 95% confidence intervals) based on weekly occurrences was determined to identify whether there is a statistical significance between weekly occurrences of specific injuries. Furthermore, statistical trend analysis using Statistica software was done to detect existing trends within the weekly occurrence data. Fisher's post-hoc analyses were done to determine whether there were statistically significant differences across 3 years. Results were considered statistically significant if $p < 0.05$.

CHAPTER FOUR

RESULTS

4.1 Number of injuries

Table 4.1 shows the total number of match hours played in the hostel leagues in 2011, 2012 and 2013. It also shows the total number of injuries across 3 years and it was found that the number of injuries has increased over time but stabilized within the last two years.

Table 4.1: Total number of match hours and injuries from 2011-2013

Year:	Total number of match hours:	Total number of injuries:	Matches per season:
2011	6195	82	234
2012	7030	132	263
2013	6355	121	236
TOTAL	19580	335	733

Figure 4.1 is a graphical representation of the injury rate in 2011, 2012 and 2013 throughout the hostel league. There was a 46% increase in injury rate from 2011 to 2012 and an overall trend of increasing injury rates from 2011 to 2013.

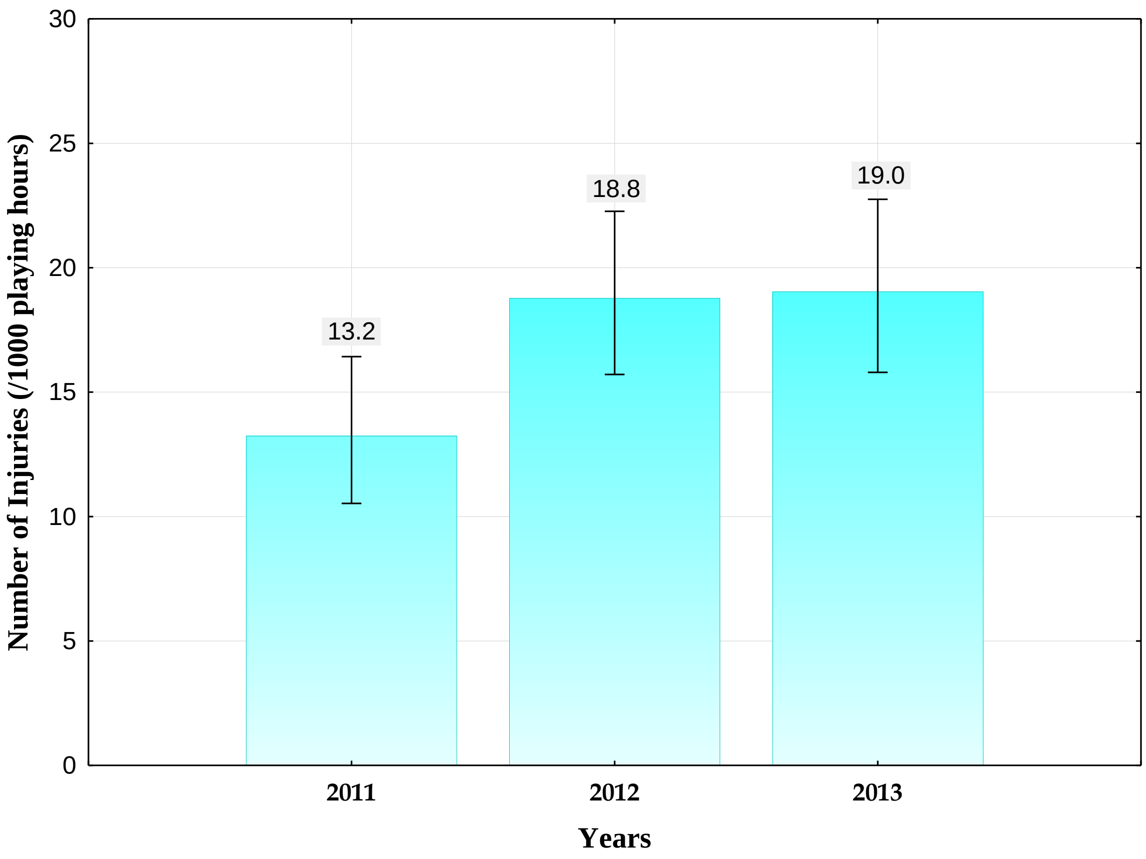


Figure 4.1: The number of injuries per 1000 playing hours during all hostel matches from 2011 until 2013.

4.2 Time loss vs medical attention injury

Figure 4.2 depicts the number of time-loss injuries compared to the number of medical attention injuries. Time-loss injuries formed the majority of the total injuries (233 injuries; 69.6%; 95% CI: 10.4 – 13.5) which was significantly more than the medical attention injuries (102 injuries; 30.4%; 95% CI: 4.2 – 6.3).

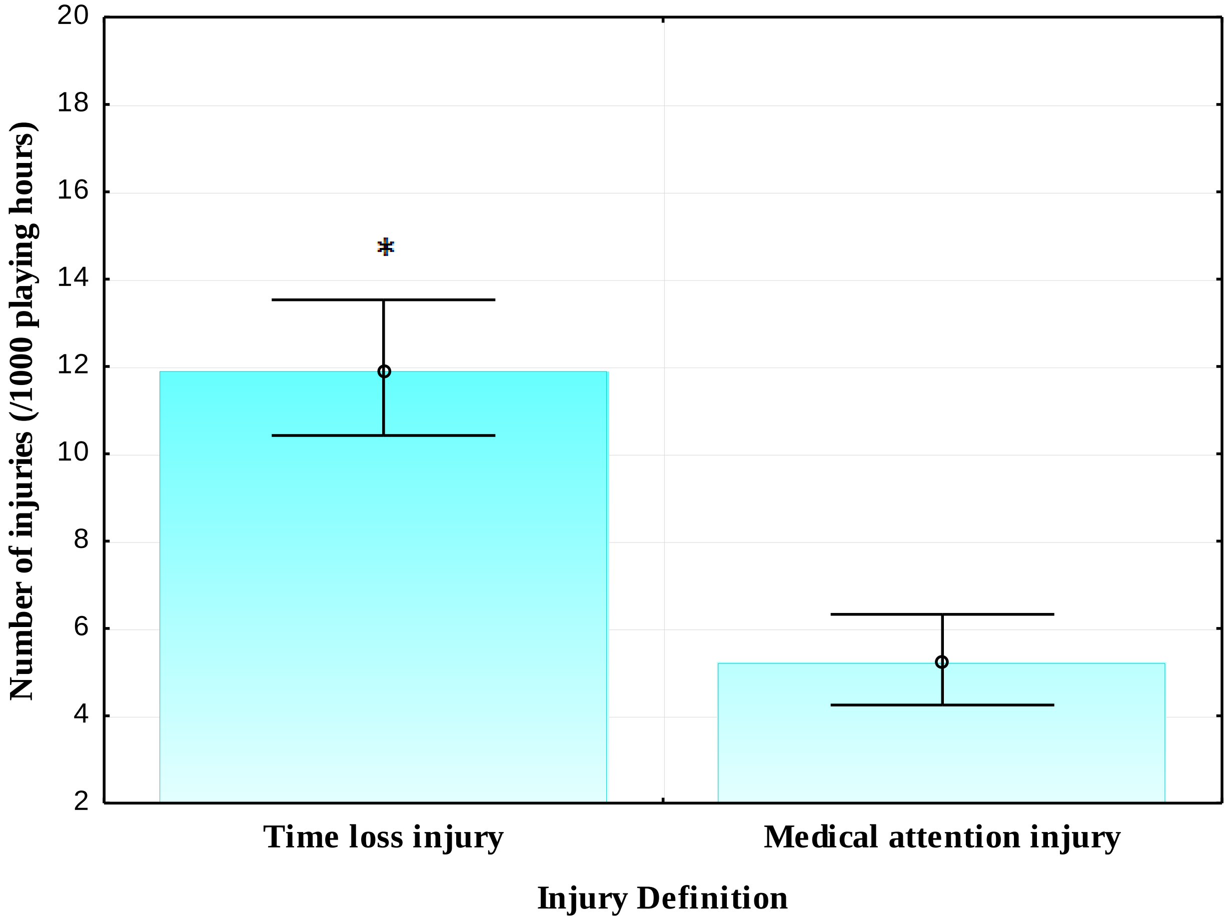


Figure 4.2: The number of time-loss and medical attention injuries per 1000 playing hours over three seasons.

4.3 Injury severity

Figure 4.3 indicates the estimated number (as determined by the consulting doctor) of days missed by the injured player in order to recover. Most injuries in the hostel leagues were of a moderate severity, meaning that between 8-28 days were missed (94 injuries; 28.1%).

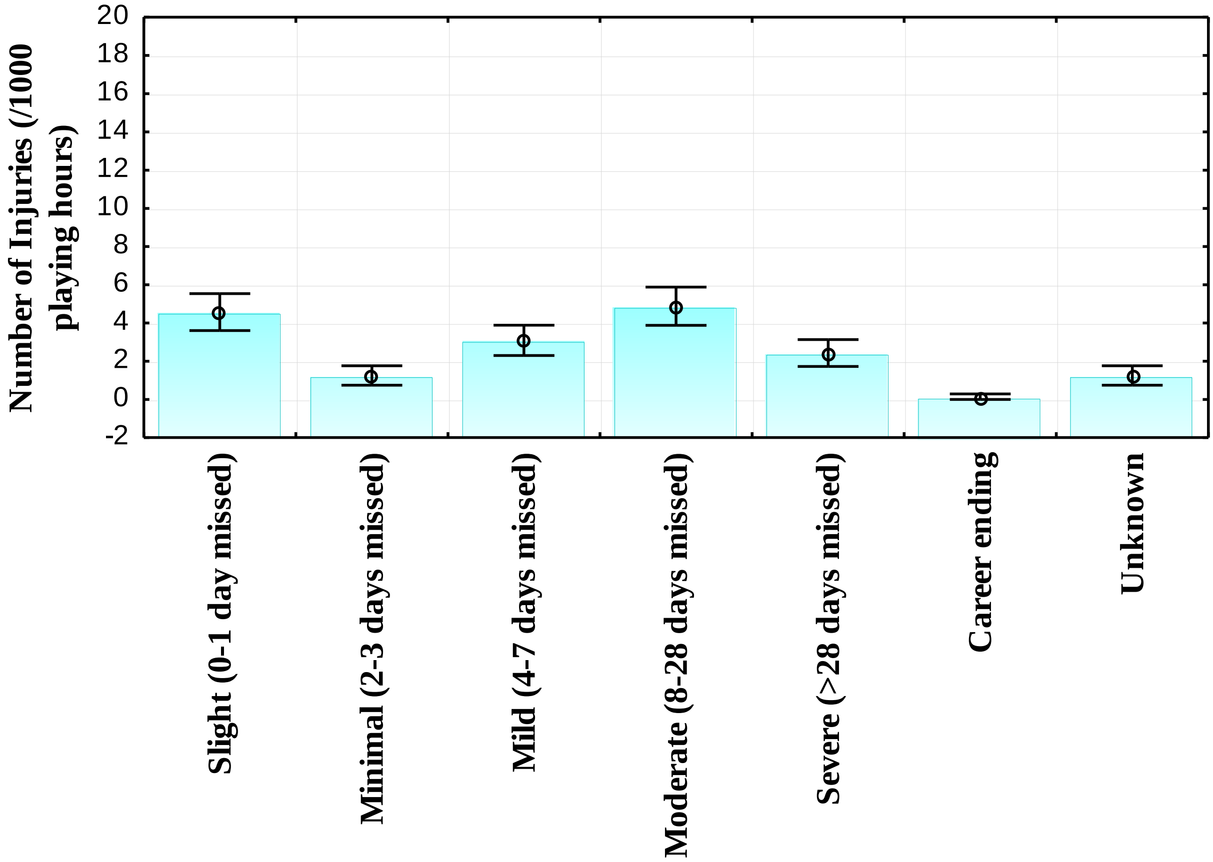


Figure 4.3: The estimated severity of injuries per 1000 playing hours over three seasons.

4.4 Level of play

Players in division 1 sustained the most number of injuries (111 players; 34%; 95% CI: 4.7 – 2.8), followed by division 2 (78 players; 24%; 95% CI: 3.1 – 5.0), division 4 (49 players; 14.7%; 95% CI: 3.1 – 5.0) and division 3 (48 players; 14.7%; 95% CI: 1.8 – 5.0). Students participating in the First Year's Tournament sustained 40 injuries (12.2%; 95% CI: 1.5 – 2.8). The injury rate in division 1 was statistically significantly higher than division 3 and 4 as well as the First Year's Tournament ($p<0.05$), but not division 2.

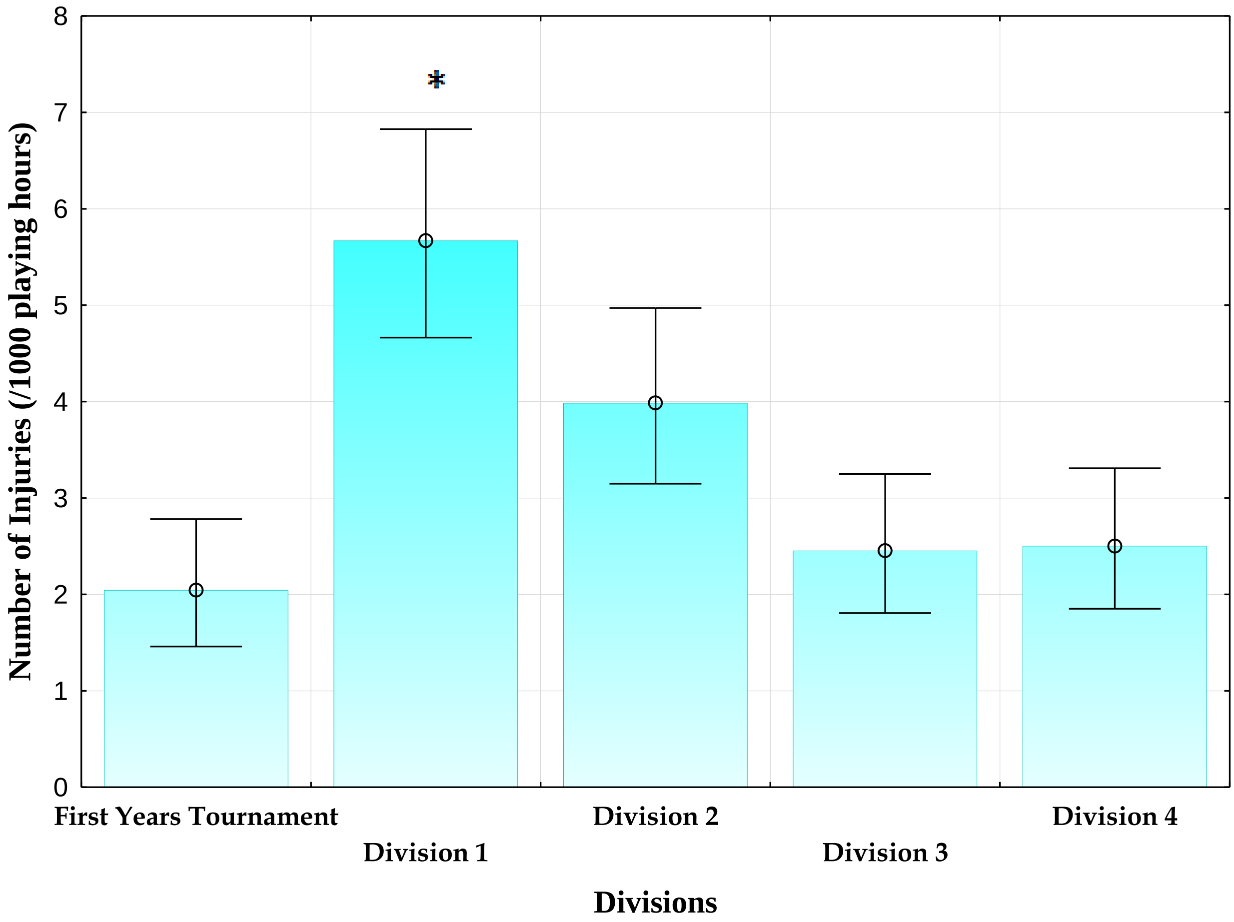


Figure 4.4: The number of injuries per 1000 playing hours across the different levels of play in Stellenbosch hostel rugby. In the hostel league division 1 is the highest level and division 4 the lowest level of competition.

4.5 Players' years of experience

Figure 4.5 shows that there were 53 injured players (15.8%; 95% CI: 2.0 – 3.5) who had played in their position for less than a year. This correlates to an injury rate of 2.7/ 1000 playing hours. Thirty nine (11.6%; 95% CI: 1.4 – 2.7) of the injured players had been playing in the same position for 1-2 years and 62 (18.5%; 95% CI: 2.4 – 4.1) of the injured players had been playing in the same position for 3-4 years. The majority of the injured players had been playing in their position for more than four years (181 injuries; 54%; 95% CI: 7.9 – 10.7), which were significantly different from the other categories ($p<0.05$).

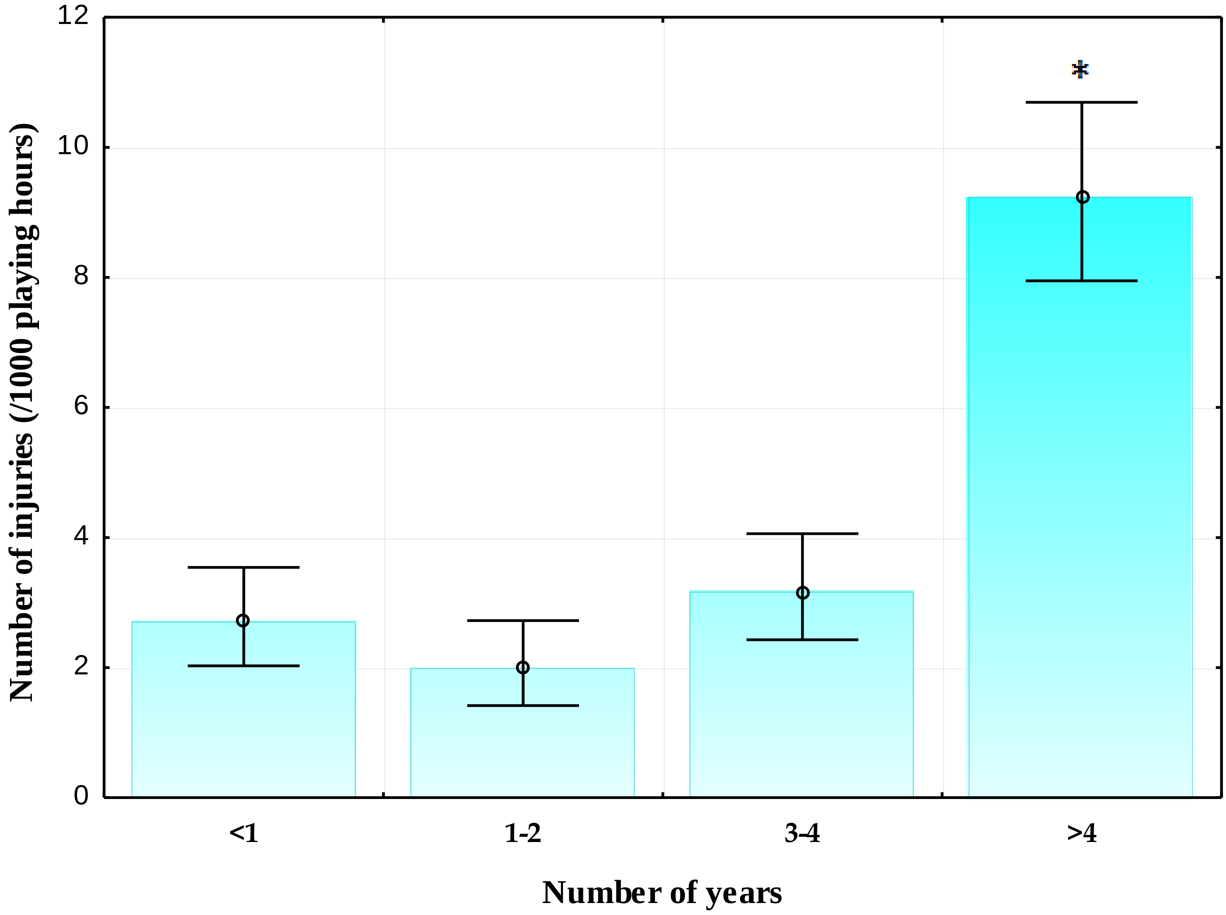


Figure 4.5: The years of playing experience in the position the individual played prior to the injury.

4.6 Type of injury

Figure 4.6 depicts the type of injuries sustained by players over the three seasons. Lacerations (79 injuries; 23.6%; 95% CI: 3.2 – 5.0), joint sprains (54 injuries; 16.1%; 95% CI: 2.1 – 3.6), concussions (52 injuries; 15.5%; 95% CI: 2.0 – 3.5), ligament injury (40 injuries; 11.9%; 95% CI: 1.5 – 2.8) and broken bone/fractures (33 injuries; 9.6%; 95% CI: 1.2 – 2.4) formed the majority of the injuries. Muscle strains (17 injuries; 5.1%; 95% CI: 0.5 – 1.4) and injuries where doctors were unsure of the diagnosis (20 injuries; 6%; 95% CI: 0.6 – 1.6) constituted the next highest injury rates. Skin abrasions (11 injuries; 3.3%; 95% CI: 0.3 – 1.0), bruises (9 injuries; 2.7%; 95% CI: 0.2 – 0.9), dislocations (6 injuries; 1.8%; 95% CI: 0.1 – 0.7), tendon injuries (2 injuries; 0.6%; 95% CI: 0.0 – 0.4), muscle tears (1 injury; 0.3%; 95% CI: 0.0 – 0.3), muscle cramps (1 injury; 0.3%; 95% CI: 0.0 – 0.3), subluxations (1 injury; 0.3%; 95% CI: 0.0 – 0.3), were reported far less over the three seasons.

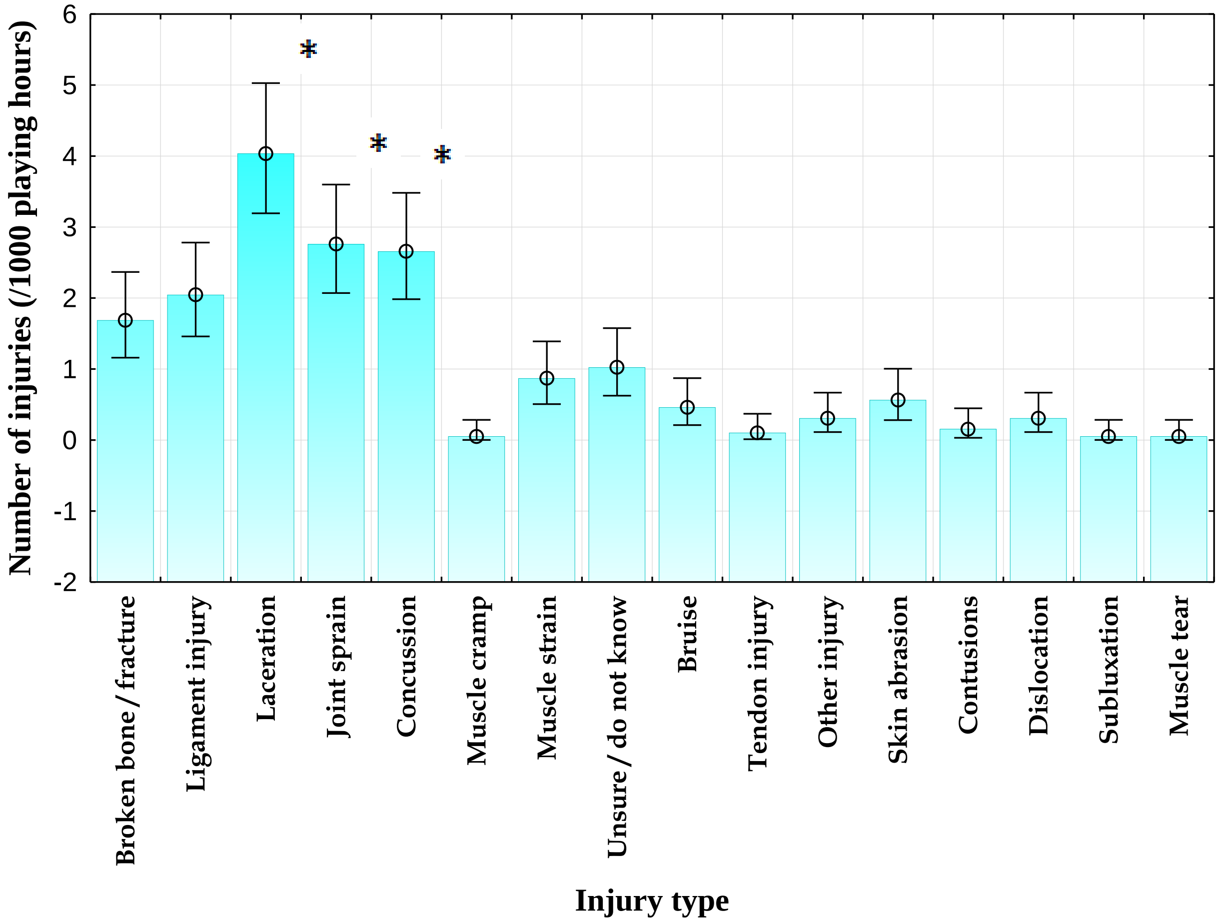


Figure 4.6: The injury rates according to the types of injuries that occurred over three seasons.

4.7 Anatomical location of injuries

The number of injuries to the head (82 injuries; 24%; 95% CI: 3.3 – 5.2) and face (78 injuries; 23%; 95% CI: 3.1 – 5.0) were significantly more than any other anatomical location and made up the majority of the reported injuries (Figure 4.7). The next highest area affected was the shoulder (43 injuries; 13%; 95% CI: 1.6 – 3.0), knee (32 injuries; 10%; 95% CI: 1.1 – 2.3) and the ankle (24 injuries; 7%; 95% CI: 0.8 – 1.8). There were 17 injuries of the hand (1.5%; 95% CI: 0.5 – 1.4), 14 of the neck (4.8%; 95% CI: 0.4 – 1.2), 11 of the hamstring (3.3%; 95% CI: 0.3 – 1.0) and 5 lower leg and wrist injuries (1.4%; 95% CI: 0.1 – 0.6).

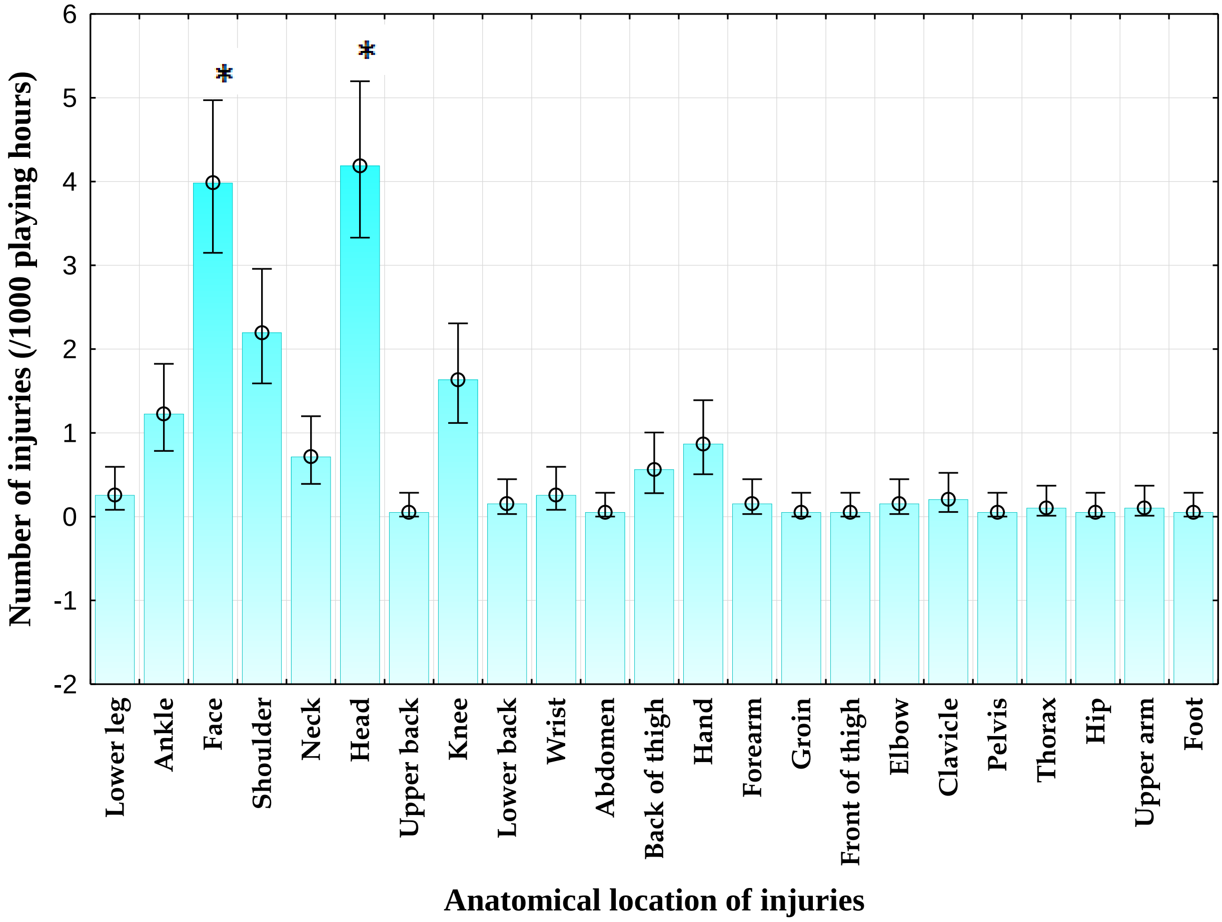


Figure 4.7: The injury incidence according to anatomical location in hostel rugby.

4.8 Playing position

Figure 4.8.1. shows there were more injuries to the backs (172; 51%; 95% CI: 154.1 - 189.8) than the forwards (160; 48%; 95% CI: 142.3 - 177.9), with 3 injuries (1%) being unspecified. This translates to a very small difference of 3% between the two groups.

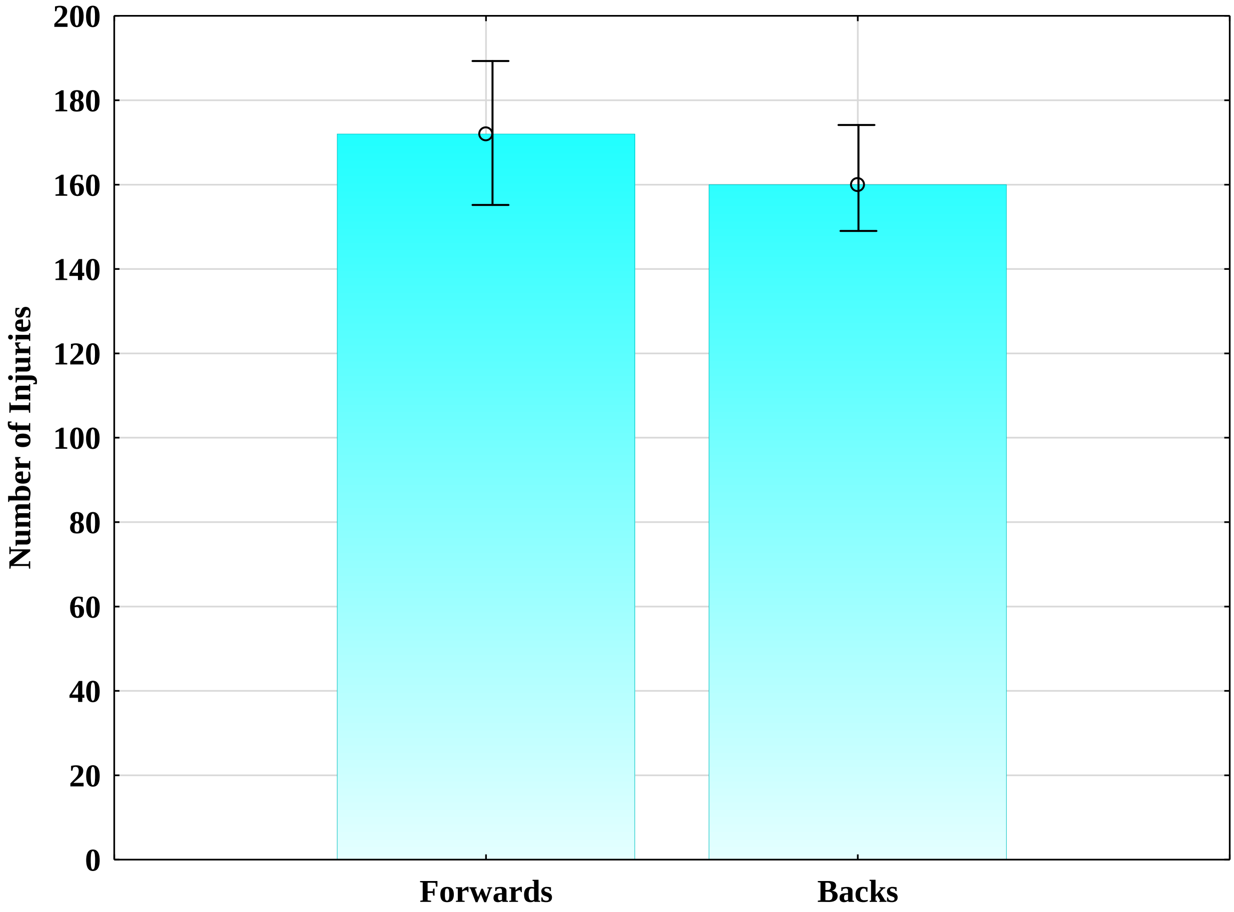


Figure 4.8.1: The number of injuries amongst forwards and backs in hostel rugby over three seasons

Injury rates according to playing positions are depicted in Figure 4.8.2. There were no significant differences in injury rate between the playing positions; however, left wings, flanks, hookers, centres and fullbacks were most prone to injury. Flanks and left wings (29 injuries each; 8.7%; 95% CI: 1.0 – 2.1) had the highest injury rates, followed by inside centres (28 injuries; 8.4%; 95% CI: 1.0 – 2.1), hookers (27 injuries; 8.1%; 95% CI: 0.9 – 2.0), fullbacks (26 injuries; 7.8%; 95% CI: 0.8 – 1.9), outside centres (24 injuries; 7.2%; 95% CI: 0.8 – 1.8) and props (20 injuries; 6%; 95% CI for loose head prop: 0.6 – 1.6 and 0.5 – 1.5 for tight head prop). As there are two locks and two flanks on each team, the number of injuries was averaged in order to make the results comparable to other positions.

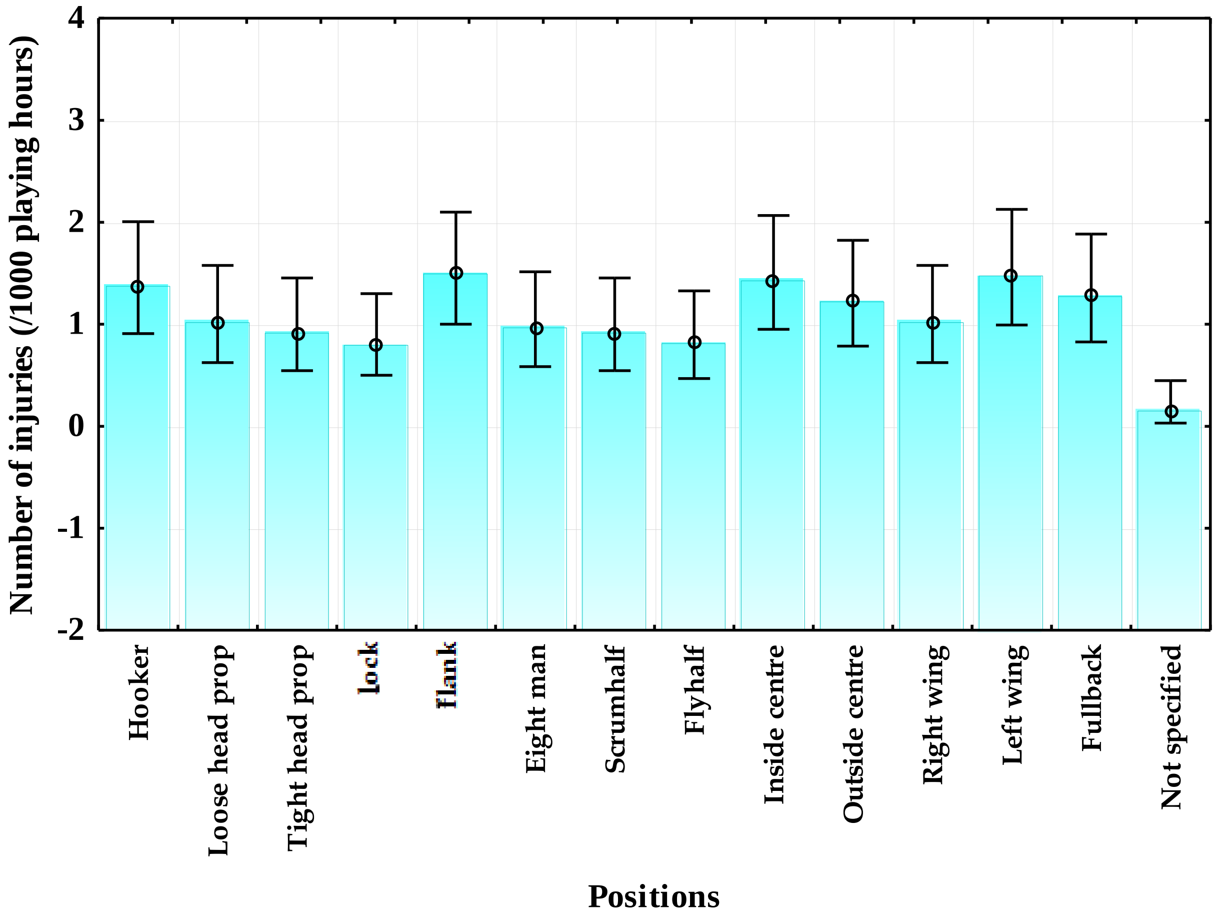


Figure 4.8.2: The number of injuries per 1000 playing hours that occurred in the different playing positions.

Figure 4.8.3 and 4.8.4 depict the differences in the major anatomical locations of the injuries amongst forwards and backs. In both groups, the head (60 injuries; 37.5%) and shoulders (81 injuries; 47.1%) formed the majority of the injuries. The injury profiles were relatively similar except for ankle injuries where more forwards occurred injuries (30 injuries; 18.8%) as opposed to backs (11 injuries; 6.4%).

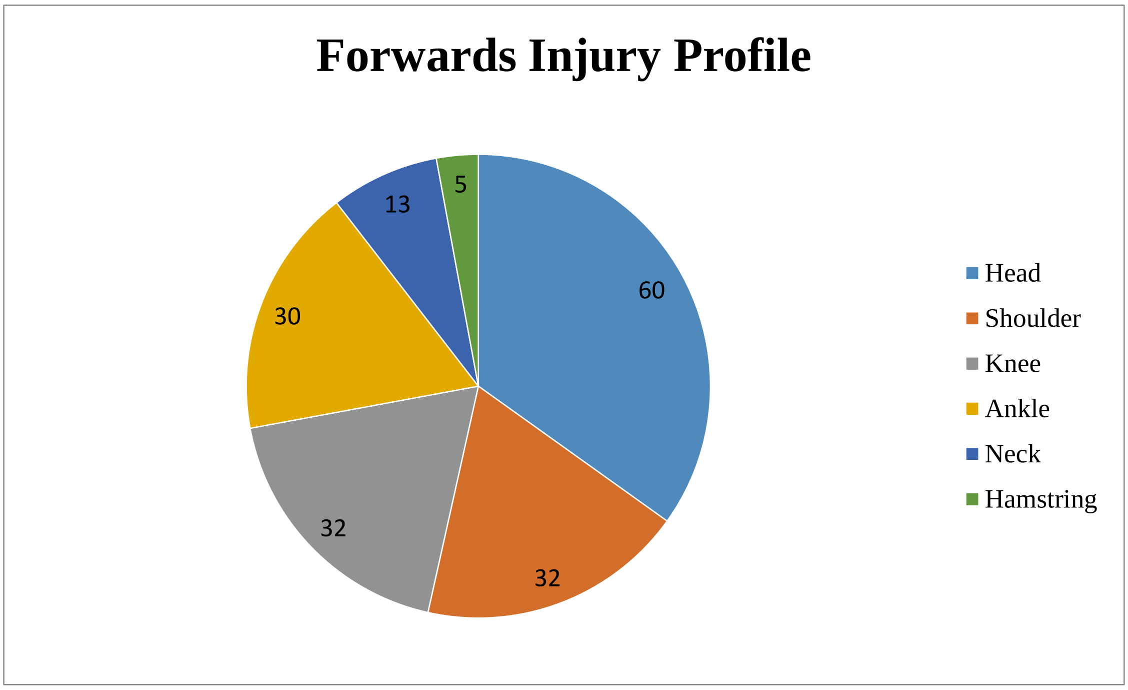
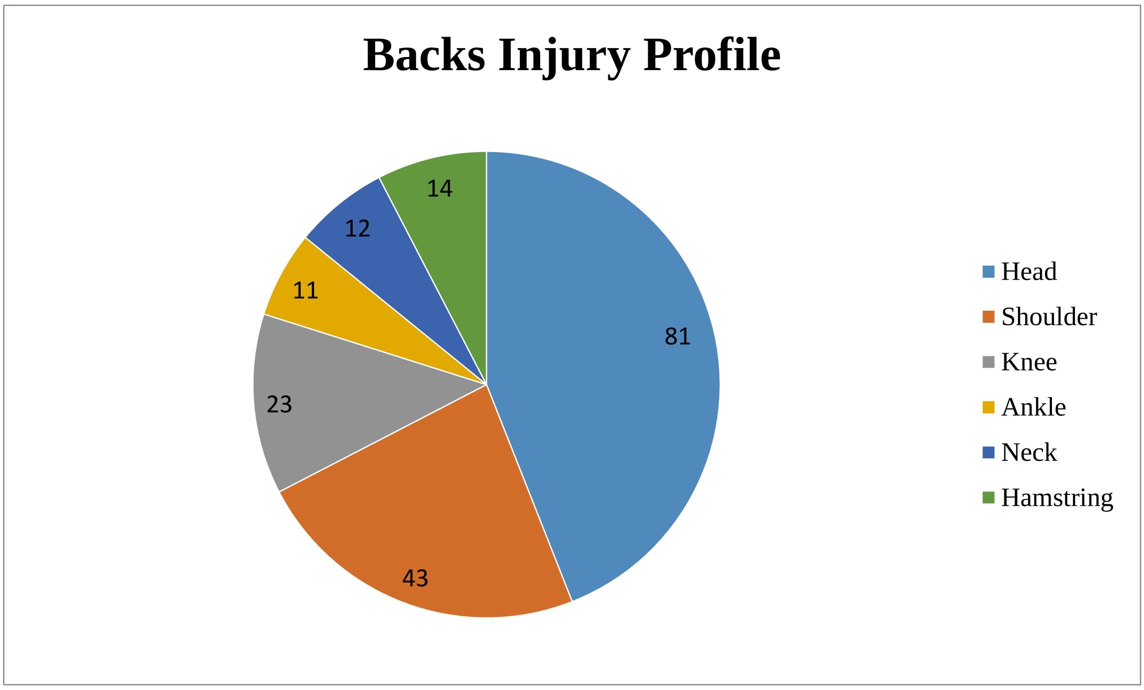


Figure 4.8.3 Number of injuries according to anatomical location in forwards



4.8.4 Number of injuries according to anatomical location in backs

4.9 Phase of play

Figure 4.9.1 shows which phase of play each injury occurred in. The tackle was the phase of play responsible for the highest number of injuries (199 injuries; 59.4%; 95% CI: 8.8 – 11.

7). The ruck produced 52 injuries (15.5%; 95% CI: 2.0 – 3.5), open play produced 32 injuries (4.6%; 95% CI: 1.1 – 2.3) and 25 injuries (7.5%; 95% CI: 0.8 – 1.9) occurred whilst running. There were only 6 injuries (1.8%; 95% CI: 0.1 – 0.7) that occurred in the scrum and 4 injuries (1.2%; 95% CI: 0.1 – 0.5) in the lineout and maul. One player (0.3%; 95% CI: 0.0 – 0.3) was injured whilst scoring a try and one player was injured whilst kicking. Ten (3%; 95% CI: 0.2 – 0.9) of the injured players were unsure as to which phase of play their injury occurred in.

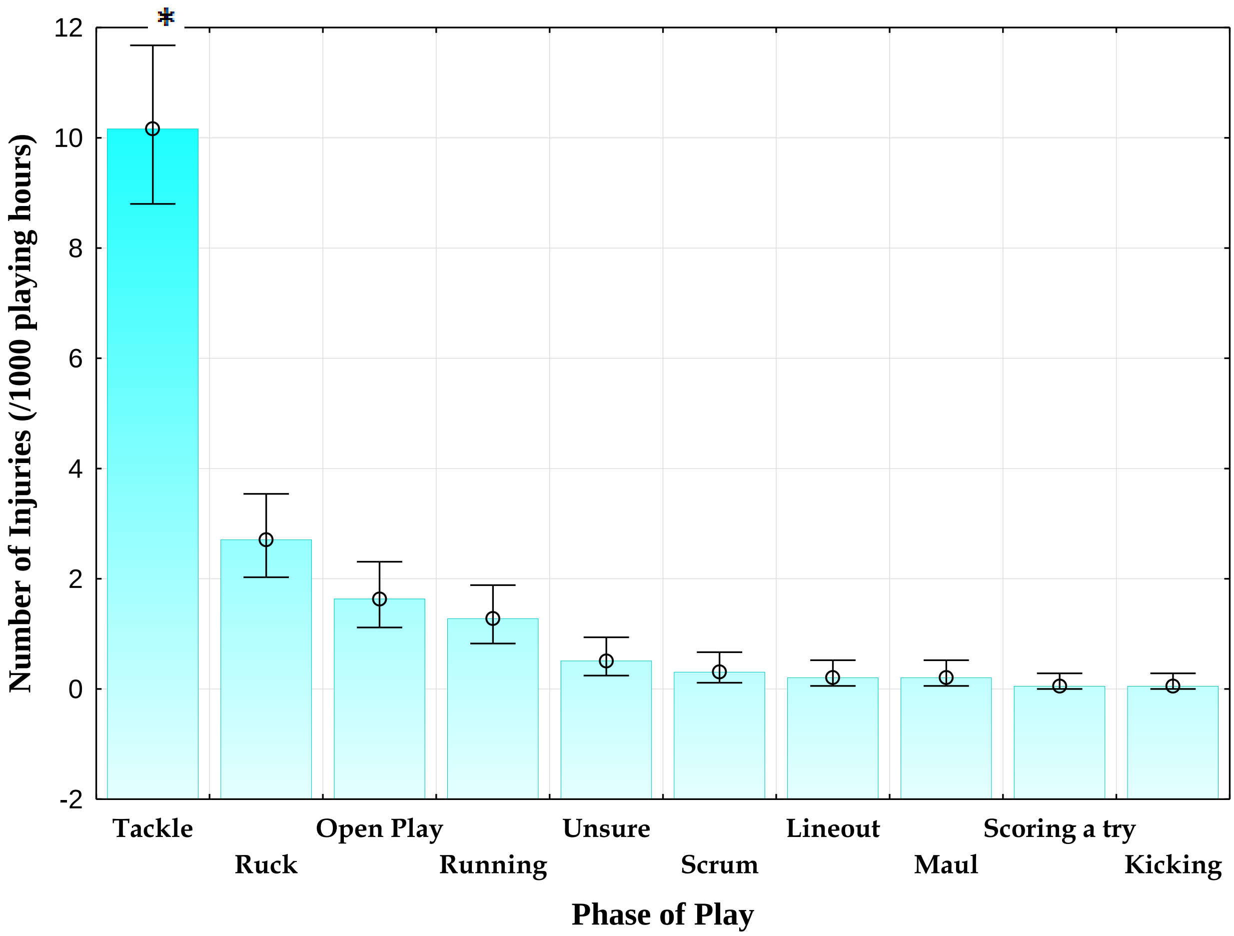


Figure 4.9.1: The phases of play which contributed to the number of injuries per 1000 playing hours

4.10 Mechanism of injury

Figure 4.10 depicts the injury rate per mechanism of injury. The highest number of injuries were due to tackling front on (tackler) (53 injuries; 15.8%; 95% CI: 2.0 – 3.5), followed by collisions (36; 10.7%; 95% CI: 1.3 -2.5), tackling side-on (tackler) (31 injuries; 9.3%; 95% CI: 1.2 – 2.2), being tackled side-on (ball-carrier) (27 injuries; 8.1%; 95% CI: 0.9 – 2.0) and being tackled front-on (ball-carrier) (24 injuries; 7.2%; 95% CI: 0.8 – 1.8).

Tackling front-on injuries were significantly higher than all other injuries, except collisions and tackling side-on. The other mechanisms of injury had a relatively low incidence of injury and were not significantly different from another.

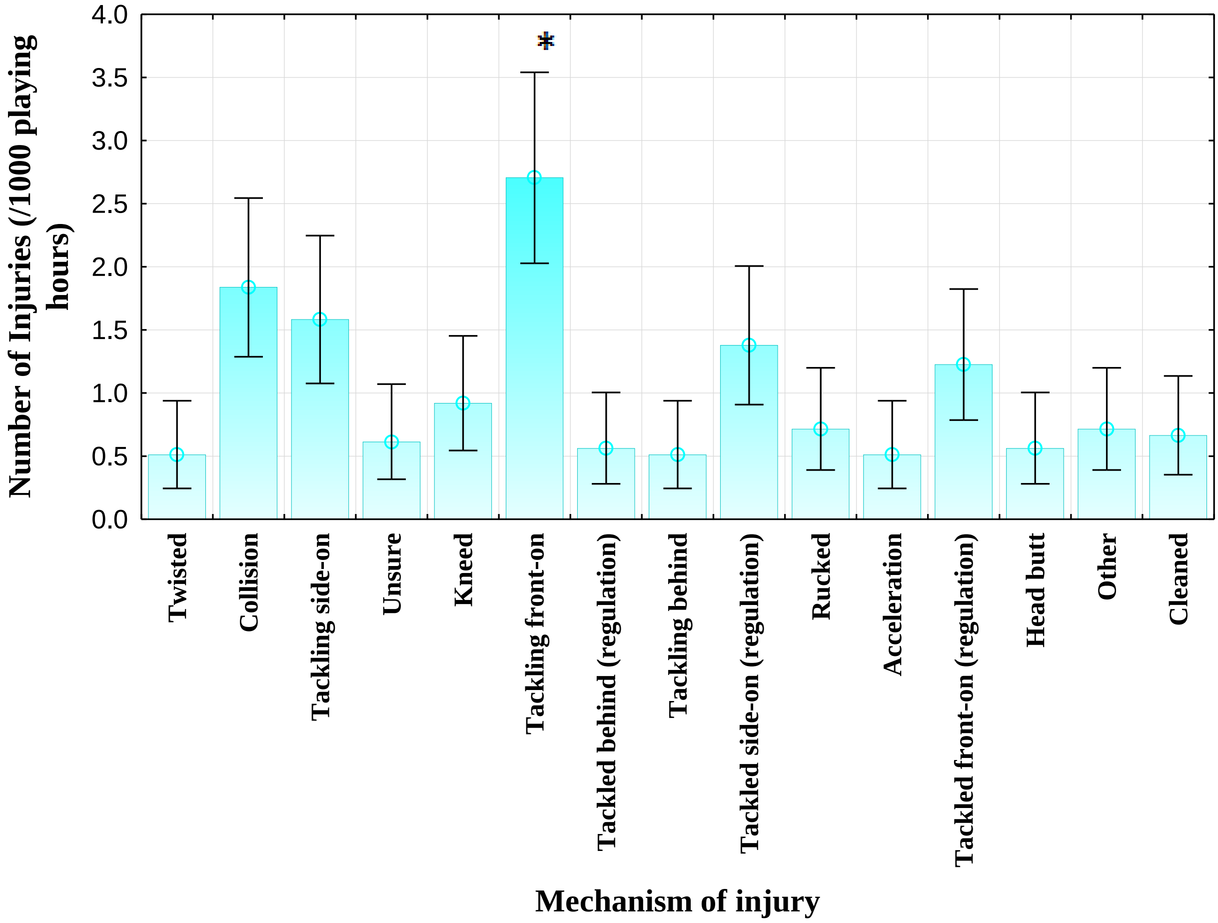


Figure 4.10: The mechanism of injury per 1000 playing hours.

4.11 Previous injury

Figure 4.11 shows the comparison between new injuries and old/previous injuries. The majority of the injuries were new injuries (273 injuries; 81.5%; 95% CI: 12.3 – 15.7). Forty eight injuries (14.3%; 95% CI: 1.8 – 3.3) were previous injuries and 14 (4.2%; 95% CI: 0.4 – 1.2) injuries were sustained where the medical history was unknown or unsure. There was an increase in the number of new injuries as the level of play increased (Division 1: 87 injuries; Division 2: 66 injuries; Division 3: 41; Division 4: 40 injuries).

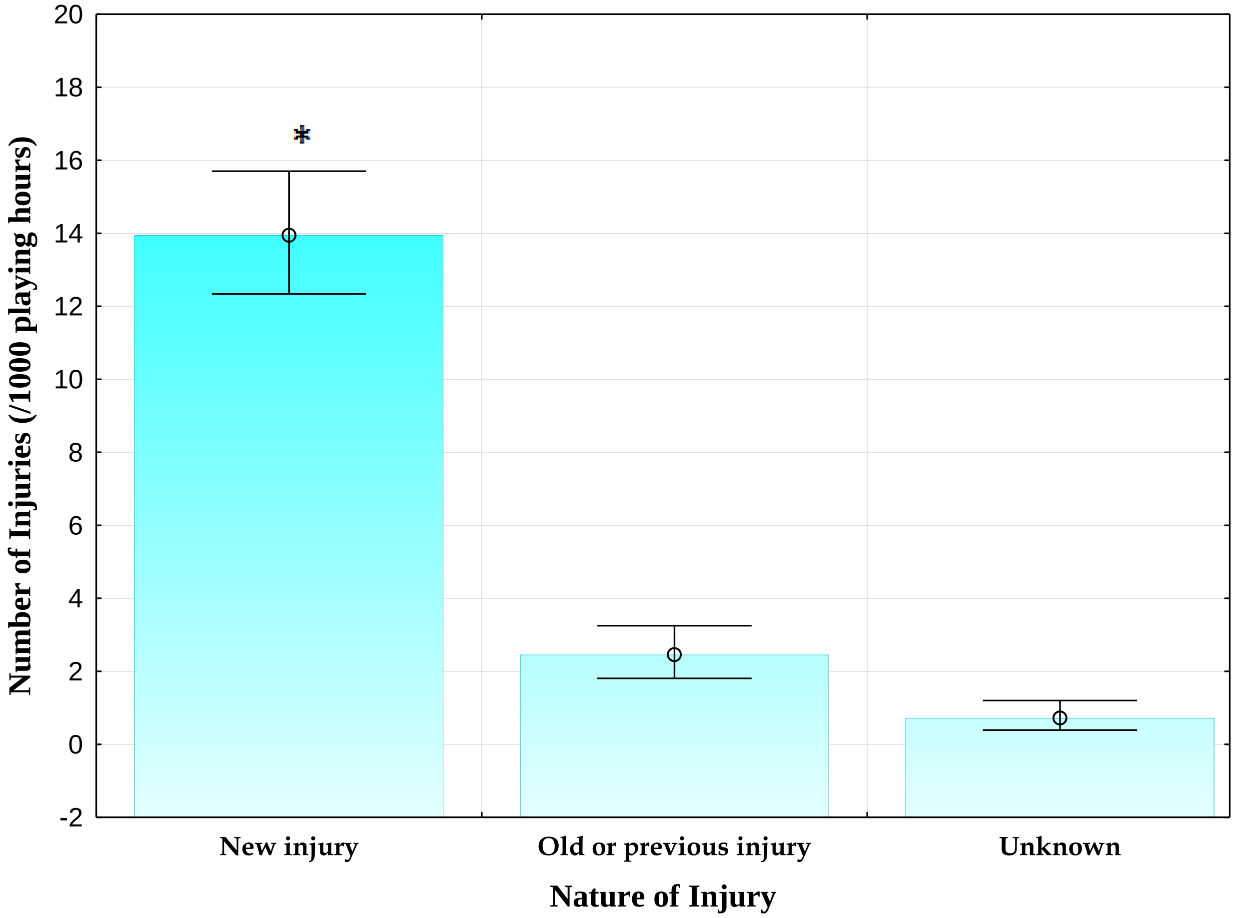


Figure 4.11: The number of new injuries compared to injuries that occurred in areas which have been injured previously.

4.12 Timing of injury

The number of injuries that occurred in each quarter is shown in Figure 4.12. The first and second quarter produced the most injuries within the hostel leagues with 100 (29.9%; 95% CI: 4.2 – 6.2) and 94 (27.5%; 95% CI: 3.9 – 5.9) injuries in each quarter, respectively. The third quarter produced 76 injuries overall (22.7%; 95% CI: 3.1 – 4.9) and the fourth quarter produced 53 injuries (15.8%; 95% CI: 2.0 – 3.5). The difference between the first and second quarter compared to the fourth quarter were statistically significant ($p<0.05$).

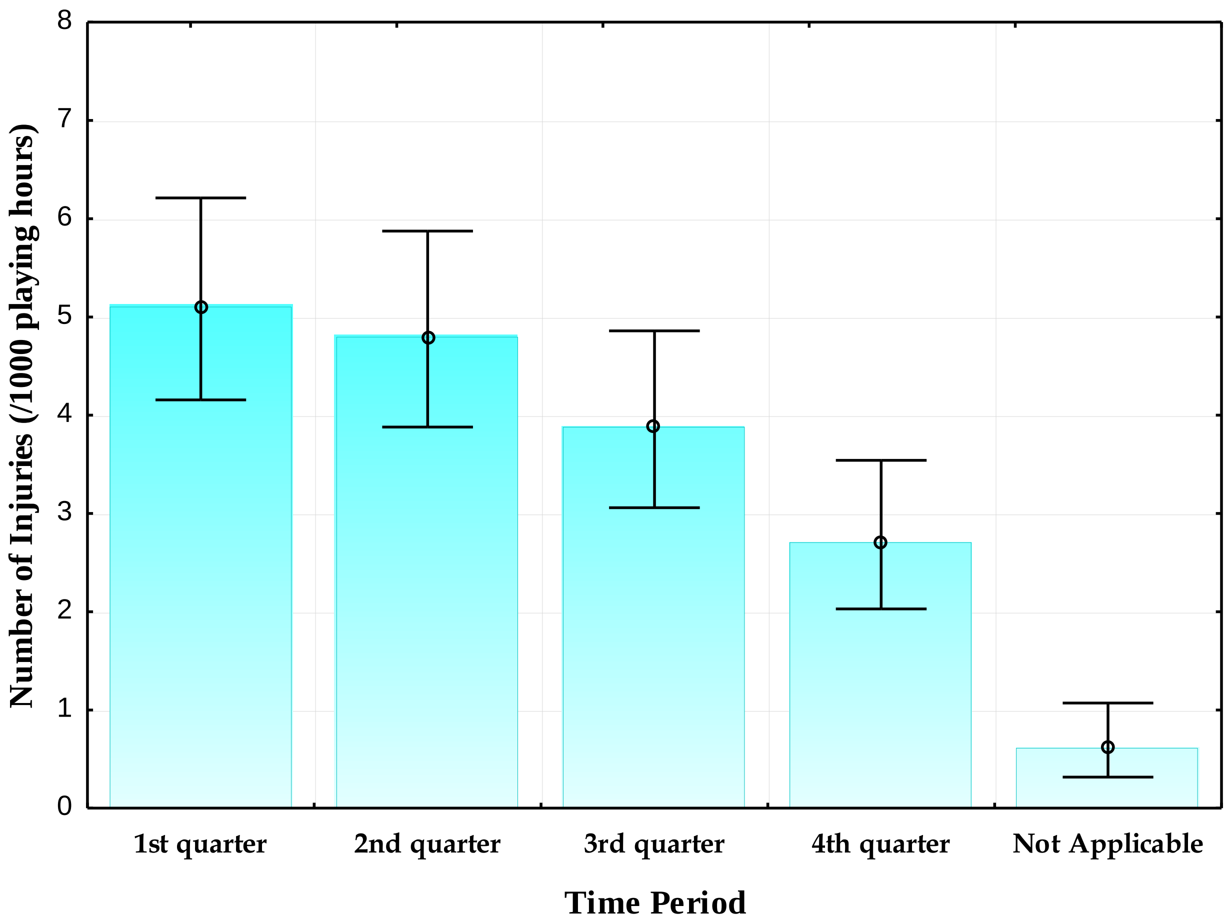


Figure 4.12: The number of injuries per 1000 playing hours that occurred in each quarter of the match.

4.13 Time of season

From fig 4.13 it can be deduced that most injuries occurred in the beginning of the season (40; 11.9%; 95% CI: 16.2 – 42.2) which was the time period when the First Year's Tournament was held. Time periods 2 indicates all of the injuries that occurred in the first semester of the university calendar and time period 3, the second semester. During these time periods, the injury rate was 17.2 (110; 32.8%; 95% CI: 13.2 – 21.2) and 15.9/ 1000 playing hours (162; 48.4%; 95% CI: 10.9 – 20.8), respectively. Time period 4 reflects all the injuries that occurred during the semi-finals and play-off matches and the injury rate was 20.3/ 1000 playing hours (11; 3.3%; 95% CI: -22.3 – 63.0). Time period 5 had an injury rate of 18.6/ 1000 playing hours (2; 0.6%; 95% CI: -3.0 – 20.2) and captured all the injuries that occurred during the finals. Most injuries occurred in time period 1 after which there was a relatively steady decrease to time period 5.

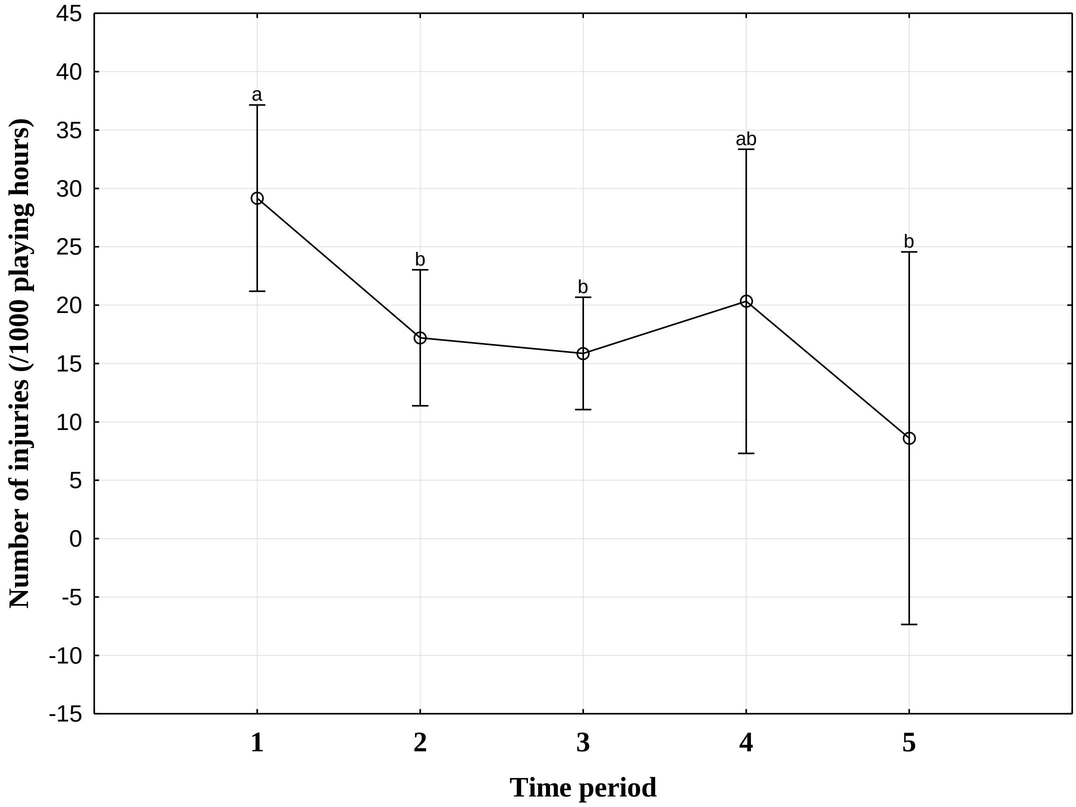


Figure 4.13: The number of injuries that occurred during each time period of the season.

Injury rates did not differ between the First Years Tournament (1) and semi-finals (4) ($p = 0.25$), however there was a significant difference in the number of injuries between the First Years Tournament and the first semester (2) ($p = 0.02$) as well as the second semester (3) ($p < 0.01$) and the finals (5) ($p = 0.02$). There were no other significant differences between the other time points ($p > 0.05$).

4.14 Playing Environment

4.14.1 Pitch level

Figure 4.14.1.1 indicates that uneven pitches produced a significantly higher injury rate as opposed to even pitches (225 injuries; 67.2%; 95% CI: 10.0 – 13.1 versus 110 injuries; 32.8%; 95% CI: 4.6 – 6.8). The distribution of injuries across the pitch levels are similar (figure 4.14.1.2), except for a 7% higher injury rate in the knee on uneven surfaces compared to even surfaces.

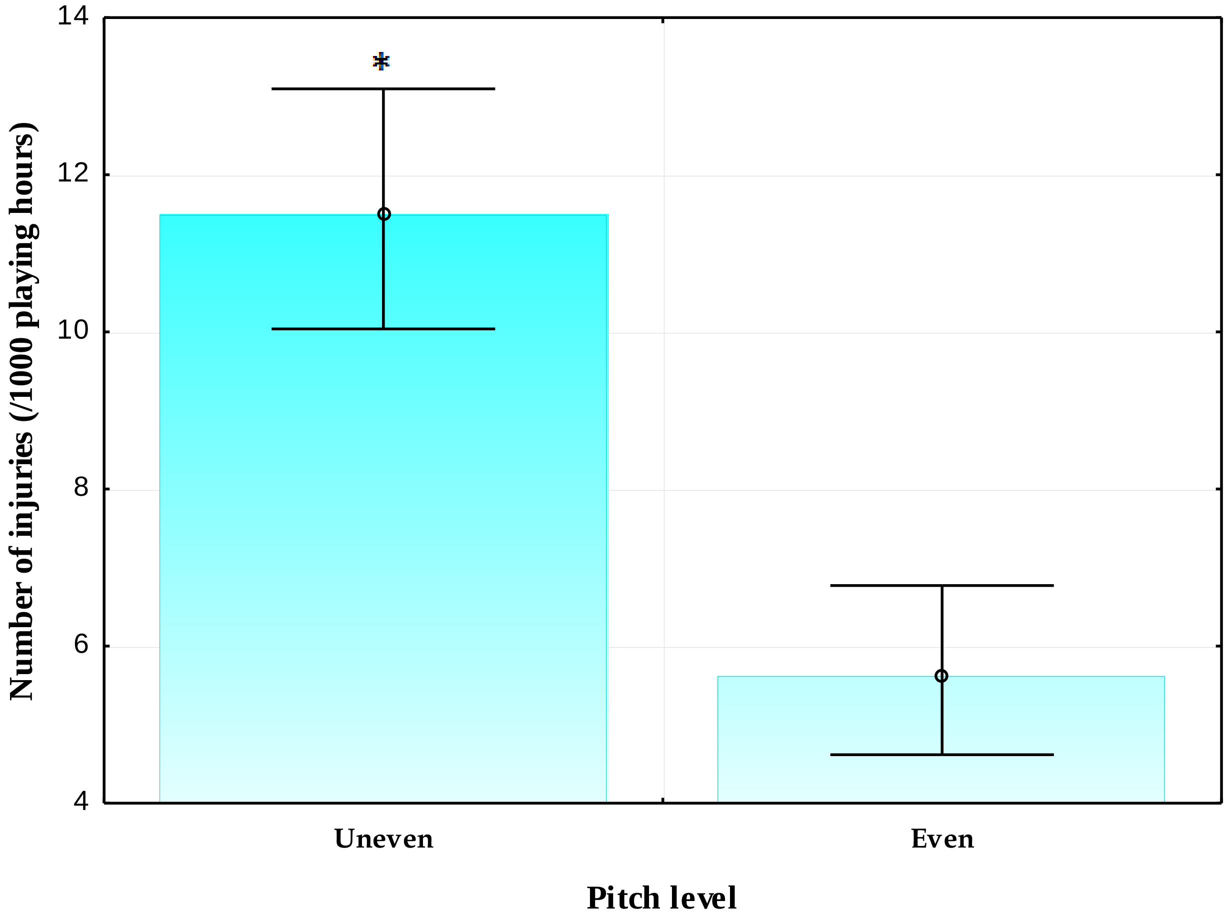


Figure 4.14.1.1: The number of injuries that occurred when the pitch level was even and uneven.

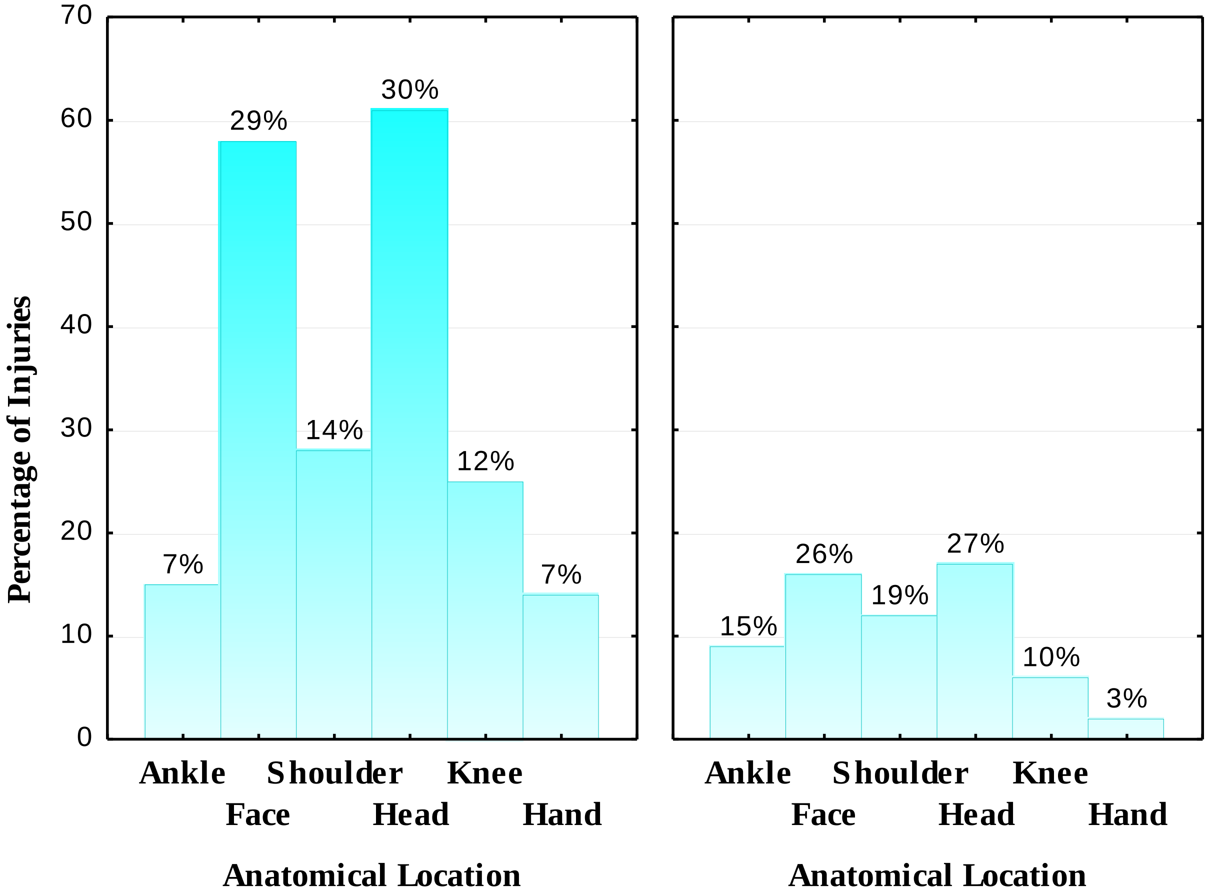


Figure 4.14.1.2: The distribution of injuries according to anatomical location between two pitch levels (uneven vs even).

4.14.2 Ground conditions

The data on ground conditions was subjectively gathered from the injured players and ranged from soft, firm, hard and very hard. 234 (70%; 95% CI: 10.5 – 13.6) of the injuries occurred on soft ground conditions and was significantly higher than the injury rate on any other ground condition. 86 of the injuries (25.7%; 95% CI: 3.5 – 5.4) occurred on firm ground conditions and despite being significantly lower than the injury rate on the soft ground conditions, firm ground conditions had a significantly higher injury rate compared to hard and very hard ground conditions. Hard ground was responsible for 13 (3.9%; 95% CI: 0.4 – 1.1) of the injuries whilst only 2 (0.6%; 95% CI: 0.0 – 0.4) of the injuries occurred on very hard ground conditions.

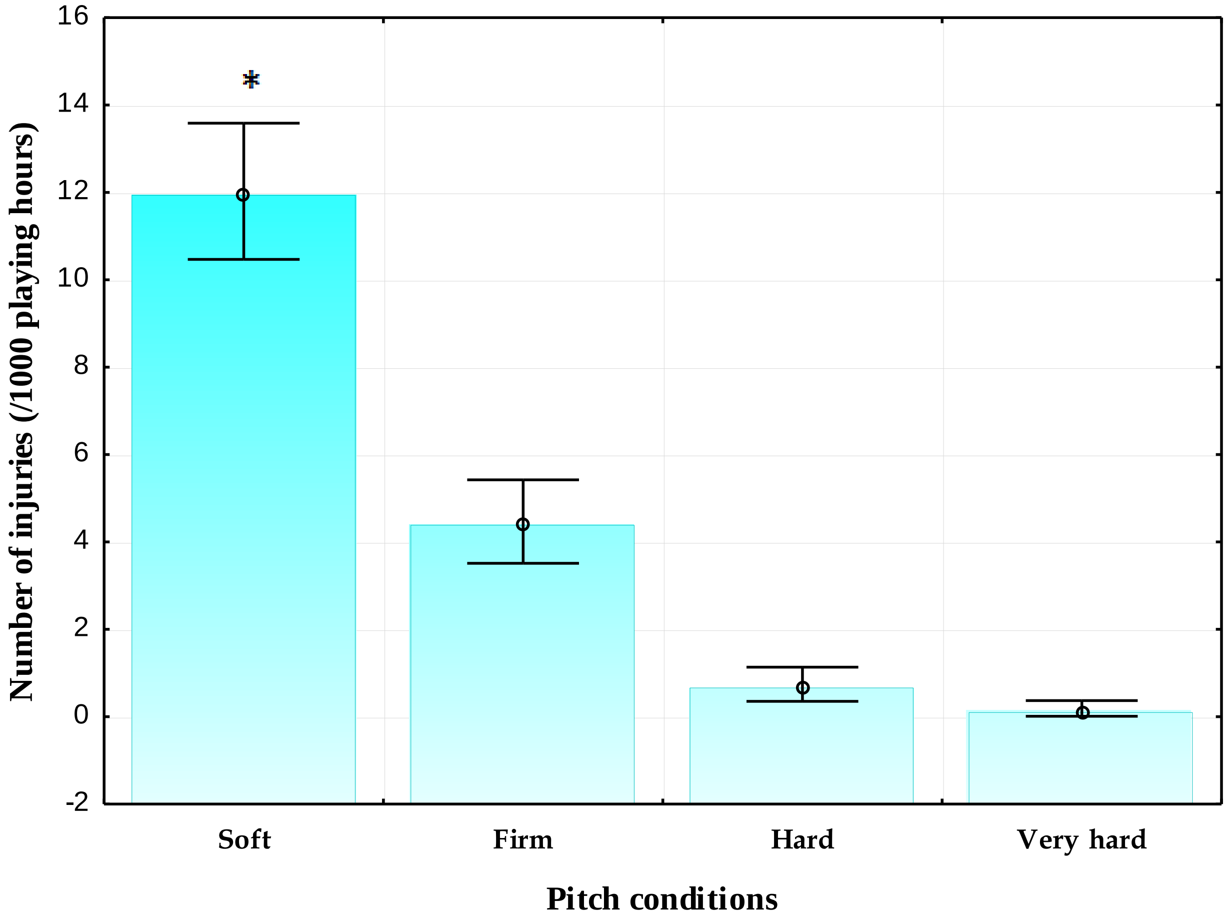


Figure 4.14.2.1: The rate of injury across different ground conditions across three playing seasons.

4.14.3 Weather conditions

In figure 4.14.1 it is shown that most injuries (105 injuries; 31.3%; 95% CI: 4.4 – 6.5) occurred in hot conditions, followed by cold (76 injuries; 22.7%; 95% CI: 3.1 – 4.9) and dry (59 injuries; 17.6%; 95% CI: 2.2 – 3.8) conditions.

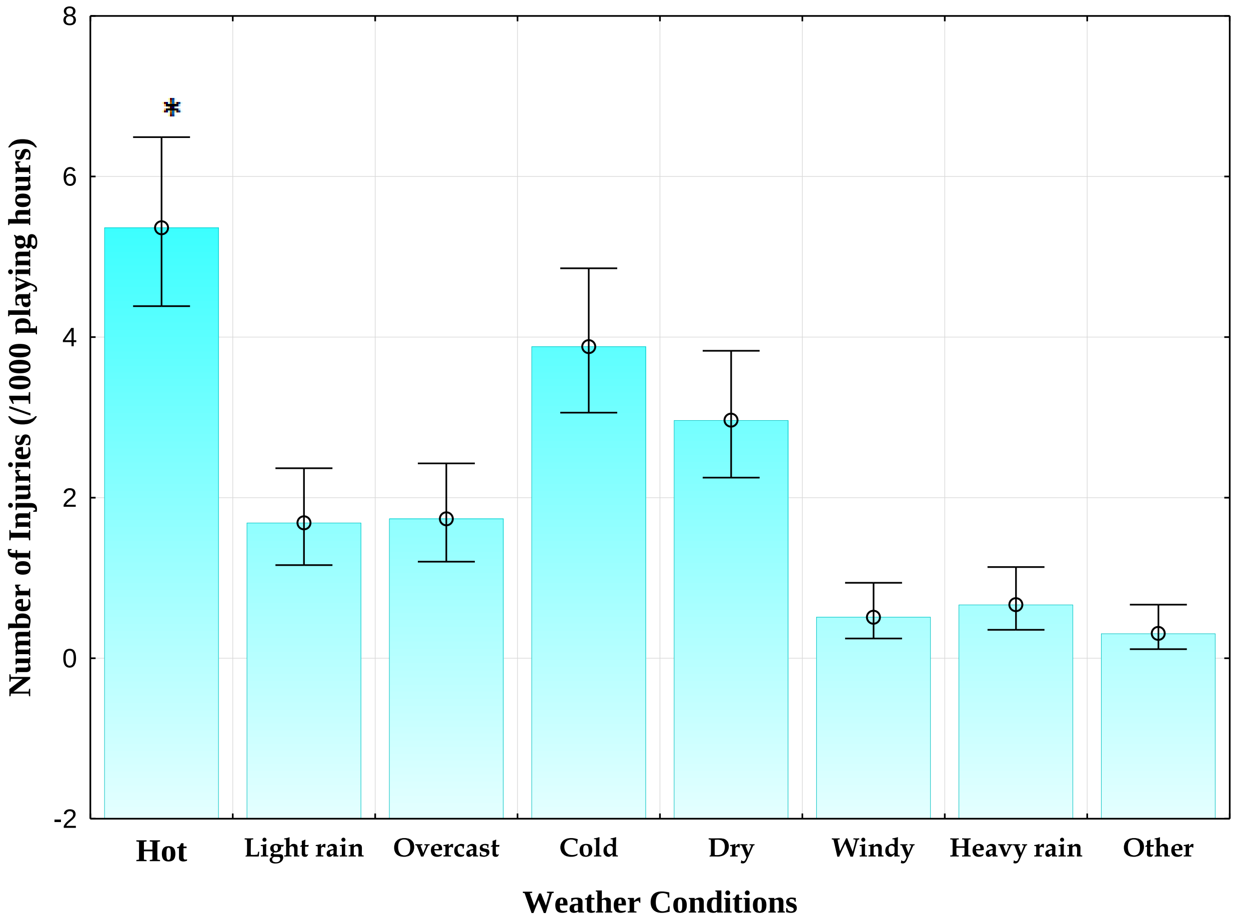


Figure 4.14.1: The number of injuries across different weather conditions per 1000 playing hours across three seasons.

As shown below in Figure 4.14.2, more shoulder injuries occurred in light rain (SD: 1.04) and overcast conditions (SD: 1.34) whilst more head (SD: 0.92), ankle (0.27) and knee (SD: 1.56) injuries occur in hot conditions. There are more facial injuries (SD: 0.31) in dry conditions and more hand injuries (SD: 1.67) in cold conditions.

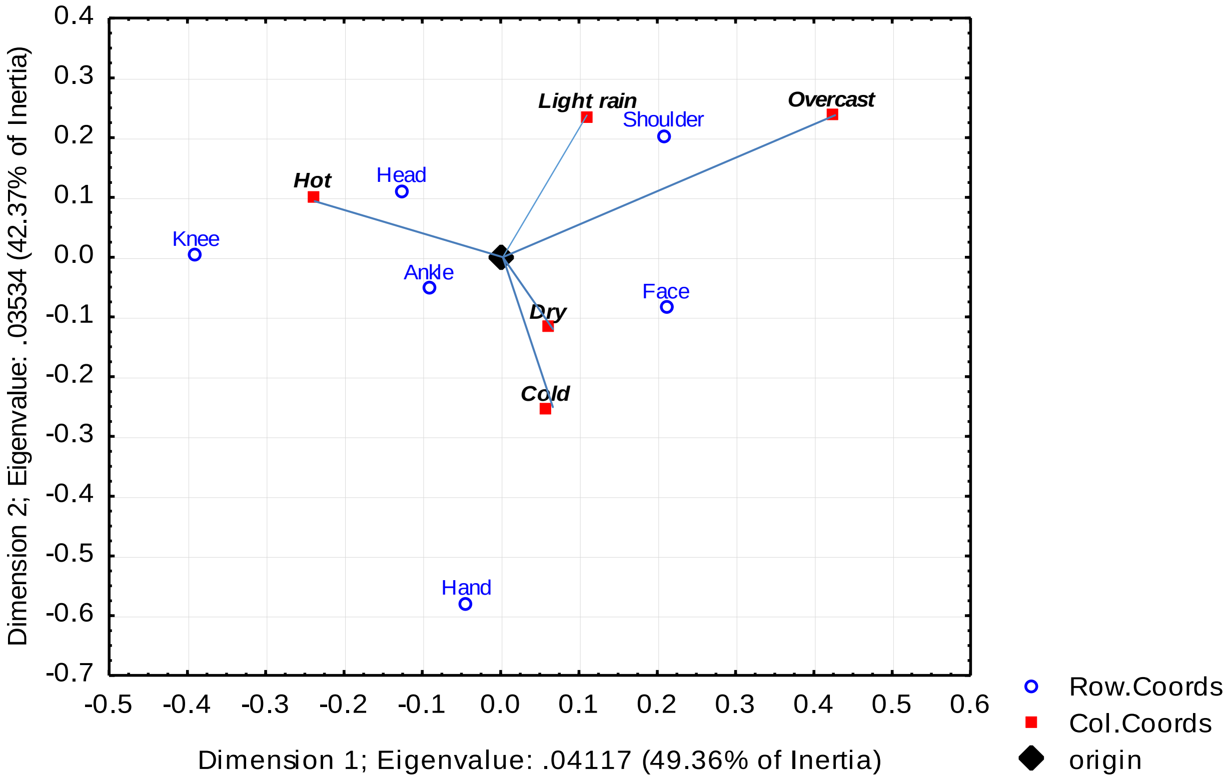


Figure 4.14.2: The relationship between anatomical locations of injuries and weather conditions. Weather conditions (shown in red) are plotted around the origin (black diamond). The closer the anatomical locations are positioned to the weather condition, the more injuries occur in that specific weather condition

4.15 Protective equipment

Figure 4.15.1 indicates the number of players who were injured whilst wearing protective equipment. Of the 335 injuries, 280 players (83.6%) were wearing mouth guards at the time of injury. 82 players (24.5%) were wearing shoulder pads, 27 players (8.1%) were wearing a scrumcap/ headgear and only 12 players (4%) were wearing strapping.

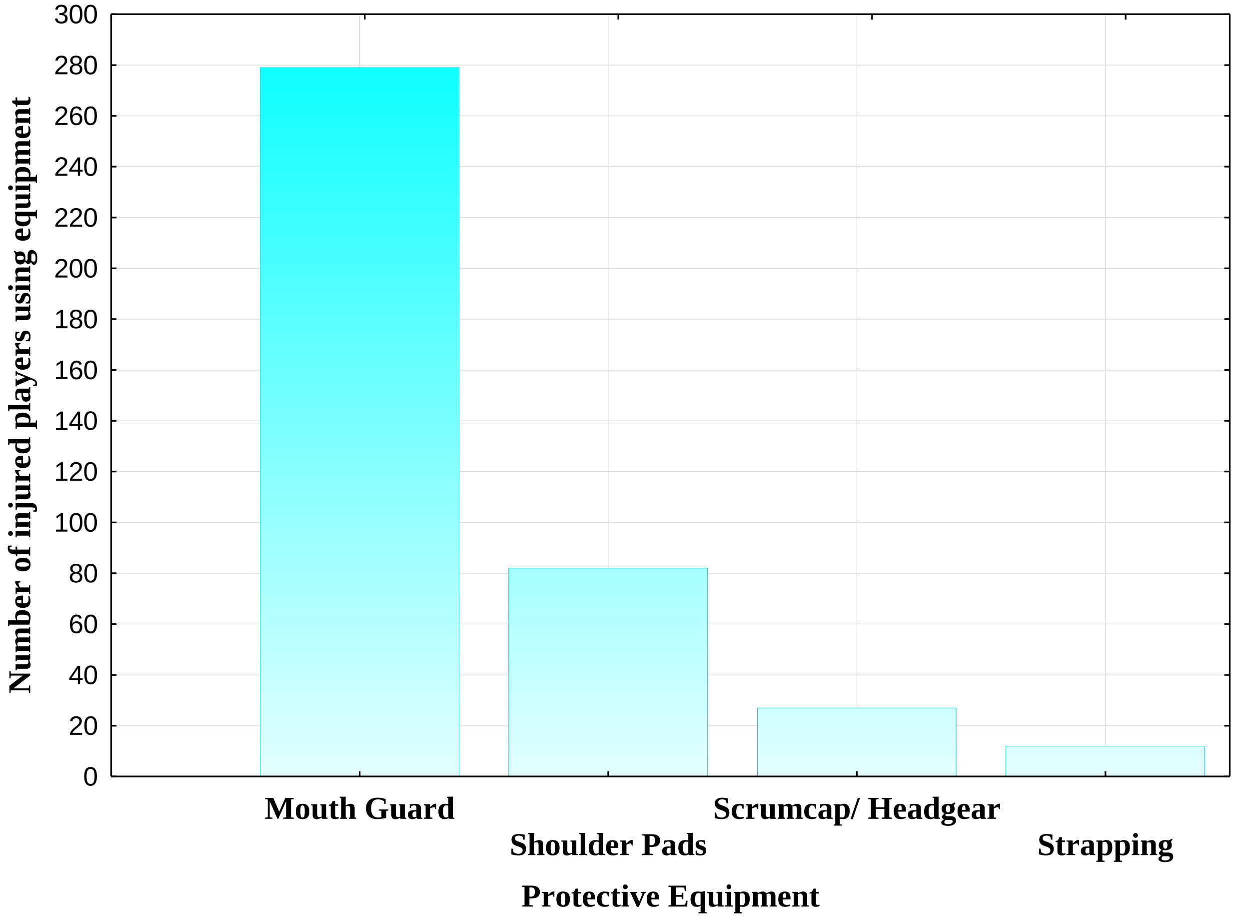


Figure 4.15.1: The number of players that wore protective equipment at the time of injury.

CHAPTER FIVE

DISCUSSION

5.1 Introduction

Rugby is a contact sport with one of the highest injury rates when compared to other sports. Injury surveillance studies have been done across many populations in order to gather data which may help identify possible ways to reduce injuries. Whilst most rugby populations have been studied (amateur, professional, schools), minimal research has been done on university hostel rugby players. The current study found most rugby injuries that occurred in the hostel leagues were head injuries, followed by shoulder, knee and ankle injuries. Most injuries occurred in the first half of the game and the beginning of the season.

The aim of this study was to describe the epidemiology of injuries sustained during hostel rugby matches at a university from 2011 to 2013.

The objectives for this study are:

- To determine the prevalence of injuries in hostel rugby union players at a university across three seasons.
- To compare injury statistics between Varsity Cup and hostel league.
- To determine the severity of the injury as well as the anatomical location of the injuries.
- To determine which playing positions are most affected and which phase of play these injuries occurred at.
- To determine whether incidence rates of hostel players at a tertiary level differ from other levels such as high school players, Varsity Cup players and senior professional players.
- To determine whether there are any trends in the injury data in relation to the academic calendar.

5.1.1 Number of injuries

Injury rates have been shown to vary according to the different rugby populations studied as well as the level of play. The current study shows that hostel players sustain a much lower injury rate compared to professional teams and in tournaments. This can be expected due to the higher intensity of the professional game as well as the increased size of players (Hendricks *et al.*, 2014).

The overall injury rates of the current study are slightly higher than school boy injury rates (Nicol *et al.,* 2011), but similar to those found by Kerr et al. (2008) who also assessed injury rates across 31 male and 38 female university teams in New England (USA). This being said, the injury rates found by Palmer-Green *et al.* (2013), who assessed 7 English school teams over 2 seasons (2006-2008), was much higher when compared to most school boy injury rates. This may be due to the fact that data was collected from well-established schools that perform well at national competitions as opposed to the average school boy rugby population.

Although the players who compete at the SARU Youth Weeks are considered school boy level, the skill level and physical conditioning is expected to be a lot higher because the players are the best players in their age group and in their province. Youth Weeks are highly competitive and involve the best provincial players, whilst the hostel games have a more social dimension to the matches which may account for the injury rates being higher than those reported in the current study.

Ras & Puckree (2014) found a much lower injury rate amongst first year academy rugby players who are the same age as most first year university students, but are in a professional academy setup. Roberts *et al.* (2014) performed a study which comprised of injury data from 4635 matches played by English community rugby clubs across the 2009/2010 season, 2010/2011 season and 2011/2012 season. The current study's results are higher than amateur teams and recreational/ social teams, but similar to those of semi-professional teams. This high injury rate emphasizes the need for injury surveillance studies on university rugby populations.

From the above comparisons, some conclusions may be made regarding hostel players. The first conclusion is that hostel players may be less likely to get injured when compared to school boy players. A possible reason for this difference may be due to the players being in different stages of their physiological development. The schoolboy players are adolescents who are more likely to endure rapid growth spurts which may decrease the strength of the growth (epiphyseal) plates of long bones. In this development stage, the growth plates increase in size but also become more fragile. The bones may become more porous because there can be a delay in bone mineralization which means there is a decrease in strength of the bones. The cartilage within the growth plate will be unable to resist large amounts of stress which places the joint at risk for injury (Caine *et al.*, 2008). There are a high number of fractures reported in adolescent rugby, especially in the collarbone and phalanges (fingers) and it is hypothesized that it is due to the above-mentioned factors (Wood *et al.,* 2010). Another possibility is that younger players may take more risks unlike slightly older players who may possibly be more cautious. However, this is purely speculation and future studies should consider investigating this matter.

Size mismatches also need to be taken into account, with hostel teams being comprised of players of different sizes and possibly also different skill levels. The literature confirms that there are definite changes in anthropometric and physiological characteristics with increasing age (Krause *et al.,* 2014). A first year student who is 17/18 years old may differ significantly from a fourth or fifth year student who is 22/23 years old as far as physical development. For example, Hamilton *et al.* (2014) reported a significant difference between the cervical strength of elite youth rugby players and adult players, with adults being stronger.

It is also known that there can be wide variability in physical size among players of the same age which has been identified as maturity-associated variation (Krause *et al.*, 2014). Players may be taller, heavier and stronger because of their early physical maturity (Caine *et al.*, 2008). These size mismatches may place some players at a higher risk for injury (Nutton *et al.*, 2012). Although smaller, slower and weaker players may mean that there is a reduction in impact forces between players similar to their size and shape, their risk for injury may only decrease when they are playing against players of similar size and shape (O'Rourke *et al.*, 2007). Injury rate will increase substantially if these smaller players were to play against larger players.

Fuller *et al.* (2013) reported that the average height and weight of national rugby players at the 2011 RWC was 186.2cm and 102.9kgs, respectively, whilst the average height and weight for the players in the current study was 179.9cm and 85.2kgs. It can be concluded that there is a significant difference between the size of professional rugby players and hostel rugby players. However, Fuller *et al.* (2010b) found no significant differences in injury rates of teams comprised of lighter and smaller players when compared to larger, heavier teams in the 2007 RWC. This may be due to the players being very well conditioned at international level so regardless of size, they are able to handle the physical nature of professional rugby. The conditioning level of hostel players is assumed to be of a much lower standard so whether they can handle the physical load of the matches is debatable.

Since rugby became professional in 1995, players have become assets to clubs and countries. Teams aim to have the best players so they can perform well in order to secure sponsorships, television rights and ticket sales (Malcom *et al.,* 2000). Some players in the professional setup may hide their injuries because they are on an incentive based contract and they lose match fees if they do not play. In the hostel league, this situation does not occur because players do not play for financial gain. There is, however, great pride and reputation to uphold so the players may feel pressured to play. They may also be pressured by the senior men within the residence to play for the team. This pressure may result in a high level of anxiety which increases the player's risk for injury (Van Niekerk & Lynch, 2012).

Another possible reason why the injury rate may be lower in comparison to previous studies might be due to the data capturing process itself. It can be assumed that teams who have medical professionals at training and matches will report higher injury rates because all injuries will be seen and reported by the medical professional.

In this study, the medical rooms were some distance from the fields where the hostel league matches were played and although first aid staff was present at the fields, some injuries may have been missed because players did not report to the medical room. The possibility that the injury incidence rate in this study is an underestimation of the true rate among hostel players is therefore a reality. Players who do not report their injuries or seek further medical attention are at risk for more severe long term effects. Baker *et al.* (2012) reported that only 36 out of 64 U20 players in Ireland sought medical attention after a concussion. A finding such as this highlights the importance of having a first aid representative with every team. They would be able to monitor their own players and refer them to the medical room for assessment (Brooks *et al.,* 2005).

The standardized definitions used in the Boksmart questionnaire may also have had an effect on the identification of the type of injuries and injury rates and thus the differences in the reported incidences among studies (Fuller *et al.,* 2007c). The Boksmart definitions are more descriptive which makes the results more specific in terms of the nature of the injury, whereas previous research may have grouped injuries into larger categories.

The differences between the injury rates of university students compared to other populations may be due to factors that are specific to each population. In other words, although some generalizations can be made, each population group is unique. Factors such as player's skill level, attitude towards the game, conditioning standards, coaching staff and the environment (i.e. university, club, province, etc.) affect players from different populations in a variety of ways. This wide variation reduces the ability to generalize about certain rugby populations and emphasizes the need for specific research in each area, which also supports the value of the current study.

5.1.2 Hostel vs Varsity Cup rugby injuries

Below is a table which compares two university rugby populations, the Varsity Cup teams and the hostel league teams. Hillhouse (2014) studied the Varsity Cup competition which is a premier division tournament whilst the hostel leagues in this study are social. There were more match injuries during the Varsity Cup which may be due to the higher level of play. There were more head injuries in the hostel league but the head features highly on the injury list in the Varsity Cup which is an important finding in university students. Most injuries occurred during the tackle in both divisions but it can be assumed that the reasons may be different because of the level of play. Varsity Cup players are technically the best players in the university so it can be assumed that their tackle technique is correct and their injuries may have come due to the high-impact and fast pace of the game. Tackle injuries in the hostel players may be due to poor tackle technique. The timing of the injuries makes for an interesting comparison because it would be expected that hostel players are not as fit as Varsity Cup players so their injuries would occur later on in the game due to fatigue. However, this assumption is not supported by the results.

Table 5.1.2: A comparison of injury statistics between the Varsity Cup and the hostel league:

Results:	Varsity Cup:	Hostel League:
Number of injuries (/1000 playing hours)	178 (6.1/1000 playing hours) Match: 125 (89/1000 playing hours)	335 (17.5/1000 playing hours)

New injuries vs previous injuries	120 (4.1/1000 playing hours) vs 52 (2.0/1000 playing hours)	273 (13.9/1000 playing hours) vs 48 (2.9/1000 playing hours)
Mechanism	Tackle	Tackle
Anatomical location	Ankle/ foot (15.9%) Head (15.3%) Shoulder (11.4%) Hamstring (10.2%) Quads (9.7%)	Head (24%) Face (23%) Shoulder (13%) Knee (10%) Anle (7%)
Forwards vs Backs	Forwards: 63.4% Backs: 36.6%	Forwards: 48% Backs: 51%
Type of injury	Strains (18.9%) Sprains (18.3%) Contusions (10.9%) Concussion (9.1%)	Lacerations (23.6%) Joint sprain (16.1%) Concussion (15.5%) Ligament injury (11.9%) Broken bone/ fracture (11.9%)
Timing of injury	4th quarter (30.7%) 2nd quarter (26.7%)	1st quarter (29.9%) 2nd quarter (27.5%)

5.2 Time loss vs medical attention injuries

This study showed that there were significantly more time-loss injuries as opposed to medical attention injuries which concur with most literature (Sedeaud *et al.*, 2012; Kaplan *et al.*, 2008). With most injuries being time-loss injuries, it can be concluded that the injuries were severe enough for the player to miss training or playing a match. These results are also similar to research by Brown *et al.* (2012) who performed injury surveillance during the 2011 interprovincial youth rugby tournaments (SARU Youth Weeks). A study by Roberts *et al.* (2013) assessed English community clubs over 3 seasons (2009-2012) in 4635 matches and chose to report on time-loss injuries only (16.9/ 1000 playing hours) because of its significance of missing training/ match days. However, Hodgson *et al.* (2007) claimed that between 8% and 30% of all injuries may be missed if one only reports injuries that result in missed matches, which would support the need for a more rigorous injury surveillance system.

During the 2012 Super Rugby Tournament, 55% of the South African players sustained a time-loss injury over the 21 weeks (Schwellnus *et al.,* 2014). This means that more than half of the South African players were unavailable to play because of injuries. With a 21 week competition, it is vital that player rotation systems are implemented so playing exposure per individual may be reduced. This will in turn reduce the risk for injury and more players will be available for selection.

In hostel rugby, although player rotation was not investigated for this study, possible suggestions may be made as to why the injury rates differed according to other tournaments. The hostel league is of similar duration to the Super Rugby Tournament but players may not be able to rotate as needed because of the lack of numbers within the residences, especially in the smaller ones. Alternatively, it is possible that players rotate too much because of other university commitments and either they are at a higher risk for injury because of lack of game time or they are unfamiliar with the other players on the field. The season is technically comprised of two sections which are played over 2-3 months, which would mean that player rotation is not necessary because the match exposure isn't very high. Super Rugby tournaments span across 6-7 months making player rotation vital in order to ensure optimal team performance.

5.3 Injury severity

Injury severity constitutes the number of days that have elapsed from the date of the injury to the date of the player's return to full participation team training and availability for match selection (Fuller *et al.,* 2007c). It is important to classify the severity of injuries in order to assess the impact of the injuries on the team, as well as other aspects of life.

The majority of the injuries reported were of moderate severity which means that 8-28 days of training/ playing are potentially missed by the player. Similar results were found in first year South African rugby academy players, with most of the injuries (37%) being of moderate severity (Ras & Puckree, 2014). Comparable results were found in higher levels of play, such as in the 2012 Super Rugby tournament, with close to half (42%) of the injuries sustained by the South African teams being of moderate severity (Schwellnus *et al.,* 2014). Of these injured players, 42% of them were unable to play for more than one week.

Injury severity does, however, differ according to anatomical locations. Knee injuries in rugby players have been shown to cause a large number of days missed. During one season in the English Premiership clubs, 353 days of training were missed due to knee injuries (Dallalana *et al.*, 2007) and 241 days were missed due to shoulder injuries (Headey *et al.*, 2007). Swain *et al.* (2011) found that neck injuries amongst Australian club rugby players are usually classified as minor injuries (69.3%), followed by mild (17%), moderate and severe (6.8%). Although the data from the two seasons from the study by Swain *et al.* (2011) seem more positive than the results of the current study because the majority of neck injuries were minor, these injuries tend to be significantly more severe when compared to for example injuries of the ankle or knee. Schneider *et al.* (2013) found that 7-10 days are needed for proper recovery from a mild concussion, however, the length of recovery depends on the age of the person and younger individuals take far longer to recover completely due to the brain still being in the developmental stages (Halstead & Walter, 2010).

Injuries such as concussions have been shown to impair a player's cognitive ability, especially with regards to their memory and attention (Moser *et al.*, 2005; Petteson, 2002). Smith (2006) assessed the effects of concussions on university rugby players, specifically before and after a season, and compared them to a non-contact sport control group (swimmers and cricket players). The results showed that the memories of the rugby players were reduced, along with their ability to process information quickly and control their impulses. Injury severity is of particular significance to university students because an injury of moderate severity means several days off attending class or studying. This may in turn affect their academic performance which can have a negative influence on their future career opportunities.

5.4 Level of play

Players are divided into teams according to their abilities. In general, the higher the division (first being highest), the better the player's abilities. Division 1 comprises of the top teams from each hostel and the players are generally the best players in the hostel who are not playing for the university club teams. The higher the level of play, the more the injury risk increases as explained in previous chapters. The standard of play generally becomes lower as the number of the division increases.

This study showed that more injuries were sustained by players in the higher divisions (Division 1: 111 injuries; Division 4: 49 injuries). Therefore it can be concluded that the higher the level of play, the higher the rate of injury. Similarly, Palmer-Green *et al.* (2013) reported a higher injury rate in academies when compared to schools. Brooks and Kemp (2008) reported a lower injury rate in senior amateur rugby and school boy rugby when compared to professional players. There is one exception, though. Takemura *et al.* (2009) reported an injury rate during matches of 69.74/ 1000 playing hours in Japanese university players over one season, which is significantly higher than the results of the current study.

Injury rates in the professional divisions are much higher than those depicted in the current study (Brooks & Kemp, 2008). Best *et al.* (2005) found a significantly higher injury rate of 97.9/ 1000 playing hours during the 2003 RWC. This may be due to the professional game being much faster and more physical, players being larger which means higher impact forces, as well as more pressure placed on the outcome of the game due to financial benefits which mean players are more motivated to play hard (Smart *et al.*,2013). Furthermore, Williams *et al.* (2013) suggested that longer seasons, higher levels of competitiveness and efficient injury data capture systems are other factors that must be considered in the higher reported injury rates in professional rugby.

The results from this study are thus typical considering the level of play within the hostel league. Players in Division 1 are the pride of their hostel and are generally better conditioned and more skillful. A lot of pressure is placed on the players to perform well in order to uphold the reputation of the hostel. This is shown in the large number of spectators present at the matches during the week. The coaches from the University club teams also often attend Division 1 matches to scout for talented players for their teams that play in the Western Province Leagues. All these factors may contribute to the pressure on the players and therefore the higher rate of injuries. The lower divisions, although competitive, tend to be more social when compared to Division 1.

5.5 Years of experience

The number of playing years has an influence on players' ability to perform certain skills on the field, as well as cope with the physical demands of the game. Rugby requires many technical skills, such as tackling and scrummaging. It can therefore be expected that the more experienced the player is, the less likely they will injure themselves when performing these skills. This is, unfortunately, not necessarily the case as is evident from the high injury rates in professional rugby. This just highlights the multiple factors that affect injury rates in rugby, as discussed previously. In this study, the majority of the injuries (181, 54%) occurred to players who had been playing for more than 4 years.

McIntosh *et al.* (2010b) analysed video footage of 400 games from matches ranging from U15 level up to the Australian national team. These data were collected as part of the Rugby Injury Surveillance Study during 2000 - 2006. They found that players below the age of 15 years were less likely to be injured during the tackle, as opposed to senior players who had been playing for a substantially longer period of time. They also noticed a difference in tackle technique, with senior players with higher skill levels being able to execute more active shoulder tackles (the tackler's shoulder is the first point of contact, they engage in a leg drive and achieve forward momentum) as well as smother tackles (tackler engages the ball carrier with his arms wrapped around the ball carrier, trapping the ball) than players between the ages of 15 and 20 years who engaged in more passive tackles (the tackler's shoulder is the first point of contact but there is no leg drive and forward momentum). There were also more missed or broken tackles amongst the younger age groups which indicate a lack of technical ability. Van Rooyen (2012) assessed the 6 Nations, Tri-Nations and RWC in 2011 and also found that players at a higher level had a better tackle technique.

Although it can be assumed that the longer a player is involved in the sport, the more capable they become in executing the sport specific techniques, this does not necessarily protect them from injury. This trend is shown with the increase in injury rate as the level of the player increases (Brooks *et al.*, 2012, McIntosh *et al.*, 2010b; Fuller *et al.*, 2008). While it may be assumed that the hostel players have a high level of experience because of the number of years the players have been playing for, the level at which they have played the game might not be so high as to ensure they are technically correct and physically conditioned. Hostel players are generally players that are not good enough to play in the university club teams so despite the fact that they may have played the game for several years, it may be at a low skill level (e.g U19F team in school). Therefore, they may not have mastered the techniques necessary for rugby. However, the same cannot be said about the division 1 teams because players are often drafted into the university club teams during the season.

5.6 Type of injury

Lacerations, joint sprains, concussions and ligament injuries were significantly more often reported than most other injuries. Although the injury rate for lacerations was not significantly higher than joint sprains and concussions, it was significantly more than the other injuries (Figure 4.6). There was a large difference of injury rates between joint sprains and concussions compared to the other injuries, with the exception of broken bone/ fractures and ligament injuries. The high number of broken bones/ fractures is a noteworthy finding due to the extended period of recovery needed for this type of injury (6-8 weeks).

Similar results were found by Schwellnus *et al.* (2014) during the 2012 Super Rugby tournament, with muscle/tendon injuries making up 50% of the injuries and joint/ ligament injuries 32.7%. Palmer-Green *et al.* (2013) also reported similar results within the schools and academies in England over two seasons, with the joint/ ligament injury rates being 24/1000 playing hours in academies and 14/1000 playing hours in schools. Both incidence rates were significantly higher than any other injury type.

In the current study, the shoulder (32) was the area where most joint and muscle/ tendon injuries occurred, followed by the knee (24) and the ankle (19). According to Van Niekerk and Lynch (2012), shoulder injuries make up 6-19% of the total joint injuries in rugby in general. McIntosh *et al.* (2010b) reported that 61% of the injuries sustained across the levels (school boys to elite level) were sprain/strain injuries. Very few dislocations (3) were reported, which is similar to the current study, however, the number of fractures reported (2) was substantially lower than in the current study. This was also true of the concussion results, with only three concussions being reported compared to the 52 in the current study.

The number of concussions in this study was also higher than previous research by Shuttleworth-Edwards *et al.* (2008). They assessed 5 schools, a university team, a premier club team and a provincial group. They found that concussions formed approximately 23% of all injuries, compared to the 33% of the current study. Sixty four out of 133 U21 rugby players in Ireland claimed to have sustained a concussion in the previous season, which is just below half of the total group. Cusimano *et al.* (2010) claimed that concussions in rugby union are the third highest injury type, which is similarly reflected in this study.

In Australian League Football, head and neck injuries steadily decreased over the years as rule changes, such as illegal head contact, were brought in. Concussions, however, have increased slightly over the years although the reasons for this are not necessarily due to the game itself. There has been an increase in research on concussions and the improvement of the management of concussions which has meant that the medical staff tend to be overcautious and are better prepared to identify and handle players with concussions (Orchard *et al.*, 2013).

There were a high number of joint sprains as opposed to tendon and muscle strains. This may have been due to a general (entire joint) diagnosis being given at the time of the initial injury because a specific diagnosis (tendons, ligaments & muscles) may have been difficult. For example, a player may have injured their knee but due to pain and inflammation, the medical doctor may have been unable to obtain a clear and accurate diagnosis so they sent the player for further scans and testing. Fong *et al.* (2009) reported that ankle injuries are often misdiagnosed initially and recommends further testing for an accurate diagnosis.

A possible reason for the high number of injuries of an unknown status may be that diagnosis directly after the injury was difficult. Swelling, pain and muscle spasms may have prevented the medical doctor from making a clear diagnosis. Players were encouraged to visit the Injury Clinic at Campus Health in the days following the initial injury in order for a diagnosis and further referrals to be made. However, this protocol may not have been followed.

In previous injury surveillance research, it has been shown that the lower limb is the site where most injuries occur (Ras & Puckree, 2014; Schwellnus *et al.*, 2014; Palmer-Green *et al.*, 2013; Williams *et al.*, 2013; Brooks & Kemp, 2008; Brooks *et al.*, 2005; McIntosh, 2005; Bathgate *et al.*, 2002), but this is not the case with the hostel players (23.2%). The head has also been noted as an area with a high number of injuries (Bathgate *et al.*, 2002) which was also found in the current study. Amongst women players, the shoulder, knee, ankle neck, finger and head were the main areas of injury (Comstock & Field, 2005), which are also very similar to the injury patterns identified in the current study. In first year academy players in Durban, the more commonly injured areas over one season included the knee (30; 25%), ankle (25; 21%), shoulder/ collarbone (18; 15%) which is similar to the results of the current study except there were very few injuries to the head/ face (8; 6.8%) (Ras & Puckree, 2014).

Schwellnus *et al.* (2014) reported the knee, thigh, shoulder and clavicle as the areas with the highest injury rates in South African Super Rugby players. Palmer-Green *et al.* (2013) provided a more general division of injuries sustained by school and academy players. The results for the academy and school players were as follows: head and neck (academy 13.8%; school 17.8%), upper limb (academy 28.4%; school 24.4%), trunk (academy 2.8%; school 10.4%) and lower limb (academy 55%; school 47.4%).

When focusing on specific phases of play such as the tackle, the tackler was more likely to injure their upper body while the ball carrier is more likely to injure their lower body (Sundaram *et al.*, 2011). The results of the current study concur with this statement as most tackle injuries affected the upper body; however, the ball carrier was more susceptible to upper body injuries rather than lower body injuries. The majority of the neck injuries occurred in the ruck situation as well as during the scrum and they were classified as moderately severe (8-28 days missed).

5.7 Anatomical location

In rugby, most areas of the body are susceptible to injury. It is important to identify which areas sustain the most injuries, as well as the reasons, so appropriate prevention strategies can be designed. Protective gear has been developed in order to help the more vulnerable areas of the body such as the head, teeth and shoulders. The effectiveness of this gear will be discussed later.

The majority of the injuries found in this study were to the head (82; 24%) and face (78; 23%) which is slightly different to most literature which shows the lower limb with the highest injury rates. In a study by McIntosh *et al.* (2010b) the injury distribution was slightly different, with the lower limb sustaining the highest injury incidence, namely thigh (18.2%) and knee (15.2%), followed by the shoulder (13.6%), head/face/neck (12.1%), ankle (9.1%), trunk (7.6%), lower leg (6.1%), wrist/hand/fingers (6.0%), elbow (4.5%) and unspecified (7.6%).

The number of concussions may be higher than normal because there was a medical doctor on duty during every match which meant players were able to be assessed correctly. This finding supports the necessity for medical doctors to be on duty despite the social nature of the hostel leagues.

Lack of technique may be responsible for the high number of head and facial injuries with hostel players generally playing at a more social level. Most injuries occurred in front-on tackles which supports the notion that the players are not using the correct tackle technique of leading with the shoulder and placing the head to the side of the ball carrier.

After head injuries, the shoulder, knee and ankle had the highest injury rates. These joints are vital in carrying out activities of daily living and may impact a student's success in the academic environment because they may be unable to attend classes.

5.8 Playing position

The current study reported a small difference in the number of injuries between backs and forwards, with forwards marginally having the highest injury rate. Backs sustained more head, shoulder and hamstring injuries, whilst forwards sustained more knee and ankle injuries. Injuries can be related to the player's position specific duties on the field but the results of this study provide contradictory data. Backs generally run and change direction at higher speeds than forwards so one would expect that they would not only sustain the most hamstring strains but also more knee and ankle injuries. This may also mean that strength and conditioning coaches and Biokineticists should strengthen these areas which are prone to injuries. The results of the current study are in accordance with those of by Brooks and Kemp (2011). These researchers assessed 14 English Premiership rugby clubs (899 players) over 4 seasons and showed that backs and forwards were most likely to injure their shoulders and knees. However, forwards were more likely to injure their ankle/heel, whilst backs were more likely to injure their hamstrings.

This finding is in accordance with Hillhouse (2014) who found that more forwards were injured during the Varsity Cup tournament in 2011 than backs. Ras & Puckree (2014) found contradicting results in rugby academy players in Durban, with backs making up the majority of the injuries (57% vs 43%). Brooks *et al.* (2005) did, however, find that despite the backs having higher injury rates than forwards, the severity of the injuries was greater among forwards. Furthermore, MacQueen & Dexter (2010) stated that if spinal cord injuries are isolated, forwards generally have a much high injury rate compared to backs.

Previous research has also identified specific positions as being more prone to injury. Bathgate *et al.* (2002) analysed the Australian national rugby team and highlighted the lock and flyhalf as being the positions with the highest injury rates amongst forwards and backs, respectively. They also noted that the scrumhalf was least likely to be injured. Hillhouse (2014) found locks (15.2%), props (12.9%), centres (9%) and wings (84%) to have the highest injury rates in the 2011 Varsity Cup tournament. Previous research has also highlighted the tackle as the phase of play that is responsible for the most number of injuries (MacQueen & Dexter, 2010; McIntosh *et al.,* 2010b; Fuller *et al.,* 2010d; Quarrie *et al.,* 2008).

Although the difference in injury rates between backs and forwards among hostel players was small, it is possible that their style of play may explain the higher number of injuries among the back players compared to other studies. In general, forward players are more involved in tackling (Van Rooyen, 2012) and close contact due to their position specific duties, whilst the backs are involved in more running and open play. The assumption that could be made in the hostel league would be that the overall style of play is more expansive which requires the backline players to make a higher number of tackles, therefore explaining the higher head and shoulder injury rate. Furthermore, hostel players are deemed to play at a more social level when compared to clubs and provincial teams and therefore they may lack structure in their game play. This assumption is supported by the fact that backline players like the wings, centres and fullbacks have higher injury rates when compared to other positions.

One of the risk factors identified in tackles is the speed at which the players are running prior to and into the contact, with higher speeds causing more injuries (Fuller *et al.*, 2010d). In general, backs cover longer distances during matches and they run at faster speeds more often when compared to forwards (Cuniffe *et al.,* 2009). According to Cahill *et al.* (2012), backs were generally standing or walking more than forwards, whilst forwards were jogging for the majority of the match. It was also found that flanks, specifically open-side, covered the same distance as wings and fullbacks which may explain the high injury rate in flanks found in this study. The lower injury rates amongst the first and second row forwards may be explained by the much lower distances that are generally covered by these positions. There is no need for them to cover major distances because position specific duties require them to assist the team in maintaining the possession during breakdowns and help secure the ball during set piece plays (Cahill *et al.,* 2012).

5.9 Phase of play

The results of this study correlate with current research which identifies the tackle as being the phase of play where most injuries occurs (Roberts *et al.,* 2014; Fuller *et al.,* 2010d; Bathgate *et al.,* 2002). According to Hendricks and Lambert (2010), up to 61% of injuries occur during the tackle. This will be expanded on further in the following section. Several tackling conditions have been assessed in research and from an injury prevention perspective, the number of tacklers and the sequence of tackler contact with the ball carrier (one-on-one/simultaneous/sequential) are areas which should be focused on (McIntosh *et al.,* 2010b). King *et al.* (2012) found that the most frequent injuries occurred when there were two tacklers involved on the ball carrier. The ball-carrier was also most frequently injured when they were tackled behind their field of vision. These results can be used to recommend correct coaching techniques in order to reduce the risk of injury in the tackle situation.

Despite ruck injuries having the second highest injury rate, it was much lower than previous research described by Fuller e*t al.* (2007b), who reported an injury rate of 7.0 and 2.3/1000 playing hours in each phase of play, respectively. This may provide insight into the style of play of the hostel teams. The hostel teams may play an unstructured game due to the more social dynamics of the league which would mean that there is a decrease in the number of rucks in the game as the players attempt to keep the ball alive.

Scrums have been an area of concern due to their propensity to cause severe injuries such as neck and spinal cord injuries (Trewartha *et al.,* 2014; Kuster *et al.,* 2012; MacQueen & Dexter, 2010; Gianotti *et al.*, 2008). More recently it was found that 33% of catastrophic injuries in South Africa occurred in the scrum (Hendricks *et al.*, 2014). Although there were a small number of injuries that occurred during the scrum in this study (n = 6), the severity of these injuries is generally higher than other injuries (Trewartha *et al.,* 2014; Fuller *et al.,* 2007a; Berry *et al.,* 2006). In fact, most scrum injuries are of moderate severity (8-28 days). It should also be noted that the injury rate in scrums may actually be underestimated due to the fact that the exposure rate formula is calculated using 15 players, while only 7 of these players are forwards who are actually involved in the scrum (Brown *et al.*, 2014).

The number of phases of play has changed over time as rugby has progressed and the injury patterns for catastrophic neck injuries have shifted to tackles (Brown *et al.*, 2013; Kuster *et al.*, 2012; Dunn & van der Spuy, 2010; MacQueen & Dexter, 2010; Shelly *et al.*, 2006). Hermanus *et al.* (2010) reported more SCI's occurred in the tackle (45%) than in the scrum (36%). Law changes have changed the style of play and players are expected to cover longer distances at a faster pace on the field, while the ball is in play for longer periods of time (Williams *et al.*, 2013).

5.10 Mechanism of injury

Injuries caused by tackling front-on were significantly higher than all other injuries, except collisions and tackling side-on. The other mechanisms of injury had a relatively low incidence of injury and were not significantly different from another.

In previous research, the injury rates in the tackle have been divided into injuries that occur whilst being tackled and injuries that occur whilst making a tackle. Most research has shown that the ball carrier is more vulnerable to injury rather than the tackler and this trend is seen from English community level rugby (Roberts *et al.*, 2014) to Rugby World Cups (McIntosh & Savage, 2005). Palmer-Green *et al.* (2013) found a similar trend in school and academy rugby players with the ball carrier sustaining 30% and 32% of all the injuries and the tackler sustaining 21% and 25%, respectively. Comstock and Fields (2005) reported that in female rugby players in the USA, more players were injured by being tackled (30.4%) as opposed to tackling (27.5%). Schwellnus *et al.* (2014) found the opposite was true in Super Rugby players during 2012 with more players being injured whilst tackling than being tackled (26.3% vs 23.1%). Schneiders *et al.* (2009) reported similar results for New Zealand premier club matches with 28.8% of injured players sustaining an injury when making a tackle and only 19% of injured players were ball carriers. Several significant risk factors were identified for ball carriers and tacklers, namely, going into the tackle at high speed, high impact force, collisions and contact with a player's head/neck (Fuller *et al.*, 2010d). These results highlighted the necessity of correct technical skills training and conditioning for all rugby players.

Collisions boast the second highest injury rate. A collision is defined as “a tackler (who) impedes/stops ball-carrier without the use of arm(s)” (Hendricks & Lambert, 2010). During a match, players are exposed to high impact contact from other players as well as the ground. This impact causes neuromuscular fatigue in addition to muscle damage which may take up to 48 hours to recover (McLellan & Lovell, 2012).

The direction in which the tackle was made may influence the risk for injury, with Brooks *et al.* (2005) finding that more injuries occur during front on tackles than side on tackles. McIntosh *et al.* (2010b) highlighted both front on and side on tackles as being responsible for most tackle injuries, which is similar to the data found in this study with there being no significant difference between the number of front-on and side-on tackles. More SCI’s are sustained during tackles, especially during spear tackles, and the ball carrier is more susceptible to this injury (Hermanus *et al.*, 2010; McIntosh *et al.*, 2010a). Tackling, especially front-on tackles, require very good technique to be effective and non – injurious. Thus, with the hostel league being classified as more social, they may not receive proper coaching and the players might not focus on using the correct technique and this may be a reason for the high number of injuries during front-on tackles. Fuller *et al.* (2015) suggested that by improving tackle technique, injury rates are likely to decrease. More specifically, during training this tackle technique should include driving into tackle bags as opposed to simply diving on them (Hendricks & Lambert, 2010).

The anatomical location which is more likely to be injured when a player is making a tackle is the head, neck and shoulders (Hendricks & Lambert, 2014). The authors proposed that the reason for this was that the tackles were made too low and the tackler collided with the forceful, moving legs of the ball carrier. The ball carrier is most at risk for lower body injuries due to the tackler’s speed and angle of contact, as well as the physical loading onto the lower body when the tackler tackles the ball carrier. This combined with the possible lack of conditioning of hostel players places them at a high risk for injury duringtackles.

Minimal injuries occurred due to foul play (head butt or high tackle) which emphasizes the more social atmosphere of the league. Although there have been positive correlations between high levels of aggressive and illegal play and the will to win in previous studies (Maxwell & Visek, 2009), there have been minimal injuries reported due to foul play.

5.11 Previous injury

The present study used the definition from the consensus statement by Fuller *et al.* (2007c) which states that a recurrent injury is "an injury of the same type and at the same site as an index injury and which occurs after a player's return to full participation. Fuller *et al.* (2007c) also included an exacerbation which is "worsening in the state of a non-recovered index injury, such that the player misses further training and/or match play." These additions and discrepancies in the literature make comparisons across the literature difficult.

Most injuries reported in this study were new injuries (273; 81.5%) which are in accordance with the literature (Roberts *et al.*, 2014). In previous research, most injuries were found to be new (or acute) injuries rather than chronic injuries (Williams *et al.*, 2013; Bathgate *et al.*, 2002) although this variable has been difficult to calculate due to the difference in the definitions of the nature of injuries (Fuller *et al.*, 2007c). Recurrent injuries generally have a higher severity as opposed to new injuries (MacQueen & Dexter, 2010). The same may be concluded from this study, with 68.8% of the recurrent injuries being of moderate to severe severity and only 38.1% of the new injuries were of similar severity. Also, players who have reported previous injuries are generally at a higher risk for re-injury (Ogaki *et al.*, 2014).

One of the major risk factors for rugby injuries is when players who have sustained a previous injury return to play too early before they have completed the full rehabilitation protocols (Chalmers *et al.*, 2013). Rugby specific rehabilitation is needed in order to return to play successfully and reduce the risk of further injury (Eaton & George, 2006). Although the medical services are of a high standard at Stellenbosch University, with a Sports Clinic, Physiotherapy and Biokinetics Centres available on location, it is possible that the hostel players do not complete appropriate treatment plans for their initial injuries. This may account for the high number of moderate to severe re-injuries.

5.12 Timing of injury

The results of this study indicate that most injuries occurred during the first quarter, which contradicts most research that reported the highest incidence of injuries in the last two quarters of the match (Brooks *et al.*, 2006; Brooks *et al.*, 2005; Best *et al.*, 2005). More specifically, the third quarter has been highlighted as the time period where most injuries occur. Fatigue is said to be the major factor influencing the injury rate in the second half of the game (Schneiders *et al.*, 2009; Best *et al.*, 2005; Bathgate *et al.*, 2002).

Cuniffe *et al.* (2009) used global positioning systems (GPS) to analyze the demands of rugby. By calculating work to rest ratios (how much players ran compared to rest) and the running distance per minute, they showed show that the third quarter of a game was the most intense. With the second half being responsible for the most number of injuries, it was proposed that fatigue was the main reason for this increase. However, a noteworthy finding in this study showed that 66% of the high level impacts also occurred in the second half. Players were also able to reach their maximum speed in the second half. This supports the reported increase in injuries as most injuries occur during contact, but lessens the likelihood that fatigue plays a major role.

Brooks *et al.* (2006) found that most hamstring injuries occur in the last quarter of the match in English Premiership club players and was probably due to fatigue. In contrast, Roberts *et al.* (2014) found that more hamstring injuries occurred in the first quarter of the game in school boy and academy players, therefore the researchers stressed the importance of a sufficient warm-up prior to a match. Proper warm-up sessions have shown to prepare the body for the upcoming demands of a game by improving blood flow and increasing the body's core temperature (Fletcher & Jones 2004). Hostel players may not be able to achieve this ready state because some university classes end at 4:50 pm and matches begin at 5pm during the week. This means that players will have to rush from class and go straight onto the field without a sufficient warm-up.

5.13 Time of season

The time in the season when injuries occur is important to analyse to identify potential risk factors. Hostel players may be affected by factors such as stressful exam periods and long holidays that other rugby populations are not affected by.

Each season was divided into five time periods. There were a statistically significantly higher number of injuries in the first time period when compared to time periods 2, 3, 5 ($p < 0.05$).

The first time period covered the duration of the First Years Tournament which happens in the beginning of the year and is typically 4 weeks long. During this time, players have generally had a 6-8 week holiday so the level of conditioning is low. The second time period covers all the matches that were played during the first semester. Midyear exams start directly after this period so it can be assumed that stress levels increase as it gets closer to exams. The third time period begins directly after the midyear holiday which is approximately 4 - 7 weeks long, depending on each player's exam timetable. The fourth time period extends across the entire second semester, excluding semi-finals and finals weeks. The fourth time period is when all the semi-finals across the leagues are played and the fifth time period is when all the finals are played. In time periods one and three, the players generally start playing after an extended holiday. Whilst some players may be dedicated and train during the break, a general assumption may be made that most players become detrained due to inactivity. The error bars in time period 4 and 5 are relatively large and this may be due to less games being played during these time periods in comparison to the other time periods.

Most of the injuries in this study occurred at the beginning of the season and may be due to several factors as suggested by Quarrie *et al.* (2002). These are lack of contact skills, lack of continued practice of contact skills, lack of impact conditioning, harder grounds, and lack of familiarity between players (especially the front row). It has been suggested that preparing for the rugby season with off and pre-season training programs will help reduce a player's risk for injury in the upcoming season (Chalmers *et al.*, 2013). However, a study by Palmer-Green *et al.* (2013) compared academy players to school players and the academy players had higher injury rates despite being on specific conditioning programs and training 2.5 times longer than the school players.

Players in hostel teams do not have preseason conditioning programs and have had an extended holiday period of approximately 8 weeks so they would not be considered as match-fit. Aerobic and anaerobic conditioning is the general focus of pre-season/ early season training sessions and not much attention is paid to contact skills despite the high tackle rate in most games.

Another factor specific to hostel teams is that old players leave the hostel and new players arrive every year so players might not have played together prior to the season. This may cause uncertainty in movement patterns and decision making which may increase the risk for injury. Players also go straight into trial matches prior to the start of the season with minimal physical conditioning and skills training and play as hard as possible in an attempt to prove themselves. A combination of the abovementioned factors places the players at an overall higher risk for injury.

5.14 Environment

5.14.1 Pitch level

The results of this study are unsurprising as previous injury data from all sports, not only rugby, show that an uneven surface produce higher injury rates (Kerr *et al.*, 2013, Soligard *et al.*, 2012; Hyrosomallis, 2007). The distribution of injuries across the pitch levels are similar, except for a 7% higher injury rate in the knee on uneven surfaces compared to even surfaces. This is to be expected because uneven surfaces require the body to adapt unexpectedly (Hyrsomallis, 2007). However, a larger number of ankle injuries were found on the even surface as opposed to the uneven surface. This may be due to the mechanism of the injury being different in rugby to that of a typical ankle injury (overstretching of ligaments due to an uneven surface). In this study, there were 23 ankle injuries that were caused during the tackle and it may be assumed to be due to the physical overloading of the joint from various angles rather than the typical “twisted” mechanism (13 injuries).

5.14.2 Ground and weather conditions

The environment in which rugby is played in may have an effect on the style of play as well as the injury rate. When the conditions are wet and muddy, players generally play a closer game, kick more and make handling errors. When the field is dry, players are able to play a more expansive game.

Petrass and Twomney (2013) explained that ground hardness is a combination of two factors, namely soil moisture content and traction with grass cover; however, there has been no standardized methodology and definitions for analysing ground hardness. More injuries have been shown to occur when the ground is hard (Chalmers *et al.*, 2013; Gabbett *et al.*, 2007; Dallalana *et al.*, 2007, Gabbett *et al.*, 2007; Alsop *et al.*, 2005). Dallalana *et al.* (2007) reported more knee injuries on hard/ firm ground as opposed to a soft/ slippery ground in 12 English Premiership clubs over 2 years.

The ground conditions depend heavily on the weather conditions as well as the amount of play that occurs on each field. The climate in Stellenbosch does tend to produce softer fields, especially during winter when most rain occurs. The fields are also played on 4-5 days of the week almost every week for the duration of the first and second semesters. This means the field have minimal rest in between match days. Matches generally continue during rain which does not help the ground conditions either.

The time of day that the matches are played also mean that dew gathers on the grass and makes conditions even more slippery and soft. Although it can be assumed that wet conditions (light/ heavy rain) would produce a higher injury rate because of the slippery conditions therefore more falls, the results above show that this is not true. Most literature show that hard ground conditions produce a higher injury rate (Chalmers *et al.*, 2012; Gabbett *et al.*, 2007; Dallalana *et al.*, 2007) as discussed in a previous paragraph.

Interestingly, despite the above findings, most injuries occurred in the hot and dry conditions so the general field conditions may be considered to be soft because of the soil quality and foundation. A possible reason for the increased injury rate in hot and dry conditions could be the change in the style of play that the weather allowed. When the ball is dry, it is much easier to pass the ball which may have meant that there was more running rugby played and more tackles at high speed need to be made. When the ball is wet, there are generally less passes made, more kicks and most phases are very close to one another.

With regards to relationships between anatomical locations and injury in contrasting weather conditions, this study found that more shoulder injuries occur in light rain and more head, ankle and knee injuries occur in hot conditions. There are more facial injuries in dry conditions and more hand injuries in cold conditions. Shoulder injuries are more likely to occur in light rain and overcast conditions.

Having more hand injuries in cold conditions makes sense because when it is cold, circulation to the body’s extremities becomes limited as the protective mechanism to keep more blood around the internal organs. A high number of hand injuries in cold conditions may be relevant to the hostel players because mid-year exams are written during the colder period of the year. If hostel players are affected by more hand injuries before exams, it may be difficult for them to study and write their exams. This may have a negative effect on the outcome of their exams and they may not pass their degrees or achieve the necessary marks to be selected for higher degree programmes. It may also affect their success in job applications.

The hot and dry conditions may allow for a more expansive style of play which means more running and passing. This would mean more tackles need to be made and considering tackles have the highest injury rate, it would be understandable to have a high number of injuries in hot conditions. Previous research has shown more injuries occur in hot conditions (Kerr *et al.*, 2013). This trend is also found in soccer with Almutawa *et al.* (2013) reporting more injuries in hot weather conditions in the Saudi Arabia Premier League over 2 seasons. The authors discussed possible reasons for few injuries occurring in high humidity and they related this to the style of play. When the match is played in these extreme conditions, the players were unable to cope with the excessive heat and humidity and the pace of the game slowed down. In the hostel leagues, high injury rates were associated with hot and dry conditions which may mean that the players were able to cope in the conditions and play at a faster pace.

Cold weather conditions had the second highest injury rate. This may be due to the players being unable to warm up properly in the cold conditions and the muscles and joints are not as flexible to handle the physical loading and stress placed on them. Proper warm-up sessions have been promoted in injury prevention programmes for all sports such as RugbyReady, NetballSmart and SoccerSmart in order to reduce the risk for injury (Gianotti *et al.*, 2010). They are effective in physiological and psychologically preparing the player for the match as well as reducing their risk for injury by preparing the musculoskeletal and neuromuscular systems (Cone, 2007).

Although ground conditions are a risk factor for injury, there were limitations in this study that make accurate conclusions difficult. The study had a retrospective design so the information regarding the ground conditions was obtained via a subjective recall by the players. This meant that the players were making their own analysis of the fields without any standardized examples to follow and their ability to recall the standard of the field may not be as reliable. Although the results of this study correlate with some previous findings, it may be difficult to isolate ground hardness as a true injury risk.

5.15 Protective equipment

The use of protective equipment, such as headgear and mouth guards, has been intensely debated in the literature (McCrory *et al.*, 2013). In other sports such as cycling, skiing and motorsports, protective headgear may be helpful in preventing serious head injuries such as skull fractures as they protect the head from hitting hard surfaces (McCrory *et al.*, 2013). The conclusions by most researchers has been that the use of the padded headgear and mouth guards in rugby may be beneficial in preventing lacerations and dental injuries, however, biomechanical studies show that headgear and mouth guards are insufficient in preventing concussions (Cusimano *et al.*, 2010; Quarrie *et al.*, 2007).

In a population group of university students, it can be assumed that preventing injuries such as concussions would generally be the main focus in order to reduce the risk of cognitive ability. The majority of the injured players were wearing protective equipment such as headgear and mouth guards which means that alternative measures for injury reduction should be researched further.

CHAPTER SIX

SUMMARY, CONCLUSIONS, LIMITATIONS AND FUTURE RESEARCH

6.1 Summary

To date, there has been limited injury surveillance data done on university level rugby players. This thesis sought to provide a detailed analysis of hostel rugby injuries during the seasons 2011-2013 at Stellenbosch University. The main objective of the thesis was to determine the prevalence and nature of hostel rugby injuries through injury surveillance and computerized statistical analysis. The results were then assessed for trends when the data was compared to the academic calendar of the university.

The injury definitions and data collection procedures were in accordance to the consensus statement developed by the Rugby Injury Consensus Group (Fuller *et al.* 2007c). This makes the results found in this study comparable to previous research done using the same guidelines.

The total number of injuries was 335 which correlates to an injury rate of 17.5/1000 playing hours. Two hundred and thirty three (233) time-loss injuries and 102 medical attention injuries were reported and the anatomical locations most affected were the head (24%), face (23%), shoulder (13%) and knee (10%). The most common injuries were lacerations (23.6%), joint injuries (16.1%), concussions (15.5%), and ligament injuries (11.9%). Most injuries were of moderate severity (resulting in 8-28 days missed). From the results obtained, it can be concluded that rugby injuries sustained by the 'hostel' players may have an impact on their academic career because of the type of injury and substantial severity.

In summary, rugby injuries are inevitable and each rugby population is affected differently. Therefore, continuous injury surveillance is necessary in order to identify specific risk factors which can support and design appropriate prevention strategies. Hostel players may be at higher risk for injury due to the more social dynamic of the league and that they are exposed to due to long pre and mid-season breaks as well as inappropriately conditioned players.

6.2 Conclusions

The university rugby league is made up of a unique population of players on which minimal research has been reported. The number of injuries at the hostel leagues may be lower than professional injury rates but do compare to other university, amateur/club injury rates as well as school injury rates. The consequences of a rugby injury is not simply that the players will miss matches, but more importantly, it may affect their academic performance as well as their future career options. The hostel leagues are generally social in nature and an enjoyable league overall, however, improvements can be made in order to help reduce injury rates as well as identify and manage injured players.

There is a great commeraderie amongst the hostel players as well as the hostel students and this should not be lost along the way whilst attempting to improve the injury rates. MatiesSport could possibly assist by providing conditioning coaches to oversee the hostel teams. These coaches could provide training programmes as well as educate the players about what training they should be doing in order to reduce their risk for injury. MatiesSport could possibly link up with the Sport Science Department of the university and recruit conditioning coaches from there. The benefits would be two-fold: the players improving their level of conditioning and the sport science students would gain valuable experience.

Most of the injuries came from the tackle so prior to the season, MatiesSport could look into providing educational workshops for the coaches and players that would promote safe tackle techniques. They could either align with the Boksmart workshops or make a Stellenbosch specific worshop which could take the student lifestyle into account (eg: quick, efficient warm-ups for players who rush from class).

The atmosphere at the hostel leagues is excellent as the supporters from the hostels surround the fields, however, the setup of these fields and the lack of crowd control are areas which can be improved. Boundary ropes may allow better control and assist first aid staff to identify injured players.

The current study shows that head injuries formed the majority of the injuries which is a concern for university students because they are studying for the future careers. The recommended guideline is a minimum of 3 weeks for players suffering from concussion. The medical doctors and first aid staff have been an important component in the hostel league and should continue to be supported.

Injuries are sometimes missed because players do not report their injuries to the medical staff so another possible solution would be to have a dedicated medical representative in each hostel who is then responsible for reporting players to the medical room after the match or to the Sports Clinic the following day. A number of the injuries require the players to report to the Sports Clinic the following day in order to reassess the injury but the responsibility lies with the players and they don't often return. The dedicated medical representative can have a record of the injured players and assist the player in attending the appointment. The Stellenbosch Biokinetics Centre based near the rugby fields could offer specialized rehabilitation sessions to the injured hostel players at greatly reduced rates.

The conclusions drawn from this research study were presented in accordance to the set objectives in Chapter One.

- **To determine the prevalence of injuries among rugby union players at a tertiary institution across three seasons**

The overall injury rate of hostel player is much lower than professional injury rates but similar to that of social and amateur teams. Hostel players are however competing in a league as well as attempting to maintain a good reputation of their relevant teams which means their social dynamic combined with their competitive attitudes places them at a higher risk for injury. They are also at a vulnerable stage in their lives where they are studying for their future careers so injuries, especially those which may have a cognitive effect like concussions, may have a large impact on their lives.

- **To compare injury statistics between the Varsity Cup and hostel league**

There was a substantial difference between the injury rate of the Varsity Cup players and the hostel league and the main assumption for this was the difference in the level of play. In both populations, head injuries featured prominently and should be a cause for concern due to the fact that they are all university students. Most of the injuries occurred in the last quarter of the game in Varsity Cup and in the first quarter in the hostel league. Most injuries were sustained in the tackle but it may be assumed that the reasoning for this was different because of the difference in level of play. Forwards had a much higher injury rate than backs in the Varsity Cup whilst the injury rate between forwards and backs was minor.

- **To determine which area of the body the injuries occurred at as well as the severity of the injury.**

The most affected site of injury was the head which is extremely relevant for university students as there is a significant academic focus due to them preparing for their career. A noteworthy finding was the average injury severity was moderate which meant a substantial number of days (8-28) were missed due to injury. Considering the severity was generally quite high, it can be assumed that players not only missed training days, but academic days as well such as attending lectures. This may again have an impact on their academic performance.

- **To determine which phase of play these injuries occurred at and which playing positions are most affected.**

The phase of play responsible for the highest number of injuries was the tackle, especially the front-on and side-on tackle. Appropriate technical skills should be taught and practiced in order for players to master a skill and reduce the risk for injury. However, most hostel teams do not have a consistent conditioning or rugby skills training program which may be an area which can be focused on in future prevention programs

With regards to playing positions specifically, there was no significant difference between injury rates of forwards and backs, although backs stood out as having slightly higher injury rates. Flanks, left wings, inside centres, hookers, fullbacks were the positions with the highest injury rates. Although conclusions were made with regards to playing positions most at risk, it must be mentioned that exposure rates were calculated according to 15 players in a team so there may have been under or overestimation of injury rates. In other words, it may have been slightly more accurate to 7 forwards rather than 15 players when calculating scrum injury risk as backline players are not involved in scrummaging.

- **To determine whether incidence rates of players at a tertiary level differ from other levels such as high school players and senior professional players.**

The injury rates found in the hostel leagues was found to be much lower to those found at professional and school teams but higher than amateur and social teams. The injury rates found in this study were similar to those found in other university teams.

There were several divisions within the hostel leagues and an increasing trend of injury rates was reported as the level of play increases with Division 1 players sustaining the highest number of injuries. The types of injuries that were most prevalent were joint injuries and concussions which corresponds with previous research.

- **To determine whether there are any trends in the injury data in relation to the academic calendar.**

A trend was identified with relation to the when the injuries occurred within the season and related to the academic calendar. Most injuries were found to occur in the beginning of the season whilst the foundations of the academic courses are being set. Although class attendance throughout the year is important, the time period may not be as vital or have as much impact as before the exam periods. However, although more injuries occur in the beginning of the season, the league continues to run until the week before exams begin. With the majority of the injuries being of a moderate severity, the players are affected for 8-28 days which will overlap into the exam period. This means that the players may be at a disadvantage when studying or writing exams due to physical discomfort and an inability to concentrate.

Hostel rugby players should certainly be considered to be a unique rugby playing population because no other groups are affected by the specific combination of risk factors that these players are exposed to. These include class timetables and exam periods which are generally of a much higher standard and intensity in comparison to school exams. Long holidays may mean deconditioning of the players occur which increases one’s risk for injury. There is also no age limit of hostel players who play, although the majority of the players are between the ages of 18-23 if one considers the length of most degrees. The nature of rugby dictates that injuries will almost always be a part of the game so injury surveillance studies such as the current study involving potential vulnerable university students are necessary in order to identify risk factors that affect the players.

6.3 Study Limitations

Certain limitations regarding this study can be indicated:

- The retrospective study design may have resulted in inaccurate reporting of injuries, especially injury mechanism. Although the medical staff and room were available during and after the game to enable quick recording of the injury, players may have been unable to recall details surrounding the injury. There was also no video footage to support the player's feedback. Gaining video footage of each match (6-8 matches per night, every night for 4/5 months) was impractical at the time of this study due to the lack of manpower. By obtaining accurate information regarding the injuries, the strength of the conclusions drawn from the data would increase.

- The formula used for calculating the exposure rate of players originated from the consensus statement developed by the Rugby Injury Consensus Group (Fuller *et al.*, 2007c) and makes the results comparable to other studies. However, it is not an exact measure of how long each player played for as it only uses 15 players per team and excludes substitutes. There is also the issue that there is significantly less actual playing time than the set period of time allocated for a match (80minutes).

- Injuries may have been under reported due to reasons such as players not reporting to the medical room when they are injured and players continuing to play despite sustaining a minor injury. Whilst medical staff were present during the matches, it was not compulsory for players to attend the medical room post injury. Players may also have chosen to see a private doctor or physiotherapist the following day.

- Only match injuries were reported and not training injuries. Injury surveillance during both training (including gym sessions) and matches would enable more holistic and accurate conclusions to be made from a population group. However, hostel teams do not always have set training times and venues which made data capturing difficult.

6.4 Future research

Injury surveillance is necessary in all sports, especially popular contact sports such as rugby. In accordance to the TRIPP model, in order for injuries to be reduced in a sport, population specific injury data should be collected. From this information, aetiology and mechanism of injury can be analysed and risk factors identified. This study completes the abovementioned steps within the TRIPP model and calls for a continuation of the model which will include further research and planning of appropriate prevention strategies to help reduce the injury rate of hostel players at Stellenbosch University. Once the prevention strategies are in place, injury surveillance can be repeated to assess the effect of these strategies.

Hostel rugby is played at most universities and this study may act as a guideline for future surveillance studies done in those universities. It may also be expanded into other sports played by the university, with university students being the common link. Data capture questionnaires will need to be adapted in this case.

This study calls for an expansion of the current Boksmart injury data questionnaire in order to capture more details regarding the injuries and make conclusions more substantial. Examples of the additions are:

1) The type of tackle can be expanded to include whether it was a high tackle or regulation tackle as well as using definitions such as those named by Hendricks and Lambert (2014). This will provide a more detailed summary of tackle injuries.

2) Which side of the body is affected (right/left)? Further research can assess whether the dominant or non-dominant side is affected most as well as analyse whether there are any trends surrounding this.

3) Did the referee indicate that the action leading to the injury was a violation of the laws? Did the referee indicate that the action leading to the injury was dangerous play? This would assess whether injuries are due to illegal actions and enable future law recommendations to be made if injuries from the foul player are severe.

4) Length of match (50, 60, 70, 80 minutes)? It is important to use the correct match period so as to calculate the exposure rate and make accurate conclusions regarding the injury data.

In conclusion, hostel rugby injuries were analysed over 3 consecutive seasons and it was shown that hostel players and their risk factors are unique. Injury surveillance studies such as these should be included in all university sports as well as at all the different levels of play within each sport (i.e: primary school, high school, club, university, provincial, national). Within rugby, all populations are affected by injury so the more information there is surrounding the injuries, the more prepared players, coaches and medical staff can become. Prevention strategies can then be developed in each sporting code and injury surveillance can be continued in order to monitor the effect of the prevention strategies.

CHAPTER SEVEN

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APPENDIX A: ETHICAL CLEARANCE

UNIVERSITEIT • STELLENBOSCH • UNIVERSITY
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13 June 2014

Ms Aimee Barrett
Department of Sport Science
Stellenbosch University

Dear Ms Barrett

Re: *The Prevalence and Nature of Koshuis Rugby Injuries at Stellenbosch*

The researcher has institutional permission to proceed with the proposed research project. Institutional permission is granted on the following conditions:

- The researcher must obtain ethical clearance from the Research Ethics Committee.
- The privacy of SU students must be respected and protected.
- Dr Pierre Olivier must act as the data curator for this project.
- As the data curator, Dr Pierre Olivier, must accept responsibility for the de-personalization of data before it may be made available to the researcher. The names and other information by which students can be personally identified may not be shared with the researcher. Only anonymized data may be provided to the researcher for analysis.
- Data that is collected may only be used for the purpose of this study.

Best wishes,

Jan Botha
Senior Director Institutional Research and Planning Division

APPENDIX B: INFORMED CONSENT FOR DATA USE

Consent for Permission for Data Use

I, Aimee Barrett (the researcher), officially request permission to use the rugby injury data captured on the Boksmart Form in the medical room at Coetzenburg Stadium April 2011 until September 2013 during the koshuis rugby league. The data will be used for research purposes, specifically in completion of the researcher's Masters in Sport Science. The research will assess the prevalence and nature of koshuis rugby injuries during the abovementioned time period and risk factors will be indentified. From this information, proposals for future injury prevention programs can be developed in order to reduce the number of injuries sustained by koshuis players.

The study protocol was approved by the Ethics Committee of Research Subcommittee A (Humanities) at the Stellenbosch University (DESC-Barrett/2014). Hard copies of participant information will remain confidential and stored in a locked cabinet at the Sport Science Department to which only the researcher (Aimee Barrett) and head of the Biokinetics at Sport Science Department, Dr Karen Welman have access to. After 3 years the hardcopy data will be destroyed. The data on the database is password protected and may be used for future research by the University.

I, Pierre Louw Viviers (print name), give the researcher, Aimee Barrett, full permission to use the Boksmart injury data obtained in the medical room at Coetzenburg Stadium and at the Sports Injuries Clinic in Campus Health at Stellenbosch University from April 2011 until September 2013 during the koshuis rugby league.

Dr Pierre Viviers
Senior Director
Campus Health Service
Stellenbosch University
Tel: 021 - 808 3492

Signature

Signed at: Stellenbosch

Date: 25/02/2015

APPENDIX C: BOKSMART FORM

INJURY SURVEILLANCE DATA CAPTURE FORM

1. **PERSONAL DETAILS** Koshuis:______________________________ Student #:________________

Surname:		Date of birth (dd/mm/yyyy):	
Full names:		Date of injury (dd/mm/yyyy):	
Known as (nickname):		I.D. Number:	
Ethnic origin:		Gender:	

Height (cm):	Weight (kg):	Age (yrs/months):

Club/school/team name:

Provincial Union:	Date of Return from injury (dd/mm/yyyy):

Do you have medical insurance?		Number of days missed due to injury:

Did the player consult with a medical professional regarding their injury?	
Did the referee indicate that the action leading to the injury was a violation of the laws?	
Did the referee indicate that the action leading to the injury was dangerous play?	

Team	Provincial League	Playing number (1-23):	Pitch conditions	Body location	Mechanism of injury	Injury Code:
National	Grant Komo week U16 squad		**Option1:**	Head	Acceleration	
Provincial	Craven week U13 squad	**Position**	Soft	Face	Deceleration	
Club	Craven week U18 squad	Loose head prop	Firm	Neck	Lunge	
Residence	Academy week U18 squad	Hooker	Hard	Thorax	Sidestep	
School	Provincial U19 squad	Tight head prop	Very hard	Upper back	Slipped	**Affected side**
Age Group	Provincial U20 squad	Lock	**Option2:**	Abdomen	Twisted	Right
Junior (<U13)	Provincial U21 squad	Blind side flank	Even	Lower back	Scrum engagement	Left
U13	Provincial amateur squad	Open side flank	Uneven	Pelvis	Collapsed scrum	Bilateral
U14	Women's provincial U20 squad	8th man	**Option3:**	Shoulder	Popped scrum	N/A
U15	Women's provincial seniors	Scrumhalf	Solid grip	Clavicle	Tackling behind	**Cause of Injury**
U16	Provincial 7's squad	Flyhalf	Medium grip	Upper arm	Tackling front-on	Acute
U17	Super league A - Team 1	Left wing	Slippery	Elbow	Tackling side-on	Chronic
U18	Super league A - Team 2	Inside center	**Weather conditions**	Forearm	Tackled from behind (regulation)	Acute on chronic
U19	Super league A - Team 3	Outside center	Hot	Wrist	Tackled front-on (regulation)	**Nature of injury**
U20	Super league A - Team U20	Right wing	Dry	Hand	Tackled side-on (regulation)	New injury
U21	Super league B - Team 1	Full back	Light rain	Hip	Double tackle (regulation)	Old or previous injury
U23	Super league B - Team 2	**No. of years at this position**	Heavy rain	Groin	Tackled from behind (high)	
Senior	Super league B - Team 3	<1yr	Overcast	Front of thigh	Tackled front-on (high)	If prevous, state time taken before full return to play
National:	Super league B - Team U20	1-2yrs	Cold	Back of thigh	Tackled side-on (high)	
SA U18 Academy squad	Premier league A - Team 1	3-4yrs	Windy	Knee	Double tackle (high)	**Protective gear**
SA Schools U18 squad	Premier league A - Team 2	>4yrs	Other	Lower leg	Tackled from behind (dangerous)	Mouth guard (custom)
SA U20 squad	Premier league A - Team 3	**Game status within team**	**Pitch type**	Achilles tendon	Tackled front-on (dangerous)	Mouth guard (shop bought)
SA Amateur squad	Premier league A - Team U20	Started match	Grass	Ankle	Tackled side-on (dangerous)	Body Armour
Emerging Boks	Premier league B - Team 1	Substitution	Synthetic	Foot	Double tackle (dangerous)	Shoulder pads
SA (A) squad	Premier league B - Team 2	**Stage of season**	Sand	Other	Spear tackled	Headgear
Springboks	Premier league B - Team 3	Off-season	Gravel	**Injury event**	Spear tackling	Shin-pads
Emerging Women's 7's squad	Premier league B - Team U20	Preseason	Other	Scrum	Bitten	Strapping
Women's Bok squad	Division 1 - Team 1	In-season	**Where injury occurred**	Lineout	Collision	None
Emerging 7's squad	Division 1 - Team 2	**Length of match**	Warm-up	Open play	Elbowed	**Injury definition**
National 7's squad	Division 1 - Team 3	60minutes	Cool-down	Tackle	Gouged	Time loss injury
Residence	Division 1 - Team U20	70minutes	Match	Ruck	Head butt	Medical attention injury
Division 1	Division 2 - Team 1	80minutes	Weight training	Maul	Kicked	**Estimated severity**
Division 2	Division 2 - Team 2	**Time in match when injury occurred**	Fitness conditioning	Kicking	Kneed	Slight (0-1 day missed)
Division 3	Division 2 - Team 3	1st quarter	Rugby skills (non-contact)	Running	Punched	Minimal (2-3 days missed)
Division 4	Division 2 - Team U20	2nd quarter	Rugby skills (semi-contact)		Rucked	Mild (4-7 days missed)
Division 5	Division 3 - Team 1	3rd quarter	Rugby skills (full-contact)		Cleaned	Moderate (8-28 days missed)
	Division 3 - Team 2	4th quarter	Other		Cleaning	Severe (>28 days missed)
	Division 3 - Team 3		**Post-injury decision**		Not supported	Career-ending
	Division 3 - Team U20		Continued		Jumping	Non-fatal catastrophic
	Paarl Region - Team 1		Discontinued, forced		Landing	Fatal
	Paarl Region - Team 2		Discontinued, precautionary		Other	
	Paarl Region - Team 3		Discontinued, blood			
	U20 League - Team A					
	Reserve Team - Team A					
	Women's League - Team 1					
	Sunday League - Team 1					