Injury in elite rugby players during the Super 15 Rugby tournament

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Declaration

I, Alan Thomson, hereby declare that the work on which this dissertation is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

Signed by candidate

Alan Thomson

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ELV	experimental law variations
IRB	International Rugby Board
RIGG	rugby injury consensus group
MCL	medial collateral ligament
PCL	posterior cruciate ligament
ACL	anterior cruciate ligament
MRI	magnetic resonance imaging
AC joint	acromioclavicular joint
SLAP	superior labrum anterior to posterior
PIP	proximal interphalangeal joint
RWC	Rugby World Cup
SCAT	sports concussion assessment tool
RTP	return to play.
SCI	spinal cord injuries
BMI	body mass index
IR	injury rate
IPP	injured player proportion
UCT/MRC	University of Cape Town, Medical Research Council).
SARFU	South African Rugby Football Union
CNS	central nervous system

Abstract

Background: Professional rugby union is a contact sport with a high risk of injury. The Super Rugby competition is a particularly demanding 16-week Southern Hemisphere tournament. In this tournament, 15 teams compete and play international level matches every week, which may be associated with an even higher risk of injuries.

Objective: The main objectives of this dissertation were 1) to review the epidemiology and risk factors of injuries in professional rugby union, with specific reference to the Super Rugby tournament (Part 1), and 2) to document the incidence and nature of time-loss injuries during the 2012 Super Rugby tournament (Part 2).

Methods: Part 1: In this component of the dissertation, a comprehensive review of injuries during Super Rugby was undertaken. A search revealed only 3 studies that have been conducted during this competition. Therefore additional data were included from other studies on Rugby Union, where appropriate.

Part 2: This component of the dissertation consists of a prospective cohort study that was conducted during the 2012 Super Rugby tournament, in which teams from Australia, New Zealand and South Africa participated. Participants consisted of 152 players from five South African teams. Team physicians collected daily injury data through a secure, web-based electronic platform. Data included the size of the squad, the type of day, main player position, whether it was a training or match injury, hours of play (training and matches), the time of the match injury, the mechanism of the injury, the main anatomical location of the injury, the specific anatomical structure of the injury, the type of injury, and the severity of the injury (days lost).

Results: The main findings from Part 2 of this dissertation were that the proportion (%) of players (IPP) sustaining a time-loss injury during the tournament was 55%, and 25% of all players sustained >1 injury. The overall incidence rate (IR per 1000 player-hours) of injuries was 9.2. The IR for matches (83.3) was significantly higher than for training (2.1), and the IR was similar for forwards and backs. The percentage of injuries to muscle/tendon was 50% and to joint/ligament was 32.7% accounting for >80% of all injuries. Most injuries occurred to the lower (48.1%) and upper limbs (25.6%). Forty-two percent of all injuries were moderate (27.5%) or severe (14.8%). The most common mechanisms of injury were tackling (26.3%) and being tackled (23.1%). The IR of injuries was unrelated to playing at home compared with away (locations $\geq$ 6 hours' time difference).

Conclusion: Fifty-five percent of all players were injured during the 4-month Super Rugby tournament (1.67 injuries / match). Most injuries occurred to the lower (knee, thigh) or upper limb (shoulder, clavicle). Forty-two percent of injuries were sufficiently severe for players to not play for > 1 week. These data form the basis of planning suitable intervention strategies to reduce the risk of injury in the Super Rugby tournament.

Keywords: injury, epidemiology, rugby union, risk

Chapter 1

Introduction and scope of the thesis

Rugby is a popular team sport played in more countries than any other sport except soccer and is amongst one of the most played and watched team sports in the world [1;2]. The game is physically demanding, involving frequent bouts of high intensity activities like running, sprinting, rucking, mauling and tackling. As such, the physical attributes necessary for the elite professional rugby player are diverse; including strength, power, speed, agility as well as endurance. The inherent risk of injury in rugby union is high as a result of the high physical demands together with the exposure to collisions and contacts[2].This has resulted in rugby union having one of the highest reported incidences of match injuries amongst all professional team sports (comparable with ice hockey, rugby league, American Football and Australian Rules Football)[2].

Previous studies on the epidemiology of rugby injuries were hampered by methodological limitations; with variations in injury and severity definitions, lack of uniform data collection methods and small sample sizes. The 2007 consensus statement has attempted to bring uniformity and allow for the improved methodological quality of published studies as well as allowing for effective interpretation and comparison across studies [3]. Recent epidemiological studies on rugby injuries in rugby union have concluded that a higher level of play (professional level) is associated with a higher incidence of injuries [4]. Possible explanations have been increased strength and body size of players, greater competitiveness, longer seasons and the fact that the ball is in play for longer periods in higher levels of the game[4]. Furthermore, there is concern about the possible harmful effects of non-stop rugby for most of the year in these players. The Super Rugby season commences shortly after the new year and runs for 16 weeks to be followed by an international season of between two and three months for the players chosen for their respective sides, with the remainder competing in the first part of local provincial competitions. Following the completion of their internationals, the national squads then join the remainder of the provincial competition. Following the completion of domestic season the South African national side undertakes a tour of the Northern hemisphere only to return just prior to the start of the next Super Rugby tournament. This leaves very little time for an off-season to allow for recovery and treatment of injuries.

The Super Rugby competition is played annually between professional rugby union teams from three rugby-playing nations in the Southern Hemisphere (South Africa, New Zealand and Australia). It was introduced in 1996 following the advent of professionalism and was the first fully professional rugby tournament at the time involving 10 teams. Currently 15 teams from the Southern Hemisphere play this tournament over a 4-month period from late summer to early winter each year. The teams play each other in a round-robin tournament, with a knockout semi-final and a final match, over a period of 16 weeks. Teams play most weeks for the duration of the 16-week tournament. The competition is generally regarded as one of the most gruelling rugby competitions in the world, placing exceptional physical and emotional stresses on the players. Furthermore, teams have to travel across multiple time zones as matches are played in venues in all three countries, resulting in very demanding travel schedules. The competition is associated with a high incidence of injuries as expected from a tournament of this calibre, and therefore scientific data concerning the aetiology and incidence of injuries are essential for medical staff to provide appropriate advice in order to prevent and manage injuries. The high injury rate amongst these players is of concern to the medical fraternity, sport administrators and the media.

The tournament is particularly demanding because: (1) it is played over a much longer duration (currently 16 weeks) compared to many other international tournaments (usually less than 7 weeks), (2) in 2005 and more recently in 2011, there have been increases in the number of participating teams, resulting in the currently long duration of the tournament, (3) matches are played weekly by each of the teams ,(4) teams are awarded bonus points for tries, which encourages a more open, flowing style of play that could result in an increased tackle count during matches, and (5) unlike in other tournaments that are played in one geographical zone , players in the Super Rugby tournament also have to contend with demanding travel schedules.

As this tournament appears to be associated with an increased incidence of injuries, the aim of this study was to document the incidences and factors associated with injuries in five South African Super Rugby teams during the 16-week 2012 Super Rugby competition. To date there have been only three studies reporting on the epidemiology of injuries in the Super Rugby tournament [4,5,6]. This is despite the fact that the Super Rugby tournament has been in existence for almost twenty years and has historically been associated with a high injury rate.

The first was a pilot study involving a single New Zealand team in the 1997 Super Rugby tournament [31]. In this study, the injury rate of “significant” injuries was 45/1000 player hours, with no difference between forwards and backs. Most injuries involved the musculotendinous unit, with the tackle responsible for most of these injuries. The first comprehensive study was conducted in 1999, where three teams of 25 players were followed during the Super Rugby tournament [4]. In this study, both training and match injuries were documented, with an overall match injury rate of 55/1000 player hours and 4.3/1000 training hours. Ligamentous sprains and musculotendinous strains were the most common injury types.

The most recent study was conducted during the 2008 Super Rugby tournament, whereby experimental law variations (ELV) were applied and the impact thereof was ascertained in a comparative study on the incidence and nature of injuries 18). In this study, 14 teams were followed during the tournament and the incidence of time-loss match injuries was 96/1000 match player hours (training injuries were not reported). There was no significant difference in the incidence of match injuries between the forwards and the backs, with most injuries involving the joint/ligament and occurring during the tackle. This study was the only one of the three that applied the current consensus statement in terms of injury definition and data collection. As the definition of injury varied in the 3 studies, the different injury rates cannot be compared.

Therefore the present study of the expanded competition is necessary and the data could be used to formulate guidelines that could be applied by medical personnel involved with prolonged rugby tournaments. This would enable team physicians to anticipate/predict injury profiles so that preventative strategies, as well as anticipatory measures, are implemented in the planning of medical services in such tournaments.

Chapter 2

A review of injuries in professional rugby union players with specific reference to the Super Rugby competition

2.1. Introduction

Rugby union is a popular team contact sport, with a high injury rate [7,4,1,8]. The Super Rugby competition is the premier regional tournament in the Southern Hemisphere involving teams from South Africa, Australia and New Zealand. In this competition, participating teams play in a round-robin format over approximately 16 weeks, involving both home and away games, with the semi-final and final played as knockout games. All the participating Super Rugby teams play matches almost on a weekly basis, and this may possibly be associated with a particularly high injury rate. Injury data collection during this competition is of importance for the planning of future preventative strategies. In this chapter, the epidemiology of rugby union injuries, with specific reference to the Super Rugby competition, will be reviewed. Where appropriate, these data will be compared with the epidemiology of injuries in professional rugby union. Finally, factors associated with injuries in professional rugby union will be reviewed. For the purposes of this dissertation, "Rugby Union" will be referred to as "rugby".

The main reason for conducting epidemiological studies on rugby injuries is to identify risk factors for injury, so that preventative strategies can be employed to reduce the risk of injury. To date, there have been a number of epidemiological studies on injuries in professional rugby, but very few studies on the Super Rugby competition, and this will be the focus of this dissertation.

Prior to 2007, a major drawback has been a lack of uniformity in terms of the methodology in the collection of injury data in rugby. As a result, the International Rugby Board (IRB) introduced a consensus statement in 2007 in an attempt to bring uniformity to future epidemiological studies on rugby injuries [3]. Following the release of this consensus statement, epidemiological studies have, in most instances, followed a uniform methodology, and this made it possible to compare results between studies. In this dissertation, the IRB consensus statement in relation to the classification of injuries and the methodology to conduct epidemiological studies in rugby has been followed.

2.2. Injury definitions and classification

As mentioned, prior to 2007 there was no standardised system of methodology when studying and reporting on injuries in rugby. The IRB therefore established a rugby injury consensus group (RICG) to standardise the definitions and classification of injuries in rugby [3]. These definitions were adopted in this dissertation and will be briefly reviewed.

Definition of an injury

An injury is defined as disruption of the integrity of the body requiring a period of absence from training and or match activities of at least one day. This is referred to as “time-loss” injury. A “medical attention” injury is defined as a player needing medical attention (time loss <1 day).

Definition of a recurrent injury

A recurrent injury is defined as an injury of the same type at the same site as the primary injury, which occurs after players return to full match fitness.

Injury severity definition

Injury severity is defined by time lost (days lost from time of injury) to the date of the players return to full participation in team training and match selection. Injury severity categories are defined as follows: slight (0-1 days), minimal (2-3 days), mild (4-7 days), moderate (8-28 days), and severe (>28 days). The severity of injuries can also be reported as days lost (mean, median).

Reporting on the incidence of injury

The incidence is reported in matches and training and reported separately as the number of injuries/1000 player-hours with 95% Confidence Intervals (CI).

Injury classification

Injuries were classified further by main anatomical location, type of injury, and the event (training or a match). The more detailed anatomical sites and final diagnosis of rugby injuries can be classified using a number of systems. For the purposes of this dissertation, the Orchard 10.1 system was used as the coding of injuries [9]. This is a system utilised globally and is the most applicable to sports medicine.

Mechanism of injury

Match injuries were further divided into contact or non-contact. The mechanisms of injuries resulting from contact were further divided into the following: tackling, tackled, maul, ruck, lineout, scrum, collision or other. Match injuries were also classified according to the period in match in which the injury occurred.

Other classifications

For the purposes of this dissertation, a further classification was added to include the pitch condition, playing surface, weather conditions, and whether play was either continued or discontinued (forced, precautionary or discontinued) following an injury. These variables did not form part of the IRB 2007 consensus protocol.

2.3. Epidemiology of injuries in professional rugby

2.3.1. Introduction

Professional rugby was introduced in 1995 and therefore, only injury data published after 1995 will be considered in this review chapter. As previously mentioned, the IRB's 2007 consensus statement on injury epidemiology brought uniformity to research on rugby, and therefore the studies in which these criteria were used, will mainly be included in this dissertation.

2.3.2. General epidemiology of injuries in professional rugby

In the first study to be published following the introduction of the professional era in rugby, Jakoet et al. [10] showed that during the 1995 Rugby World Cup, the incidence of match injuries was 45/1000 player hours. This injury rate was much higher than previously documented in amateur rugby. Since then, a number of studies documenting injuries in professional rugby have been conducted, and these have recently been reviewed, and were included in a meta-analysis [11]. These studies included those conducted during a number of Rugby World Cup competitions, other international teams, and club rugby. In this meta-analysis, the overall incidence of injuries in professional male rugby players during matches was reported as 81 / 1000 match player-hours (95% CI: 63-105) and during training it was 3 / 1000 training player-hours (95% CI: 2-4). However, to date, only three studies have been conducted during the Super Rugby competition, which is the focus of this dissertation.

2.3.2. Epidemiology of injuries in the Super Rugby competition

As mentioned, to date only three studies have reported the epidemiology of injuries in the Super Rugby tournament [4, 5, 6]. The first study was a pilot study where a single team was followed during the 1997 Super 12 Rugby season [6]. In this study, the injury rate of "significant" injuries was 45 / 1000 match player-hours. There was no difference in the injury rate between the forwards and the backs, and most injuries were musculotendinous sprains and strains. The tackle was the most common phase of play responsible for injuries [6].

The first comprehensive study was conducted during the 1999 Super 12 Rugby tournament [4]. In this study, 3 teams of 25 players were followed and training injuries and match injuries as well as missed training/ session injuries were documented [4]. In this study, the overall match injury rate was 55 / 1000 match player-hours and the overall training injury rate was 4.3 / 1000 training player-hours. Ligamentous sprains and musculotendinous strains were the most common injury types, and the tackle was responsible for the majority of injuries [4].

The most recent study was conducted during the 2008 Super 14 Rugby tournament. This study was part of a comparative study to document the impact of experimental law variations on the incidence and nature of match injuries [5]. In this study, 14 teams were followed during the tournament and the incidence of time-loss match injuries was 96 / 1000 match player-hours. There was no significant difference in the incidence of match injuries in forwards and backs. The majority of injuries were joint/ligament injuries, followed by musculotendinous injuries. The majority of injuries were associated with the tackle phase of the game [5]. In this study, training injuries were not reported. As the definition of an injury varied in these three studies, the injury rates cannot be compared.

It is important to note that in only in the most recent study [5], the current consensus on injury definition and data collection procedures for rugby injuries applied [12]. In this single study, the match injury rate of 96 / 1000 match player-hours was considerably higher than that reported for professional rugby in general (81 / 1000 match player-hours)[2]. Therefore, more data are required to determine the overall incidence of injury in Super Rugby tournament, and this is the focus of this dissertation.

The following aspects regarding the epidemiology of injuries in professional rugby will now be discussed: level of play (matches vs. training), player position, main anatomical areas injured, types of injury, severity of injuries, mechanisms of injury, and the period in a match when the injury occurred. There will be a brief discussion of the data from professional rugby injury studies in general, but where possible, the main focus will be on the studies in the Super Rugby competition.

2.4. Level of play: match injuries and training injuries

In professional rugby, there are five studies that report both match and training injuries [13],[14],[4;15],[16]. In all these studies it was consistently shown that the injury rate was substantially higher in matches, compared with training. Furthermore, in the meta-analysis of injuries in professional rugby players in general, the match injury rate was 27 times higher in matches (81 / 1000 match player-hours vs. 3 / 1000 training player-hours) [2]. In the Super rugby competition, only one study to date reported match and training injuries [4]. In this study, the overall match injury rate was 12.8 times higher in matches compared with training (55 / 1000 match player-hours vs. 4.3 / 1000 training player-hours). In professional rugby, the level of play is one of the most important factors associated with injury. However, in the Super rugby competition, this has not been well researched.

The level at which rugby is played tends to have a bearing on the severity of injuries. It is suggested that the greater body weight of the elite player, increased fitness levels, ball-in-play time and the more competitive nature at this level may have a bearing on match injuries [17]. Most match injuries involved the lower limb (hamstring strain/lower limb haematoma), and the tackle was the main cause of injury. Finally, most match injuries occurred in the second half (final quarter), which was similar to studies in amateur rugby.

In contrast to match injuries, training injuries have received less attention in the literature. As mentioned, only one study to date reported on training injuries in the Super rugby competition [4]. Rugby training involves several modalities: weight training (gym work), fitness conditioning (primarily running activities), and rugby skills (non-contact, semi-contact and full-contact). In a study by Brooks et al. [15], endurance running and contact drills had the highest risk for injuries during training. The lower limb (hamstring) was the region most injured. Further data from Brooks et al. [15] demonstrated training injuries to be more severe than match injuries. This could be as a result of more time being spent on the training pitch than playing matches. They also demonstrated that more injuries occurred in the pre-season games, which could be attributed to secondary to decreased fitness levels, lack of proper rehabilitation, insufficient off-season breaks or even over eagerness in players. It was suggested that although the above training methods are essential, non-weight-bearing endurance training (rowing, cycling) and weight training could be of benefit by reducing the overall incidence of injury. Weight training reduces muscle imbalance and increases strength/power, and non-weight bearing activities reduce the impact load. As high-risk training activities, such as fitness testing, defence drills, rucking and mauling are integral to any training programme and may be regarded as indispensable, it would be effective to perhaps limit these in an attempt to decrease the injury rate. Furthermore, there appears to be a predisposition to injuries in the second half of the game [18] related to player fatigue. By reducing the volume of high-risk training activities and incorporating running during training and introduced together with increased skills development, this may help to prevent this fatigue.

2.5. Player position

In a recent study by Brooks et al.,[16] previously held views on the equivocal nature of position-related injuries in rugby union were challenged. Most previous studies tended to suggest that although forwards had a higher incidence of injury, the results were generally inconclusive. Brooks et al.[16] stated that position was an independent risk factor in the incidence of injuries and the implementation of position-specific preventative programmes could be introduced in future training programmes. Specific injuries have been associated with certain player positions as shown in Table 2.1.

Table 2.1 Common rugby injuries associated with specific player positions [16]

Player position	Specific injuries
Loose-head props/hookers	Cervical root or cervical disc injuries Rotator cuff injuries
Tight-head props	Lower-leg injuries (calf muscle strains) Lumbar disc injury
Locks	Ankle injuries (from jumping in lineout)
Flankers	Thigh muscle strains (hamstring) Neck injuries (injuries related more to high tackle rate)
No-8's	Hand, shoulder, and arm injuries Foot injuries
Scrum-halves	Lumbar spine injuries Shoulder injuries Knee injuries
Fly-halves	Thigh muscle strains (hamstring) (related to kicking)
Centres	Face injuries Head injuries and concussion (high contact)
Wingers	Hamstring muscle strains (sprinting) Thigh haematomas
Full-backs	Groin, buttock and hip injuries Rib injuries

There are certain trends that can perhaps be deduced from this study as follows:

- Centres and loose forwards have high injury rates as the contact at breakdown or tackle is considerable

- Hookers and loosehead props have a higher risk of neck and shoulder injuries from scrumming
- Tighthead props have a higher risk of calf strains/lower back sprains from pushing
- Number 8s have a wider spectrum of injuries because of their more linking type of play
- Scrum-halves develop injures from bending or being tackled
- Fly-halves and fullbacks develop injuries from kicking-related activities (groin, upper leg, hip)
- Wingers have a higher risk of hamstring strains related to sprinting

2.6. Anatomical areas injured

The general anatomical areas that are included in most epidemiological studies on rugby match injuries are the lower limb, upper limb, trunk and head/face area. In the recently published meta-analysis [2], data from seven studies could be included in an analysis to determine which main anatomical areas have the highest incidence of injury [13,17, 19, 15, 20, 14, 5]. These data clearly show that the highest incidence of injury occurs in the lower limb area (47 / 1000 player match hours; 95% CI: 26-84). The incidence of injury was similar in the upper limb (14 / 1000 match player hours; 95% CI: 8-25), head/face (13 / 1000 match player hours; 95% CI: 7-23), and slightly lower in the trunk area (9 / 1000 match player hours; 95% CI: 5-16). In the next section, more common rugby-related injuries in each of the main anatomical areas would be briefly reviewed. A detailed review of each injury type is beyond the scope of this dissertation, which mainly focuses on the epidemiology of rugby injuries in the Super Rugby competition.

2.6.1. Lower limb injuries in rugby

As mentioned, lower limb injuries are the most common in rugby union [20, 1, 21 ,22]. The more common lower limb injuries in rugby union will be discussed briefly.

2.6.1.1. Knee

The knee is commonly injured in rugby union and the most common lower limb joint injury [23]. Most knee injuries involved the medial collateral ligament (MCL). An anterior cruciate ligament tear (ACL) is the most severe knee ligament injury [23] in rugby union. In the RWC study of 2007, the knee was the most commonly injured structure during both training and matches, causing the most time lost [14]. Knee injuries amongst professional players are associated with a lower incidence of injury due to weight training and proprioceptive exercises integrated into their training programmes. Although most knee injuries are as a result of contact, many were secondary to cutting/pivoting type manoeuvres. PCL (posterior cruciate ligament) injuries are quite rare, often under-diagnosed, and often classified as sprains. Many players continue to play with minor degrees of PCL/posterior-lateral type of chronic injuries. Patella dislocation is rare as are the chondral or meniscal type injuries.

2.6.1.2. Muscle strain injuries in the lower limb

Muscle strains, tears, haematomas and contusions in the lower limb are also common in rugby. The anatomical location of these soft tissue injuries is mostly in the posterior thigh (hamstring muscles), anterior thigh (quadriceps), groin (adductor muscle group) and the calf muscle complex.

Hamstring muscle injuries

The hamstring is vulnerable as this group of muscles is involved in the action of sprinting, specifically the stretch-shortening cycle. As this region is often recurrently injured, players tend to return to play prematurely or are insufficiently rehabilitated following injury, thus predisposing themselves to recurrent injury. Brooks et al., [24] concurred that most hamstring injuries occurred in the second half of the game. Recurrent injuries tended to occur in the final quarter, with the most severe injuries in the third quarter. Risk factors implicated in hamstring injuries are: imbalance of strength between hamstrings and quadriceps, fatigue and muscle cooling, high volume training, incomplete rehabilitation and poor conditioning. Proposed preventative mechanisms in hamstring injuries are: stretching, correction of muscle imbalance and Nordic eccentric strengthening exercises [17, 19, 15, 24].

Quadriceps muscle injuries

Injuries to the quadriceps muscle group would constitute mainly strains; haematomas and contusions. They constitute a major percentage of injuries to the lower limb. Earlier studies from New Zealand demonstrated that the thigh haematoma was a common injury both in games and matches [25]. In a study of elite Australian players [26], the authors noted that most of the lower limb injuries involved the knee and thigh, with bruising/haematoma and muscle strains/tears accounting for 30% of the type of injury. This was further supported in a study involving professional English rugby players, which showed that training injuries involving the thigh were most common [19]. The same authors in their analysis of match injuries demonstrated that thigh haematomas were the most common injuries for forwards and backs [17]. The authors concluded that these injuries were related to the contact situation, primarily the tackle.

Groin muscle injuries

There is little information regarding groin/hip injuries in rugby union. In rugby union, injuries to the adductor group of muscles occur. These injuries are notoriously difficult to treat, particularly when they become chronic and are often career-ending. In rugby union, adductor muscle injuries have been reported as a main cause of match and training injuries [27].

Calf muscle injuries

The gastrocnemius and soleus muscles form the calf muscle complex. They are part of the lower leg, an area with a high incidence of injury, mainly calf strains. Calf strains or haematomas were reported by Brooks et al. to be a common cause of match and training injuries [27].

High volume/intensity running during training explains the greater proportion of lower limb injuries seen in training. A higher proportion of muscle/ligament sprains/strains are reported in training compared to matches, in that training constitutes mainly running-type activities. Hamstring, calf and hip flexor/quadriceps strains and lateral ligament injuries are all common [27].

2.6.1.3. Ankle, Achilles tendon and foot injuries

Lateral ankle ligaments are most commonly injured, with syndesmotic, deltoid and Achilles injuries less common [28]. According to this study, other injuries involving the ankle mortis were: tibia/fibula fractures and ankle haematomas. The authors emphasised that with regard to ankle injuries in rugby union, a scarcity of information exists with regard to their epidemiology. Most ankle injuries in rugby union are lateral ankle sprains, involving the lateral ligament, resulting in considerable time-loss. Whilst most were grade 1 injuries; grade 3 injuries (following diagnostic MRI) had a high percentage of osteochondral defects (71%). The majority of ankle injuries (74%) were sustained in matches.

The most severe injuries were Achilles tendon injuries (rupture) and lateral malleoli fractures. Achilles tendon rupture was usually as a consequence of chronic tendinopathy. Front-row forwards are particularly prone to this injury as a result of explosive and eccentric muscle loading patterns. Most injuries were sustained in the latter part of the game, with fatigue being a possible injury risk factor. Possible preventative measures advocated in the prevention of ankle injuries could be; ankle taping/brace, proprioceptive training and eccentric calf muscle strengthening in cases of Achilles tendinopathy [28].

In general, the foot represents a small but significant proportion of professional rugby injuries [29]. Most injuries of the foot tend to be of an acute nature but chronic injuries (e.g. navicular stress fractures) tend to result in greater morbidity. Navicular stress injuries are second only to ACL injuries in terms of severity in professional rugby [29].

2.6.1.4. Injuries of the hip and pelvis

The most common hip injury in rugby union is the hip-pointer which is a sub-periosteal haematoma of the ilium. Hip dislocation is rare in rugby-union, generally occurring more frequently in high velocity trauma. Stress fractures of the neck of femur, pubic ramus and acetabulum can present as chronic injuries in senior rugby players and apophyseal injuries in youth rugby players similarly. Cases of acetabular fractures in rugby players, both sustained in the tackle have been reported [30]. These injuries resulted from “double tackles” with the tackled player falling onto a flexed knee. Pelvic fractures are, however, very rare. Scrotal injuries have been reported and furthermore, osteitis pubis can present as a chronic injury in a rugby player, as well as tendinopathies of the adductor group.

2.6.2. Upper limb injuries in rugby

The upper limb accounts for less than 20% of injuries in rugby and include lacerations, contusions, sprains, dislocations and fractures. It has been reported that upper limb injuries when they do occur, tend to be more severe in nature [27],[26], [6].

2.6.2.1. Shoulder and clavicle injuries

Injuries of the shoulder complex constitute the highest proportion of injuries in rugby involving the upper limbs [31]. These injuries range from dislocations, rotator cuff impingement and tears, instability, acromioclavicular joint (AC joint) injuries, haematoma, superior labrum anterior to posterior (SLAP) injuries of the glenoid labrum and Bankart/Hill-Sachs’ injuries (avulsion fractures of the glenoid rim and humeral head respectively).

Most shoulder injuries are as a result of contact. There are three common mechanisms involved in shoulder injuries: Firstly, in the tackled player where the arms are held in flexion with resulting posterior force and secondly, in the tackler, where the arms are held in abduction. The third mechanism is the direct impact situation where the ball-carrier receives direct impact onto the shoulder [31].

It has been noted that with the advent of professionalism there has been a decline in reported AC joint injuries. The precise reasons for this are not apparent, but could be secondary to the use of protective padding, under-reporting by the players, or a higher tolerance to the injury [31].

Nerve-related injuries in the upper limb and shoulder area are not uncommon in rugby players and are known as stingers. This injury is a neuropraxia of the cervical or brachial plexus and usually presents as burning pain radiating down the arm with associated weakness and parasthesias. It can take some hours to recover from this injury and it is often necessary to withdraw the player from the field [32]. Brachial plexus/cervical nerve root injuries often present as stingers/burners secondary to traction of the nerve complex. A neuropraxia results with weakness/pain radiating down the arm and can take some time to recover. Severe brachial plexus injury necessitating surgery has been reported in 13 players as a result of falling in the tackle, with avulsion of the nerves, rupture and compression [32]. This was as a result of the posture of the neck and forequarter at the moment of impact [32]. Repair by nerve transfer and decompression of lesions resulted in recovery and pain relief [32].

2.6.2.2. Elbow injuries

It was reported that elbow injuries account for less than 1% of injuries in a cohort study of professional rugby players [1]. The more common elbow injuries are dislocations, sprains, muscle strains/haematomas and fractures. However, there appears to be a paucity of information on elbow injuries in rugby. This may be as a result of a low incidence of elbow injuries or under-reporting of injuries.

2.6.2.3. Forearm, wrist and hand injuries

In general, there are very few studies reporting rugby-related injuries of the forearm, wrist and hand areas. Anecdotally, players are often seen with heavily strapped wrists, but there is generally a low incidence of injury [13]. The forearm is also not reported as an area with a high incidence of injury [27].

There is also limited information regarding injuries to the hand/fingers in rugby union. Historically, hand and finger injuries in rugby have been reported and are often fairly severe [33]. In this study, rugby injuries presenting at a hand clinic were reported, 46 / 72 injuries were fractures and 26 /72 soft tissue injuries. Most of these injuries were thought to be preventable and caused by opponents. In another study, 80% of rugby related injuries to the hand were fractures, including Bennett's fractures, metacarpal fractures and fracture dislocations of the proximal inter-phalangeal (PIP) joint [26].

2.6.3. Trunk and abdominal injuries in rugby

Injuries to the trunk constitute less than 12% of professional rugby union injuries and tend to be less severe than injuries to other areas of the body [4, 1, 27]. It has been reported that, in the professional rugby player, these injuries result in an average six days absence following injury [19].

The abdominal area is an infrequently injured area although abdominal muscle injuries (strains, contusions, and haematomas) can occur. Intra-abdominal trauma is rare, but splenic ruptures or renal contusion injuries have been reported to occur in rugby union [34].

2.6.4. Injuries to the upper back, sternum and ribs

Rib injuries in rugby union are quite common and fractures and contusions are more common in matches than in training. Sternal injuries are quite rare, as are injuries to the thoracic spine [27]. Sterno-clavicular subluxations can occur in rugby union, more commonly anterior with posterior dislocations having more serious consequences. Commotio cordis can occur, but is rare [35].

2.6.5. Lower back injuries

Lower back injuries include fractures, lumbar disc injuries, nerve root injuries as well as ligamentous injuries and muscle strains of the lower back musculature [27]. It has been reported that lower back injuries are the second most common training injury amongst the forwards. These were related mainly to weight training, significant as these injuries caused a high rate of absence. However, amongst the backs, this area is associated with a low incidence of injury during training but a higher incidence during matches, such as at the 2011 RWC [13].

2.6.6. Injuries to the head neck and face

2.6.6.1. Concussion

Concussion is a very important injury in rugby union and is the most common head injury recorded and the third most common match injury [36.]. The main mechanism for injury for concussion in rugby union is the tackle and most concussive injuries resulted from tackling or being tackled head-on. The midfield backs (centres) have the greatest risk of concussion. Furthermore, mouth guard usage was associated with reduced incidence as most occurred during matches [37]. In addition, data from one study showed that 48% of the players were able to play within 7 days [37], but there is also a suggestion that underreporting occurred, as fewer than 50% of concussed players were removed from play.

The field-side assessment, diagnosis, management and return- to- play in concussion, has, in recent years, been given more attention and a number of consensus groups have provided sport concussion guidelines. The most recent guidelines were published in the 2012 Zurich consensus statement [38]. In this statement it was emphasised that concussion remains a subset of mild traumatic brain injury and although most cases (80-90%) resolve over 7-10 days, it remains an essential condition to manage appropriately. The clinical assessment of concussion is based on physical, cognitive, emotional and sleep-related symptoms and signs [36].The on-field evaluation and management of the player with suspected concussion remains the responsibility of the attending physician. Following first aid treatment, the injured player needs to be assessed clinically using the most recent Sport Concussion Assessment Tool (SCAT) [38]. Currently this assessment tool is the SCAT3, and it evolved from previously developed the SCAT and SCAT2 tools [38]. The SCAT3 takes into account special populations such as children under the age of 13, which often manifest differently from adults in relation to concussion. Therefore a specific child SCAT3 was developed as children often have a delay in presentation, may have a prolonged recovery, and are more prone to diffuse cerebral swelling in the ”second-impact” syndrome as a result of brain immaturity. Therefore, children with concussion should be managed more conservatively when returning to full contact sport [39].

More recently, a pitch side concussion assessment tool (PSCA) was introduced by the International Rugby Board (IRB) [40]. The PSCA allows medical staff to remove a player with suspected concussion to be removed from the field of play and is temporarily replaced. The time period for this is still debated but currently this is for a period of 5-10 minutes. During this period, a player can be assessed for mental status, cognitive functioning, and gait and balance so that a decision can be made regarding the players fitness to continue [40].

At the professional or semi-professional level, most players also have access to cognitive database systems such as “CogStateSport” to assess neuropsychological parameters [36]. These neuropsychological tests allow for the assessment of cognitive functioning, and can be used to compare pre-season (baseline) tests to a player's status following a concussive injury. These data can add to information from the SCAT3 so that the best return-to-play (RTP) guidelines are followed.

Return-to-play (RTP) following concussion is a multidisciplinary process and should be based on sound clinical judgement. It is essential that players undergo a full medical assessment followed by both physical and cognitive rest until they are asymptomatic with normal baseline cognitive values before embarking on a stepwise RTP programme [38]. Recent studies suggest that increased cognitive activity following concussion is associated with prolonged recovery [41]. A sound RTP program is essential, as recent evidence suggests that concussed players are also at risk developing additional injuries within a year following a concussive injury [42].This has bearing on players returning too soon to full contact with mild cognitive impairment and the importance of adhering to the RTP protocol. Finally, poor management of concussion can predispose players to Chronic Traumatic Encephalopathy (CTE), which is a progressive tauopathy with distinctive pathological features occurring after repetitive mild traumatic brain injury and can manifest with a number of symptoms [43].

In South Africa, a successful educational initiative, BokSmart, based on the New Zealand product, RugbySmart [44], has been developed. This initiative is aimed primarily at educating coaches, referees and other stakeholders, and has been adapted to local conditions. There is some evidence that this initiative is successful in reducing cervical and concussive related injuries, particularly at the neglected rural level of the game [44].

2.6.6.2. Injuries to the cervical spine and spinal cord

Rugby union, as a collision sport, has a high propensity for spinal cord injuries; both fatal and non-fatal. Cervical facet joint sprain, neck muscle strain and cervical nerve root/brachial plexus neuropathy appear to be the most recurring neck injuries in rugby union [45].They also appear to cause the most time lost (severity) in rugby union.

Injury to the cervical spinal cord injuries can result from one of the following mechanisms: Hyper flexion, hyperextension, severe rotation or cervical compression where a severe force is transmitted through the vortex of the skull.

The alarming increase in spinal cord injuries in the 1970s and 1980s resulted in increased media exposure as well as an attempt by authorities to address the matter. The biggest problem appeared to be a lack of accurate registers in all countries with database registries. This had important significance, particularly amongst the amateur-playing majority. Law changes to the scrum, both at youth and senior levels, were implemented in an attempt to address the scourge of cervical spine injury. In some countries at youth level, size/weight restrictions as well as minimal strength limits were imposed. However, since the 1990s, the tackle is where most spinal injuries occur and this is an area far more difficult to address [46].

Intervention programmes like RugbySmart in New Zealand and BokSmart in South Africa have had a positive effect on the rugby community in general. RugbySmart in particular showed a decrease in the rate of spinal injuries in the scrum [47]. Despite changes implemented in response to the increased rate of spinal injuries in the 1980s the frequency of spinal injuries did not decrease in New Zealand (up to 2000) and South Africa (up to 1997), but some success was noted in the UK and Australia [48].

Most of these law changes were initiated by the RFU relating to the scrum, maul and ruck, implemented initially at youth level in the 1980s and later adapted to senior level by 1990. At schoolboy level in South Africa, Noakes et al. [12] showed a reduction in incidence of spinal injuries for the period 1990-1997. Although there was a 46% decrease in spinal cord injuries among schoolboys, there was an increase in adult players. The reduction was felt to be secondary to fewer high tackles. It was suggested by Noakes et al. [49] that as a developing country, South Africa lacked the infrastructure to adequately prevent spinal injuries at the amateur level. The lack of a competent register was also raised, as were possible preventative strategies: neck strengthening, medical supervision, protective gear, and law changes. Possible law changes could be related to the front-on tackle whereby reducing vertex impact and protective neck braces as used in American football. The latter seems highly unlikely to be implemented at rugby union level. One area where the IRB attempted to enforce law changes was the scrum. Player restraint at engagement is vital, as poor timing can result in extreme forces exceeding the structural forces of the cervical spine [48].

In 2007, the IRB changed the scrum engagement call to: "crouch-touch-pause-engage". This was implemented at all levels to control the forces at engagement, as well as to reduce scrum collapse by standardising the distance between the two front-rows [50]. As this was conducted in New Zealand, it is important to remember that in this country the scrum is heavily scrutinised with under-19 safety restrictions imposed, even at senior rugby level. They deduced that after one year following the implementation, there was a reduction in the incidence of scrum-related injuries. As most spinal cord injuries (SCI) in rugby are as a result of cervical facet dislocation [51], recommendations are that low-velocity dislocations be reduced within four hours. Fuller's study in 2007 [52] evaluated all spinal injuries in English premiership players and showed that players were more likely to sustain cervical injury in matches and lumbar injury in training. Forwards were more likely to get injured: lumbar disc injuries in training and cervical nerve root injuries in matches. They concluded that players were at risk when tackling and doing weight-training, and that preventative strategies should be implemented at an elite level [52].

A further interesting study from France, where Bohu et al. [53] looked at the period 1996-2006 and noted a decline in cervical spine injuries. They attributed this to the implementation of safety measures on scrum engagement and particular physical characteristics necessary for front-row play.

Hermanus et al. [54] did a retrospective analysis of spinal cord injuries from 1980-2007 and found an alarming trend in that there was an increase in spinal injuries in the 1980s, 2000 and 2006 (South Africa actually has fewer SCIs than New Zealand and Australia).They noted that hookers were at the greatest risk, particularly with the tackle. The lack of a register was perceived to be problematic, as were absent medical personnel, particularly in the compromised rural areas where the problem is far more prevalent. In South Africa, the introduction of BokSmart has gone a long way towards addressing the problem and results appear promising, with a proactive educational programme attempting to minimise injury and promote safe play by educating all role players.

2.6.6.3. Facial injuries

Facial and scalp lacerations are extremely common in rugby union [55]. Lacerations involving the face and scalp require suturing, thus necessitating the blood replacement rule whereby the player be removed from the pitch and temporarily replaced. Under the 2007 consensus statement on injuries, these would fall under a ‘medical attention’ injury. Prior to 2007, these injuries would be classified together with other more severe injuries. Facial fractures also constitute a proportion of injuries involving the face secondary to rugby union being a collision sport.

Dental and orofacial injuries are as a result of player not wearing mouth guards. Mouthguards are one protective item in rugby that are of significant benefit [56]. Their benefit in the prevention of concussion is, at best, debatable.

2.7. Severity of injuries

For purposes of this dissertation, the severity of injuries is graded on time lost from competition and training; minimal (2-3 days), mild (4-7 days), moderate (8-28 days) and severe (more than 28 days**).** Only three studies [13, 14, 5] had similar methodologies in terms of definition of injury severity. In these studies, the most common injury severity was “moderate”, followed by “mild”, “minimal” and “severe”. Holtzhausen et al. [4] graded injuries according to the number of sessions missed: minor (1-3 missed), intermediate (4-9 missed) and severe (more than 9 missed). Minor injuries accounted for 39% of all injuries, 27% were intermediate and 34% were severe. A further 3 studies [57, 26, 6] classified injuries as mild (one game lost), moderate (two-three games missed) or severe (more than three games missed). The authors noted that mild injuries were the most common (64-70%), with similar incidences of moderate and severe injuries (14-22%).

2.8. Mechanisms of injury

2.8.1. Level of play (training vs. match play)

2.8.1.1. Training injuries

At the elite level, the rugby union player has a year of highly intensive rugby frequently combining international, franchise, provincial and club commitments. Therefore, there is rarely a period of rest between seasons. Professional Super Rugby players are particularly vulnerable, as administrators and owners largely planned the prolonged tournament of 16 weeks. Coaches also demand results and players are expected to play from week-to-week with weekly matches and perhaps several training sessions.

The concept of periodization is particularly challenging in this competition and weekly match demands make planning of training and conditioning difficult. Training incorporates conditioning training (weights, endurance, and speed/agility), skills (contact/non-contact), team/phase play and fitness testing. Rugby being primarily a game of strength/power/speed incorporates speed endurance through its stop-start nature. The conditioning phase seems to be dominated by endurance (running based) activities, weight training (power/strength), cross-fit type training (gym/field), speed/agility drills as well as skills/phase play. As the season progresses more emphasis is placed on skills/phase play as well as power/speed type sessions. Therefore, the risk of injury during training sessions is important to study. In one study it has been noted that during the 2003 England RWC training camp prior to the RWC, injury incidence increased as a result of the accumulative effect of the volume and intensity of the training [2]. Similarly, it has been documented that in the English premiership the incidence of injury was highest in pre-season period [19].

As a result, a more personalised training programme was used during the 2003 World Cup to develop strength and endurance. This approach resulted in a decreased incidence of injury. Earlier reports suggested that the incidence of injury during training is lower than during competition, but the greater time spent training actually may increases the overall number of injuries.

It has been documented that during training, most injuries involved the lower limb, particularly the musculotendinous and ligament units. The joint injuries were the most severe, with injuries to the knee most problematic. Injuries sustained during skills training were higher than during conditioning and although most injuries were as a result of non-contact training, those sustained during contact were the most severe. The highest incidence of endurance training injuries was as a result of running. Increased training (volume and intensity) therefore increases the incidence and severity of training injuries [19, 15, 18].

Finally, weight training is very integral to rugby training, both during the pre-season and competition. One of the aims of weight training is to develop muscle strength and endurance, thereby reducing the incidence of training injuries as well as improving on-field performance. However, weight training is also associated with a higher incidence of lumbar disc/nerve root injuries [193]. It was suggested that poor technique, poor condition of the lumbar stabilisers, fatigue from scrumming and excessive overload could all be factors increasing the risk of lumbar disc injuries during training.

2.8.1.2. Match injuries

In a recent meta-analysis it was shown that international rugby had a higher incidence of match injuries than rugby played at the sub-elite levels [2]. The study also reported that there was no difference between the injury incidence of backs and forwards in matches when analysing pooled data. Furthermore, the study confirmed that muscle/tendon and joint injuries were the most common injuries encountered in matches with bone/stress injuries the most severe. The lower limb was the area most likely to be injured followed by the upper limb, head and trunk with the upper limb most likely to be severely injured. In terms of injury severity in matches, ‘moderate’ injuries were the most common followed by ‘mild’, ‘minimal’ and severe. The study demonstrated a clear trend in terms of injuries for each match period: most injuries occurred in the third quarter, only slightly more than in the final and second quarters. Finally the study reiterated that the tackle was implicated to cause most injuries; with being tackled resulting in more injuries than being the tackler, followed by the ruck/maul, collision area, scrum, lineout and category labelled ‘other’. This non-specific category, not uncommonly encountered in the review process in many journals under an array of various headings; constituting a high proportion of injuries which can be perceived to be a limitation in terms of epidemiological methodology in rugby injuries.

According to Brooks et al. [17],who reported on match injuries, thigh haematomas were the most common injury, both for forwards and backs. The ACL caused the most severe injury amongst forwards and the hamstring the severest amongst the backs. The ruck/maul caused the most injuries to forwards and the tackle for backs, mostly in the second half. They found a lower incidence during the pre-season (they looked at English premiership players), which they felt, was attributed to the higher quality of play later in the season. Most injuries involved the tackle; with tackled injuries generally from the side and head-on and most tackling injuries from the front and side as well. In this study backs tended to have a higher incidence of injury, particularly in the tackle, with centres especially vulnerable.

These results were supported by Fuller et al. [58] when evaluated at men’s international u-20 rugby tournaments-the overall risk for injury at this level is lower than at an open level but the nature and causes are similar. At RWC 2011, Fuller et al. [13] found that players were bigger than in 2007, but not as big as predicted by Sedeoud et al. [59] The law variations introduced from 2007 did not appear to alter the time for ball-in-play, thus the injury profile was similar to 2007. However, the severity of the 2011 injury profile was higher than 2007. Head /face injuries were the most common match injury for forwards while the shoulder was the most common injury in the backs. The most severe injuries involved the knee; the anterior cruciate ligament (ACL) and the hamstring/knee ligament the most common match injury resulting in the greatest time-loss. Although position has been fairly equivocal in terms of injury classification, in this 2011 study the inside backs (halves, inside centre) were the most vulnerable positions. The tackle was yet again the phase causing the most injuries and it was interesting that teams' adapted their training accordingly by cutting back on the running and contact skills sessions, which are deemed high risk.

2.8.2. Phase of play

2.8.2.1. Kicking

The act of kicking is fairly unique in rugby union in that it is fairly position specific. In contrast to football (soccer), kicking is intermittent and usually carried out by the backs, mainly by the halves and full-back. The out-of-hand kick can involve kicking for field position or the kick-chase whereby the chasers contest the ball, often in the air. The grubber and the drop-kick are variations but essentially involve similar actions. The place-kick, or penalty /conversion kick involves kicking a stationary ball. In kicking, physiologically, there is strain on the upper leg and groin area (adductors), and this increases the risk of hamstring, quadriceps and groin (adductor) muscle strain injuries.

2.8.2.2. Lineout

The lineout is a set piece phase, where the hooker throws the ball from the touchline, and the opposing forwards compete for the ball. The locks (second row) are usually the targets for the hooker, positioned most of the time at number 2 and 4 in the lineout. Much jostling is often the case, with to–and–fro movement between the jumpers and supporters (In 1996 supporting in the lineout was permitted). The ball is sometimes thrown deep to the rear of the lineout and the short lineout is often employed (usually 5 players). Although the rolling maul is often employed, the lineout is a fairly low risk set piece with ankle sprains the most common injury related to the lineout [1]. This was also found to be the case in English premiership players as well as in Vodacom cup, RWC, and super rugby competitions [17, 19, 5]. The lineout tends to contribute less to the overall structure of the modern game, but not in its significance as a first-phase launch base. This will obviously vary from team to team and game-to-game, with some teams favouring the set piece from which to attack. Fuller et al. [7] showed this in their study, with most lineouts taking place in the oppositions 22m area and with most teams hoping to use the driving maul off the lineout (most mauls were shown to take place down the flanks of the field, demonstrating the link between lineouts and driving mauls). They also showed that teams generally tended to kick out of their 22m,but that attacking teams in the oppositions 22m area tended to hang on to the ball through the phases. Interestingly they also showed that 88% of players injured in the lineout were removed from play, indicative of the severity of injuries sustained at lineout time. Nonetheless, in terms of contact events the lineout is considered low risk in cause of injury.

2.8.2.3. Maul/Ruck

The ruck and maul are non-set piece phases that together with the set pieces and the breakdown define rugby union. They involve intense contact with a high propensity for injury, second to the tackle being the most common cause of injury in rugby union. Since the advent of professionalism there has been an increase in the number of rucks but a decrease in the number of mauls [27]. The reintroduction of the ‘use it or lose it `rule at the maul has attempted to increase the tempo of the game but confusion reigns when attempting to differentiate a ruck from a maul (the ruck is defined when 2 players stand bound over the ball). Fuller’s seminal study on contact events in 2007 reflected the modern name of the game: rucks are increasing steadily despite the fact that the use of the boot in rucking is outlawed in the modern game [7]. Most contact events take place centre field, increasing into the opposition’s 22. They concluded that collapsed mauls were not more likely to cause injury than non-collapsed mauls, possibly challenging the rule on collapsed mauls.

Brooks et al. [19] showed that for the forwards the incidence and severity of rucking/mauling injuries during training is high. Acromioclavicular (AC) joint and tibial/fibular fractures were the injuries with the highest incidence and absence from rugby-related activities when the forwards trained these skills. They concluded that if these high risk skills are incorporated too frequently into the training regimen the risks would outweigh the benefits in terms of player loss due to injury.

This was borne out in a further Brooks et al. study of the 2003 England RWC squad [15], where injuries sustained during rucking/mauling drills were as high as in the tackle.

2.8.2.4. Running

Running is the main type of training for endurance in rugby players, particularly in the pre-season conditioning phase. The act of running forms the basis of endurance training, as well as on the field, where sprinting is central to the game itself. The game is one of perpetual motion, teams attempting to get from point A to point B by overpowering one another either through force or speed. There is simply no substitute for speed in rugby and the ability to sprint at speed will always be advantageous in rugby union.

Brooks et al. [15] demonstrated that during training for the 2003 world cup, endurance running and contact training were the highest risk activities. They demonstrated that if off-feet activities (rowing, cycling) replaced running for endurance activities then the injury risk was markedly reduced. However this is problematic as rowing and cycling are not game specific for rugby. They also showed that the most severe/frequent injuries were hamstring/calf muscle injuries, usually resulting from sprinting. They also showed that there were 2.1 injuries/1000 player-weight training hours for weights and 24 injuries/1000 player-endurance training-hours for endurance running

2.8.2.5. Scrum

The scrum is a set piece phase with the potential for a high incidence of injury. The front rows make contact with considerable force, with the ensuing post-scrum fracas often chaotic. The number of set scrums per game is often variable, but poor technique and policing can result in both fatal/non-fatal catastrophic injuries. This is often the case in the amateur ranks with resulting catastrophic cervical injuries. Certainly at an elite level the scrum is heavily sanctioned, often unfairly, with the injury rate fairly low. Recently, the referee has changed the call from “crouch-touch-pause-engage” to “crouch-bind-set”.

The collapsed scrum is a major cause of cervical nerve injury in rugby. Vulnerable positions are the front-row forwards. When the head hits an object it decelerates the body, forcing the neck into a buckling type of movement rather than hyper-flexion [60]. At the elite professional level, scrum related c-spine injuries are less of problem than at the amateur level where poor technique and refereeing can result in more injuries. However, the scrum still has the highest propensity for injury [27]. Cervical-spine injuries tend to occur more frequently in the tackle in the modern game, secondary to the high tackle rate and low frequency of the scrum.

It appears that facet dislocation is the mechanism in cervical spine injuries, primarily involving the lower cervical levels (C4/5/6). The set piece, of which the scrum is a component, has declined in the modern game. Contact events tend to occur mainly in centre-field, with teams favouring the scrum as a launching mechanism from which to attack [7]. Scrums also tend to be heavily penalised, understandable in that the scrum still represents the greatest injury risk of all the contact events.

Although the tackle is the phase resulting in most injuries by virtue of it being the most frequent, if the scrum increased in frequency it would surpass the tackle in causing the most injuries. In the Brooks et al. study [19] the scrum was more or less on par with the lineout in terms of incidence and severity of injury. However, in a further study of English premiership players [18] the scrum was the cause of the highest incidence and severity of injuries, with the calf muscle being the area most injured. Fuller et al. [7] concluded that the scrum was second to the collision as the phase most at risk to cause injury (Scrums carried a 60% greater risk of injury than the tackle).

2.8.2.6. Tackle

The tackle is one consistent theme in the literature review that without doubt is the main cause of injury in phase play. The tackle is a fundamental part of the game and altering this could radically change the nature of the game. Present research is focussed on the tackle, and rightly so, because this is one area which needs to be properly policed. Strict sanctioning of the high, late, stiff-arm shoulder- charge and airborne tackles are essential. However the front-on tackle, peripheral from-behind tackle, tackle-assist two-man tackle, side-on tackle, dislodge thorax-tackle and the kick-chase tackle remain the very substance of the game. Nonetheless, it is essential that the correct tackle technique is taught, i.e. the head in the correct place, use of arms and correct rolling or falling.

It appears that there is no clarity between the tackler and the tackled as to who is most at risk for injury and studies appear to be divided on the matter. Fuller et al. suggested that at RWC 2007, being on the receiving end of the tackle resulted in greater injuries [14]. However, Brooks et al. [17] suggested that backs have a higher injury rate when tackled as a result of more kinetic energy generated and greater dissipation of energy when tackled. Fuller et al. [7], in their cohort study on contact injuries, again placed the tackle as the biggest cause of injuries (24%-58%), with on average over 200 tackles per game. Most tackles occurred in the centre-field with at least five times more chance of injury than any other contact event, more by virtue of the volume of tackle in the modern game (collisions and scrums still presented greater risk per event than other contact events). Tackles were also responsible for the most time lost after injury.

In 1999, Garraway et al. [61] concluded that most tackle injuries occurred in the blind spot, i.e. tackled from behind as well as when there is a difference in the speeds of tackler and ball-carrier. It was also suggested that the front-on tackle results in a higher frequency of injuries. Furthermore, a difference in speed/velocity between tackler and the tackled player was deemed significant. This finding was challenged in a more recent study by Fuller et al. [20] which suggested that ball-carriers are prone to injury when tackled at high speed/velocity. High tackles, no use of arms, high intensity collisions and the head on wrong side of ball-carrier were all implicated in tackle injuries. Most injuries occurred when tackling ball-carriers at high speed, in high impact tackles and when striking the legs of the ball-carrier with the head on the wrong side. The authors also noted that midfield backs (centres) were the most vulnerable. As the research was sanctioned by the IRB, the consensus was that above shoulder tackles be outlawed/sanctioned heavily by the referee. The onus was on the referee to protect the ball-carrier by applying heavy sanctions to transgressors.

Fuller et al. [7] concluded that the tackle caused at five times more injuries than any other contact event, i.e. mauls, rucks, lineout's and scrums, explained by the fact that the tackle is far and away the most frequent phase of play. However, these authors pointed out that whilst the scrum carried at least 60% greater risk of injury than the tackle, scrums were far less common so resulting in fewer injuries. Lineouts and rucks were the least likely contact events to cause injury. The maul is a fairly high-risk phase as players often make contact with flexed heads, thus increasing the incidence of cervical spine injuries.

Recent work by Hendricks et al. [8] has raised some interesting questions regarding velocity and acceleration in the tackle, with tacklers adjusting their velocity to reach a suitable relative velocity before making contact with the ball-carrier. Tacklers enter the pre-tackle phase by adjusting velocity if different from the ball-carrier and elite players are able to adjust quicker.

Rugby league has almost set the bench-mark in terms of defensive strategy in union. Union has often employed defensive analysts from league, with league defensive drills filtering over to union. King et al. [62] produced statistically significant results in a rugby league study showing that double-hits at mid-torso/shoulder produced more injuries. They also concluded that tackles made behind the ball-carriers visual field had an increased injury incidence and the tackler was more likely to be injured than the tackle-assist.

2.8.3. Period in a match when the injury occurred

Most injuries occur in the 2nd–half, the final quarter at RWC 2011 and in the third quarter at RWC 2003 [13, 57]. In the RWC study of 2007 most injuries occurred in the third quarter [14].

This could be as a result of player fatigue or perhaps the threat of substitution at 60 minutes (the substitution rule was introduced in 1997 whereby uninjured players be substituted by fresh legs).

2.8.4. Other factors associated with injuries in rugby union

2.8.4.1. Playing surface

It appears that surface condition, in particular ground hardness, is an important contribution to injuries in rugby union. Lee et al. [63] proved this to be so in Scotland, with a higher incidence of injury in the early season when grounds tend to be harder. Takemura et al. [64] demonstrated similar results with a decrease in the level of injuries in the New Zealand domestic rugby season as the season progressed. It is assumed that ground hardness is an indirect cause of injuries via increased traction, acceleration and greater forces. Other variables have to be factored in early season, i.e. poor conditioning, overtraining, insufficient rehabilitation and early season over-zealousness.

Artificial surfaces appear to be equivocal. Fuller et al. [65] showed the difference between artificial turf and grass in the prevalence of injuries was not significant, both in training and in matches.

2.8.4.2. Weather conditions and timing of season

Ideal weather conditions (calm, warmish, windless conditions) have been shown to be associated with an increased incidence of injuries in rugby union [21],[63]. Injuries were also more likely to occur when games were played on hard grounds [21]. The fact that the grounds are harder earlier in the season (autumn) could, however, be incidental. When conditions are optimal the intensity of the game is often played at a higher level, which could result in more injuries. Furthermore, fitness levels are often not optimal in the early season and players could be harbouring injuries or insufficiently rehabilitated. Grounds tend to soften up as the season progresses, but so do fitness levels improve. Playing on hard surfaces tends to increase the risk of injury by placing more strain on tendons and ligaments. Soft grounds may reduce injury by cushioning impact to ground and perhaps by decreasing the intensity of the game by reducing the traction. Hard grounds can also result in an increased tackle count thus increasing the chance of injury. Interestingly, Lee and Garraway [63] evaluated environmental factors in the 1993-94 seasons in the Scottish borders region and concluded that timing of the season and weather may influence the incidence of injuries, but the state of the pitch does not (they felt that when corrected for, the increased injury rate was as a result of the increased tackle count).

2.8.4.3. Protective equipment

In a study by Marshall et al. [66], it was shown that protective equipment used in rugby union has fairly limited effectiveness in preventing injury. Most of the other studies are fairly equivocal. However, mouth guards do reduce dental injuries. Padded headgear does not reduce the incidence of concussion but will obviously reduce head lacerations. Ankle strapping/braces have been shown to reduce sprains, but braces are outlawed in rugby. Other measures, such as, shoulder pads, joint strapping and thermal tights do not reduce injury incidence.

2.8.4.4. Law changes

One way to make rugby a safer game would be to implement law changes as has been the case through the years. Law changes are principally to make rugby a safer game as well as to make it a more appealing spectacle. The breakdown excluded, changes to the set piece and tackle have perhaps made the game safer and more free-flowing. The breakdown remains a shambles with the result that referees seldom blow with much consistency and it is difficult to see how the new law changes have improved the game. An example is the scrum, an area of heavy scrutiny as a result of catastrophic neck injuries. Recent changes at the engagement are a case in point: in 1992/3 the referee instructed the front-rows to-"crouch-pause-engage", this was altered to "crouch, touch, pause, engage" in 2007 [50]. This call was again altered in the 2012/13 season to: "crouch, touch, and set", to the present call of "crouch, bind, set". These changes were brought about to limit c-spine injuries in the front-row.

In 2007 the IRB introduced experimental law variations (ELV) to elite rugby union competitions in the southern hemisphere via the tri-nations, Super14, Currie Cup and Vodacom Cup competitions relating mainly to the lineout, tackle and the maul [5.] Whilst the ELVs did not increase the risk of injury in these competitions, it was concluded that at the lower elite level (Vodacom cup) the incidence of injury was lower, but at the higher elite level tiers the injuries tended to be more severe [5].

2.8.4.5. Player age

Most studies of the epidemiology of rugby injuries involve senior players, mainly elite player's post-1995 and amateur players proceeding this period. There is a dearth of information on youth rugby, nonetheless one thing is clear: youth rugby injury incidence is a lot lower than senior rugby, understandable in that size plays a significant part in rugby. Heselar et al. [67] showed an increasing correlation between age and injury rate at a youth level. At youth level the most frequently injured areas are the head, neck, shoulder and wrist. Interestingly, the thigh and lower leg, whilst representing high proportions in adult players, actually represent a much lower incidence at youth level. The study also showed that younger players have fewer severe injuries than adult players, with the u/16 and u/17 players having injury patterns more reflective of older players. The tackle was again implicated as the phase most likely to cause injury. At an elite u-20 level, Fuller et al. [58] showed that the incidence of injury for both forwards and backs was lower than RWC studies, mostly as a result of the tackle in the third quarter.

2.8.4.6. Player anthropometric factors

According to numerous studies, professional rugby players are increasing in size [13;68]. This applies particularly to players in the professional game, where the number of tackles, rucks and mauls has increased by a factor of 4 in 30 years [69].This could be as a consequence of the ball in play for longer periods, resulting in more injuries or as a consequence in a more physical modern game. Sedeaud et al. [59] showed that between the 1987 and 2007 RWC's the body mass index (BMI) of the players increased substantially, with the collective mass of the forward pack one of the determinants of success. Fuller et al. [68] evaluated player size in English premiership players over a period 2002-2011. Statistically significant weight/size differences were found in various positions; fly-half, prop and back- row; forwards specifically. This is a trend which is becoming clear as fly-half's (stand-off/1 st 5/8's) are more like centres, centres are more like loose-forwards (back-row) and loose-forwards more like locks (2nd-row) forwards. Thus the modern game has evolved to where power is important, particularly at set-pieces and the break-downs.

2.8.4.7. Previous injury

Rehabilitation/Fitness/Rest

This area has important relevance in the Super Rugby arena. The international season is arguably too long, with practically a year round programme. Players are therefore not given enough rest in order to rehabilitate from their injuries. Top players are generally overplayed by clubs, provinces and internationally. Super Rugby squads get plagued with injuries, with the more marginal sides' lack of depth badly exposed. Therefore, players often enter the new season over-trained/fatigued and are unable to cope with the demands of the new season. Furthermore, insufficient rehabilitation is a serious problem, with players often rushed back too early to matches. Under reporting of players' injuries is a worrisome trend, particularly with respect to concussion. This was particularly relevant in the time when the three-week rule was applied globally.

Chalmers et al. [22] evaluated amateur club players from New Zealand. An increased injury rate (IR) was noted for increasing age, pacific island ethnicity, strenuous physical activity, playing while injured, hard ground, foul play and use of headgear. Interestingly at this level no association was found for BMI, previous injury and pre-season training. Furthermore, players are generally unwilling to disclose 'minor niggles' thus not undergoing full rehabilitation, increasing the risk of recurrent injuries. This was already shown in 1994 by Bird et al. [25], when players were unwilling to disclose some injuries in order to ‘make the cut’.

As expected players at a higher elite level are more at risk for pre-season injury by playing with an incompletely rehabilitated injury and/or overtraining [43]. Similar results were demonstrated by Holtzhauzen et al. [4], when evaluating Super Rugby. Training injuries constituted a proportion of injuries with a high number of recurrent injuries. This they concluded could be due to no pre-season break, overtraining, insufficient rehabilitation and too soon a-return-to-play. They also showed higher injury rates in the pre-season suggesting lack of a satisfactory break, overtraining, insufficient rehabilitation and early return to play following an injury. These researchers concluded that the seasons were too long, players were not given enough rest, and many injuries were recurrent/chronic, with pre-season injuries linked to poor conditioning, lack of match fitness and lack of adequate recovery.

These conclusions were also borne out by Lee et al. [70] in a study conducted over a decade ago who also concluded that injured players were not given enough time to allow their injuries to heal, and players injured at end of previous season were more likely to be injured in the following season. They also noted that players attending pre-season training with a perceived level of increased fitness had a greater risk of subsequent injury. This was even more so for professional players. This finding could be interpreted as players who train longer and harder at the elite level are more injury prone by virtue of increased intensity. This has indeed been proven to be the case in latter studies. The researchers also observed that injured players tended to undertake ‘catch-up’ training, thus exposing themselves to more injury risk. Fairly alarming was the researchers’ argument that rugby injuries were actually rugby specific and not related to fitness training. This goes against the recommendation of possible preventative measures in terms of fitness training. The researchers even went so far to suggest that heavy pre-season training rather than overtraining per se will predispose players to injury through increased fatigue. On the contrary, they found that players who undertook no pre-season training did not have an increased tendency to injury.

2.9. Summary and conclusion

Rugby union, a game having evolved of over nearly two centuries, has since the advent of professionalism in 1995 faced many law changes aimed to reduce the risk of serious injury and to keep the ball in play for longer periods. Despite this, the injury rates in rugby union have been comparable with some other collision sports (ice hockey, rugby league) but greater than some other contact sports (soccer) [2]. A higher level of play is associated with a greater incidence of injuries, with international matches having the highest incidence [2]. This is despite the 2003 study on the England Rugby World Cup squad which had inflated values [15], and the perception that the higher level of play was associated with increased size/ strength of players, longer seasons, greater ball-in-play time and players covering distances at greater speeds. Professionalism has also resulted in an increased tackle count and more rucks with a reduction in mauls, scrums and lineouts [27].

The authors of the meta-analysis [2], cautioned that a deduction such as the above needs to be tempered against the perceived methodological limitations of some studies [71, 26]. The inconsistencies in the methodologies used in the epidemiological analysis of rugby injuries have been problematic when reviewing the literature prior to 2007.This problem was addressed in 2007 following the consensus statement [3], in an attempt to bring about uniformity related to the epidemiology of injuries in rugby union.

Although the incidence of injury is significantly higher in matches as opposed to training [27], it has been shown that the incidence of training injuries increases with age and standard of play [25], tending to be more severe [17,19, 26]. The high incidence of lower limb soft tissue injuries seen in training reflect the high volume of running in training as opposed to injuries such as haematomas, lacerations, fractures/dislocations and concussion which are more commonly sustained during contact/collisions in matches [27].

The lower limb was the most common injury location [2], with the knee, thigh and ankle the most commonly injured areas [27]. The knee joint in particular causes the most absence from training and matches [27]. Lateral ankle ligament injuries are the most common ankle injuries, with Achilles tendon injuries making up the greatest proportion of ankle injuries [17]. Upper limb injuries were the most severe [2], with the shoulder in particular responsible for most injuries [27]. Most injuries were found to be of moderate severity (8-28 days), implying players missing between one and four games [2].

The muscle/tendon complex and the joint/ligament unit were the most common injury types [2], with fractures and stress fractures accounting for the most severe types of injuries. Thigh haematomas and hamstring injuries are the most common injuries in rugby union [17, 2] and are responsible for considerable time-loss in rugby union [2]. Thigh haematomas are secondary to collisions/contact common in rugby union [76] and hamstring injuries as a result of the stretch/shortening cycle implicit in sprinting.

Although previous studies suggest that the forwards are more prone to injury than the backs [26,6], the meta-analysis [2] concluded that the injury rates and severity between forwards and backs were in fact equivocal [2]. However, there appears to be some evidence to suggest that there are injury pattern differences between different positions [16].

As the third quarter appears to have the highest incidence of injury, fatigue must be considered as an important factor in injury aetiology [2]. Furthermore, as the tackle is the most common contact event in rugby union[2], fatigue has to be implicated as a causative factor in the high incidence of injuries associated in the tackle as well. Being tackled was the most common injury incident [2], higher than that of tackling. The ruck and maul are, after the tackle, the most common injury events [72], with the scrum representing a low proportion in the modern game. However, when correcting for the infrequency of the scrum during matches, the scrum has a high propensity for injury [27].

Finally, as part of the review process, an attempt was made to identify specific intrinsic and extrinsic injury risk factors in rugby union players that might aid in the epidemiological analyses of rugby injuries. A harder playing surface has injury related implications as do weather conditions-both hard surfaces and better weather conditions are associated with a greater incidence of injuries. Protective equipment has been equivocal in terms of injury prevention, other than the use of gum guards in reducing dental injuries in rugby union. Youth rugby is associated with fewer injuries and increasing physical dimensions of senior professional players has seen an increasing incidence of injuries. The rehabilitation of injured players is essential to avoid recurrent injuries. Recurrent injuries, although accounting for relatively fewer injuries are more severe than new injuries [2] and as such have to be effectively rehabilitated.

To date, there are only three studies that have documented injuries in the Super Rugby competition [4, 5, 6].Furthermore, since these studies have been reported the tournament has changed with respect to its nature. At present:

1) the tournament is played over a longer duration (currently 16 weeks) compared with many other international tournaments (usually ≤ seven weeks duration),

2) in 2005, and more recently in 2011, there have been increases in the number of participating teams, with weekly matches resulting in the current long duration of the tournament,

3) teams are awarded bonus points for tries, which encourages a more open, flowing style of play that could result in an increased tackle count during matches, and

4) unlike other tournaments that are played in one geographical location, players in this tournament also have to contend with demanding travelling schedules across multiple time zones as matches are played in venues of each of the three countries.

The effects of these changes could lead to alterations in the incidence of injury in the present form of Super Rugby competition. However, this has not previously been studied.

Thus, the epidemiology of injuries sustained during the recent format of the tournament is the subject of the study presented in Chapter 3.

Chapter 3

The epidemiology of injuries sustained during the 2012 Super Rugby tournament – a prospective cohort study involving 14 801 player-days

3.1. Introduction

The Super Rugby competition is played annually between 15 professional rugby union teams - five each from three Southern hemisphere rugby-playing nations (South Africa, New Zealand and Australia). As rugby union is a contact sport, and is played at the elite level year round, the injury rate is known to be amongst the highest of all professional sports [2]. The Super Rugby competition is played weekly over a period of approximately 16 weeks, which is longer than most international tournaments. This places particularly high physical and psychological demands on the players due to the nature of the competition. Teams are awarded bonus points for tries and for limiting the point's loss to seven points, and this encourages a more open flowing style of play in which the ball is in play for longer periods. This is likely to result in increased tackle counts. Therefore, a number of factors may make this competition particularly prone to an increased incidence of injury. In addition, to a very demanding match and training regimen, players also have to contend with travelling across multiple time zones in order to play matches in each of the three countries.

To date, there are only three studies that have documented injuries in the Super Rugby competition [4, 5, 6]. The original pilot study undertaken in Super Rugby was in 1997, and involved only one team during the competition [6]. In this study, the injury rate of "significant" injuries was 45/1000 player hours, with no difference between the forwards and the backs. Most of the injuries involved the soft tissues and occurred during the tackle.

A study conducted during the 1999 Super Rugby tournament [4] was the first comprehensive study in which three teams of 25 players were followed during the tournament and both training and match injuries were recorded. The overall match injury rate was 55/1000 player match hours and the overall injury rate (match and training combined) was 4.3/1000 player training hours. Most of the injuries occurred during the tackle involving mainly the soft tissues (ligamentous sprains and musculotendinous strains). The definition of injury in these two studies varied so comparison of the injury rates is not valid.

The most recent study was conducted during the 2008 Super 14 Rugby tournament [5.] In this study, the current consensus for injury definition and data collection in rugby union injuries was applied [3]. This was a comparative study to document the impact of experimental law variations on the incidence and nature of match injuries (training injuries were not reported). In this study, 14 teams were followed during the competition, and the incidence of time-loss match injuries was 96/1000 player match hours. The tackle was the mechanism most responsible for injuries, with no difference between forwards and backs noted and soft tissues the site most implicated.

Currently, 15 teams from the Southern Hemisphere play this tournament over a four-month period from the late summer to the early winter period each year. The tournament is particularly demanding because: 1) the tournament is played over a much longer duration (currently 16 weeks) compared with many other international tournaments (usually $\leq$ seven weeks duration), 2) in 2005, and more recently in 2011, there have been increases in the number of participating teams, resulting in the current long duration of the tournament, 3) matches are played weekly by each of the teams, 4) teams are awarded bonus points for tries, which encourages a more open, flowing style of play that could result in an increased tackle count during matches, and 5) unlike in other tournaments that are played in one geographical location, players in the Super Rugby tournament also have to contend with demanding travelling schedules across multiple time zones as matches are played in venues of each of the three countries.

This tournament may therefore be associated with an increased the risk of injuries. Furthermore, to our knowledge, the association between inter-continental travel and risk of injuries in rugby union has not been studied. Therefore, the aim of this study was to determine the incidence and factors associated with injuries in five South African Super Rugby teams during the 16-week 2012 Super Rugby competition.

3.2. Methods

3.2.1. Type of study

This was a prospective cohort study involving 152 players from five South African Super Rugby teams over the 2012 Super Rugby tournament.

3.2.2. Participants

The Clinical Sport and Exercise Medicine Research Group of the UCT/MRC Research Unit for Exercise Science and Sport Medicine at the University of Cape Town conducted the study. This was a joint project with the Medical Committee of the South African Rugby Football Union (SARFU). All the players from the 5 participating teams were considered potential participants in the study. Each of the team physicians accompanying the teams was provided with detailed information about the study. The team physicians then briefed all the players about the details of the study (Appendix A – Participant information sheet). Written informed consent (Appendix B – Informed consent form) was obtained from the players. Prior to commencing the study, approval was obtained (Appendix C – Approval letter) from the University of Cape Town Research Ethics Committee (REC 008/2011). The demographic data for the study population is depicted in Table 3.1.

Table 3.1: Demographic data for the study population (all players, teams and player position) Values are mean (SD)

		Nº of players	Age (years)	Body Mass (kg)	Height (m)	Body Mass Index (kg/m²)
All players		152	25.0 (3.4)	101.5 (12.1)	1.87 (0.07)	29.1 (2.9)
Teams	**A**	18 *	22.7 (3.3)	105.6 (12.9)	1.87 (0.07)	29.9 (3.4)
	B	29	25.9 (3.6)	101.1 (11.5)	1.86 (0.07)	29.3 (2.4)
	C	33	24.8 (3.4)	99.4 (12.4)	1.86 (0.07)	28.6 (2.8)
	D	35	25.7 (3.1)	100.9 (13.0)	1.86 (0.07)	29.1 (3.3)
	E	37	25.0 (3.1)	102.3 (11.3)	1.88 (0.07)	28.9 (2.8)
Main player position	**Forwards**	85	24.9 (3.3)	110.0 (7.9)	1.89 (0.07)	30.7 (2.8)
	Backs	67	25.2 (3.6)	90.5 (6.3)	1.83 (0.06)	27.0 (1.5)

*: Only 18 of the approximately 34 players in this team gave consent to participate in the study. There were no significant differences in the age (p=0.278), height (p=0.456) and body mass (p=0.899) between the Teams.

3.2.3. Injury data collection

In this study, injuries were defined according to the "Consensus Statement on Injury Definitions and Data Collection Procedures for Studies of Injuries in Rugby Union" [7]. Both medical attention injuries (requiring medical intervention but not resulting in loss of training or match play > 1 day), and time loss injuries (preventing playing in matches or training for > 1 day) were recorded. However, for the purposes of comparison with other studies, only time loss injuries will be reported in this dissertation. The severity of time loss injuries was subdivided into the following categories, according to the number of days that players were unable to train or play matches: minimal (2-3 days), mild (4-7 days), moderate (8-28 days) and severe (>28 days) [7].

The team physicians of the participating teams collected injury data during the tournament. Each team physician was provided with a laptop or portable tablet to collect the data through a secure, web-based electronic platform that was specifically designed for this purpose. Data capture commenced a few days before the start of the tournament and ended after each of the teams played their last game. The team physician reported the following daily data: size of the squad (number of players), type of day (rest day, training day or match day, travel day was recorded as a rest day), team training hours, and whether or not a player was injured. If a player injury was reported, the following specific details were recorded: new or recurrent injury, playing conditions at the time of injury (surface type, condition of surface, weather conditions), main player position (forwards, backs), training or match injury, time of the match injury (which quarter of the game), and the mechanism of injury. Finally, the main anatomical location of the injury, the specific anatomical structure of the injury, the type of injury (muscle/tendon, joint/ligament, skin, bone, brain/CNS), and the severity of the injury (days lost from training or matches) was recorded. More than one injury could be recorded and two injuries in the same player were recorded as separate injuries. The electronic data collection system allowed the research team to monitor data input (logging in and entering data) on a daily basis. This allowed the research team to contact team physicians if data entry was not done regularly. There was contact between the central research office and the participating physicians via email or telephone to discuss any difficulties with the technical recording of injuries. Complete daily data entry at the end of the tournament was confirmed. In this manner, compliance of the team physicians could be verified, and 100% compliance for daily entry of data was achieved.

A system of coding was used to ensure player confidentiality. Teams and players were allocated random numbers, and these were kept in sealed envelopes until after completion of the tournament. All data were securely stored and accessed by the central research office only at the end the tournament.

3.2.4. Calculation of the player-hours (training and match)

The team physicians also recorded the number of hours of training performed by their team on training days. Daily training player-hours for each team were calculated as the number of team training hours x the number of players in the team on that day. It was assumed that all players in the team participated in the entire training sessions. The total training player-hours were calculated as the sum of all the daily training player-hours for each team over the study period.

The usual total duration of a rugby union match is 80 min (1.33 hours of play). Match player- hours for one team playing a match was calculated as 1.33 x 15 players (20 match player-hours). The total match player-hours for a team were calculated as 20 x the number of match days for a team. For team A, with only 18 players consenting, 7.9 instead of 15 players per match were counted. The 7.9 was the proportion (18/34) of the 15 players counted for a match in a team size of 34. In addition, injury data will also be expressed as the number of player-hours until an injury occurs (1 injury per number of player-hours).

The total number of player-hours (all, training, match) for all teams, individual teams, as well as main player positions (forwards and backs), is depicted in Table 3.2.

Table 3.2: Player-hours (all, training, match) for all players, individual teams and main player positions (forwards and backs)

		All player-hours	**Training player- hours**	**Match player-hours**
All players	All players	17340	15828	1512
	Forwards	9248	8442	806
	Backs	8092	7386	706
Team A	All players	1948	1763	185
	Forwards	1039	940	99
	Backs	909	823	86
Team B	All players	3363	3051	312
	Forwards	1793	1627	166
	Backs	1570	1424	146
Team C	All players	4658	4287	371
	Forwards	2484	2286	198
	Backs	2174	2001	173
Team D	All players	3469	3157	312
	Forwards	1850	1684	166
	Backs	1619	1473	146
Team E	All players	3902	3570	332
	Forwards	2081	1904	177
	Backs	1821	1666	155

3.2.5. Statistical analysis of data

Data were in the form of counts, i.e. the number of injuries each player sustained, and number of players injured. The proportion of injured players (injured player proportion – IPP) (also known as a period prevalence) was calculated as the % of players injured during the tournament. In addition, the IPP for different grades of injury severity are also reported. Standard descriptive statistical analyses were conducted. For injuries, these include numbers, proportions / percentages (including 95% confidence intervals) and incidences (including exact 95% confidence intervals) of injuries in the total sample as well as sub groups according to matches vs. training, main player position, main and specific anatomical location of injury, injury severity categories, period of matches and geographical location.

The incidence of injury was calculated as injuries per 1000 player-hours of training (training injuries) and match play (match injuries). This enables comparison to the incidence of injuries during matches (match player-hours) to training (training player-hours) reported in other studies and followed the international guidelines for injury reporting in rugby union [7]. The incidence and severity of injuries was recorded for both forwards and backs and the incidence of injuries was grouped by severity and main player position. The anatomical location of injury was analysed both in training and match play, with incidence and mean severity of match injuries as a function of playing position. Injury type was documented, with incidence and mean severity of training/match injuries. The most common match/training injuries were reported, as was severity of injuries (in terms of time lost). Training activity, phase of play and time period in a match when the injury was sustained, were investigated.

3.3. Results

3.3.1. Injured player proportion (IPP; Period prevalence) of time-loss injuries in all players

During the tournament, 160 time-loss injuries were recorded in 83 players. The proportion of players sustaining a time-loss injury (IPP) during the tournament was therefore 54.6%. The IPP during the tournament for injuries, by injury severity, was as follows: 19.7% for minimal and mild injuries (2-7 days missed), 20.4% for moderate injuries (8-28 days missed), and 14.5% for severe injuries (> 28 days missed). Therefore, 34.9% of players sustained an injury during the tournament that was severe enough to prevent training or playing in a match for 8 days or more. Furthermore, 38 of all players (25% of all players) sustained more than one time-loss injury during the tournament. Most of the injuries (126/160; 78.8%) occurred during matches, compared with training (34/160; 21.2%).

3.3.2. Incidence of all time loss injuries (all, match and training injuries)

A total of 17 340 player-hours were monitored during the tournament, of which 1 512 were match player-hours, and 15 828 were training player-hours. The overall incidence of time-loss injuries was 9.2 per 1000 player-hours (95% CI: 7.9 – 10.8). The incidence of match injuries (per 1000 player-hours) was significantly greater (83.3; 95% CI: 69.4-99.2) compared with training injuries (2.1; 95% CI: 1.5-3.0). Injury rates (per 1000 player-hours) were not significantly different between individual teams.

3.3.3. Main player position (forwards and backs)

In forwards, a total of 95 injuries were recorded, while 65 injuries occurred in back players. The number of injuries, playing hours (match and training) and the incidence of all injuries (per 1000 player-hours) and injuries during matches and training in forwards and backs is depicted in Table 3.3.

Table 3.3: The incidence of injuries (injuries per 1000 player-hours) (95%CI) in all players, forwards, and backs during matches and training

		Number of time loss injuries	Player-hours	Incidence of injuries / 1000 player-hours	95% CI	
All injuries	Forwards	95	9248	10.3	8.3	12.6
	Backs	65	8092	8.0	6.2	10.2
Match injuries	Forwards	75	806	93.0	73.2	116.6
	Backs	51	706	72.3	53.8	95.0
Training injuries	Forwards	20	8442	2.4	1.4	3.7
	Backs	14	7386	1.9	1.0	3.2

The incidence of injuries in forwards was not significantly higher compared with injuries in backs for all injuries (forwards 10.3; 95% CI: 8.3-12.6; backs 8.0; 95% CI: 6.2-10.2)(p=0.125), match injuries (forwards 93.0; 95% CI: 73.2-116.6; backs 72.3; 95% CI: 53.8-95.0) and training injuries (forwards 2.4; 95% CI: 1.4-3.7; backs 1.9; 95% CI: 1.0-3.2).

3.3.4. Main anatomical location (all players, forwards and backs)

The incidence of all injuries (per 1000 player-hours) by main anatomical location for all players, forwards and backs is depicted in Table 3.4.

Table 3.4: Frequency (% of injuries) and incidence (per 1000 player-hours) of all injuries and match injuries in all players, main player positions (forwards and backs), and by main anatomical location of injury

		Main anatomical location	n	%	Player-hours	IR	95% CI	
All injuries	**All players**	**Head/neck**	21	13.1	17340	1.2	0.7	1.9
		Upper limb	41	25.6	17340	2.4	1.7	3.2
		Trunk	21	13.1	17340	1.2	0.7	1.9
		Lower limb	77	48.1	17340	4.4	3.5	5.6
	Forwards	**Head/neck**	14	14.7	9248	1.5	0.8	2.5
		Upper limb	26	27.3	9248	2.8	1.8	4.1
		Trunk	11	11.6	9248	1.2	0.6	2.1
		Lower limb	44	46.3	9248	4.8	3.5	6.4
	Backs	**Head/neck**	7	10.8	8092	0.9	0.3	1.8
		Upper limb	15	23.1	8092	1.9	1.0	3.1
		Trunk	10	15.4	8092	1.2	0.6	2.3
		Lower limb	33	50.8	8092	4.1	2.8	5.7
Match injuries	**All players**	**Head/neck**	19	15.1	1512	12.6	7.6	19.6
		Upper limb	38	30.2	1512	25.1	17.8	34.5
		Trunk	17	13.5	1512	11.2	6.6	18.0
		Lower limb	52	41.3	1512	34.4	25.7	45.1
	Forwards	**Head/neck**	12	16.0	806	14.9	7.7	26.0
		Upper limb	23	30.7	806	28.5	18.1	42.8
		Trunk	9	12.0	806	11.2	5.1	21.2
		Lower limb	31	41.3	806	38.4	26.1	54.6
	Backs	**Head/neck**	7	13.7	706	9.9	4.0	20.4
		Upper limb	15	29.4	706	21.3	11.9	35.1
		Trunk	8	15.7	706	11.3	4.9	22.3
		Lower limb	21	41.2	706	29.8	18.4	45.5

n=Number of time-loss injuries
%: % Of injuries in all players, forwards and backs-the % are out of the total number of injuries, not the total number of players
IR: Incidence rate per 1000 player-hours

All injuries

The majority of injuries in all players occurred in the lower limb (48.1%), followed by the upper limb (25.6%). Less commonly, the trunk (13.1%) and the head/neck region (13.1%) were affected. The majority of the injuries in the forwards occurred in the lower limb (46.3%), followed by the upper limb (27.4%). Less commonly the head/neck region (14.7%) and the trunk (11.6%) were affected. The majority of the injuries in the backs occurred in the lower limb (50.8%), followed by the upper limb (23.1%). Less commonly the trunk (15.4%) and the head/neck region (10.8%) were affected.

Match injuries

The majority of the match injuries in all players occurred in the lower limb (41.3%), followed by the upper limb (30.2%). Less commonly the head/neck region (15.1%) and the trunk (13.5%) were affected. The majority of match injuries in the forwards occurred in the lower limb (41.3%), followed by the upper limb (30.7%). Less commonly the head/neck region (16.0%) and the trunk (12.0%) were affected. The majority of match injuries in the backs occurred in the lower limb (41.2%), followed by the upper limb (29.4%). Less commonly the trunk (15.7%) and the head/neck region (13.7%) were affected.

3.3.5. Specific anatomical structure

The incidence of time-loss injuries (per 1000 player-hours)(all, match, training) by specific anatomical structure for all players is depicted in Table 3.5.

Table 3.5: The incidence of time-loss injuries (per 1000 player-hours) (all, match, training) by specific anatomical structure of injury

			n	IR	95% CI	
All injuries	**Head/neck**	**All head/neck injuries**	**21**	**1.2**	**0.7**	**1.9**
		Head / Face	18	1.0	0.6	1.6
		Neck / Cervical spine	3	-	-	-
	Upper limb	**All upper limb injuries**	**41**	**2.4**	**1.7**	**3.2**
		Shoulder / Clavicle	27	1.6	1.0	2.3
		Upper arm / forearm / elbow	5	0.3	0.1	0.7
		Hand / Fingers / Wrist	9	0.5	0.2	1.0
	Trunk	**All trunk injuries**	**21**	**1.2**	**0.7**	**1.9**
		Upper trunk / Chest / Thorax / Rib	9	0.5	0.2	1.0
		Lower back / Lumbar	7	0.4	0.2	0.8
		Pelvis / Sacrum / Abdomen	5	0.3	0.1	0.7
	Lower limb	**All lower limb injuries**	**77**	**4.4**	**3.5**	**5.6**
		Hip / Groin	11	0.6	0.3	1.1
		Thigh	19	1.1	0.7	1.7
		Knee	25	1.4	0.9	2.1
		Ankle	8	0.5	0.2	0.9
		Foot/ Toe	6	0.3	0.1	0.8
		Lower leg	8	0.5	0.2	0.9
Match injuries	**Head/neck**	**All head/neck injuries**	**19**	**12.6**	**7.6**	**19.6**
		Head / Face	17	11.2	6.6	18.0
		Neck / Cervical spine	2	-	-	-
	Upper limb	**All upper limb injuries**	**38**	**25.1**	**17.8**	**34.5**
		Shoulder / Clavicle	25	16.5	10.7	24.4
		Upper arm / forearm / elbow	4	-	-	-
		Hand / Fingers / Wrist	9	6.0	2.7	11.3
	Trunk	**All trunk injuries**	**17**	**11.2**	**6.6**	**18.0**
		Upper trunk / Chest / Thorax / Rib	9	6.0	2.7	11.3
		Lower back / Lumbar	4	-	-	-
		Pelvis / Sacrum / Abdomen	4	-	-	-
	Lower limb	**All lower limb injuries**	**52**	**34.4**	**25.7**	**45.1**
		Hip / Groin	7	4.6	1.9	9.5
		Thigh	10	6.6	3.2	12.2
		Knee	22	14.6	9.1	22.0
		Ankle	5	3.3	1.1	7.7
		Foot/ Toe	3	-	-	-
		Lower leg	5	3.3	1.1	7.7
Training injuries	**Head/neck**	**All head/neck injuries**	**2**	**0.1**	**0.0**	**0.5**
		Head / Face	1	-	-	-
		Neck / Cervical spine	1	-	-	-
	Upper limb	**All upper limb injuries**	**3**	**0.2**	**0.0**	**0.6**
		Shoulder / Clavicle	2	-	-	-
		Upper arm / forearm / elbow	1	-	-	-
		Hand / Fingers / Wrist	-	-	-	-
	Trunk	**All trunk injuries**	**4**	**0.3**	**0.1**	**0.6**
		Upper trunk / Chest / Thorax / Rib	-	-	-	-
		Lower back / Lumbar	3	-	-	-
		Pelvis / Sacrum / Abdomen	1	-	-	-
	Lower limb	**All lower limb injuries**	**25**	**1.6**	**1.0**	**2.3**
		Hip / Groin	4	-	-	-
		Thigh	9	0.6	0.3	1.1
		Knee	3	-	-	-
		Ankle	3	-	-	-
		Foot/ Toe	3	-	-	-
		Lower leg	3	-	-	-

n=Number of injuries
IR: Incidence rate per 1000 player-hours
Incidence rate and 95%CI are only reported for n $\geq$ 5

All injuries

The specific anatomical structure with the highest incidence of all injuries (per 1000 player-hours) was the shoulder / clavicle (1.6), followed by the knee (1.4), thigh (1.1) and the head / face (1.0).

Match injuries

The specific anatomical structure with the highest incidence of all match injuries (per 1000 match player-hours) was the shoulder / clavicle (16.5), followed by the knee (14.6), and the head / face (11.2).

Training injuries

The specific anatomical structure with the highest incidence of all training injuries (per 1000 training player-hours) was the thigh (0.6).

3.3.6. Type of injuries

The frequency and incidence of injuries by type of injury for all injuries, match injuries, and training injuries is depicted in Table 3.6. For all injuries, the detail about the type of injury was available in 150/160 (93.8%) injuries, 119 match and 31 training injuries (Table 3.6.).

Table 3.6: Incidence (per 1000 player-hours) and frequency (% of all injuries) of all injuries, match injuries and training injuries by tissue type

	Anatomical type	n	%	IR	95% CI	
All injuries	Muscle/tendon	75	50.0	4.3	3.4	5.4
	Joint/ligament	49	32.7	2.8	2.1	3.7
	Skin	6	4.0	0.3	0.1	0.8
	Bone	10	6.7	0.6	0.3	1.1
	Brain/CNS	10	6.7	0.6	0.3	1.1
Match injuries	Muscle/tendon	55	46.2	36.4	27.4	47.4
	Joint/ligament	40	33.6	26.5	18.9	36.0
	Skin	6	5.0	4.0	1.5	8.6
	Bone	9	7.6	6.0	2.7	11.3
	Brain/CNS	9	7.6	6.0	2.7	11.3
Training injuries	Muscle/tendon	20	64.5	1.3	0.8	2.0
	Joint/ligament	9	29.0	0.6	0.3	1.1
	Skin	0	-	-		
	Bone	1	3.2	-		
	Brain/CNS	1	3.2	-		

n=Number of injuries (n=150)
%: % of injuries
IR: Incidence rate per 1000 player-hours

The majority (> 90%) of injuries (all, match, and training) occurred in the soft tissues (muscle, tendon, ligament, skin, brain or CNS). Of the soft tissues, muscle / tendon injuries accounted for the majority of all injuries (50.0%), match injuries (46.2%) and training injuries (64.5%). This was followed by joint / ligament injuries (all injuries=32.7%, match injuries=33.6%, and training=29.0%). During matches, the incidence of musculotendinous injuries (IR=36.4 / 1000 player-hours; 1 in 27.5 player-hours) and joint / ligament injuries (IR=26.5 / 1000 player-hours; 1 in 37.7 player-hours) is notably higher than the incidence of injuries in all other tissue types.

3.3.7. Injury severity

The severity of injuries was classified according to number of days lost. These data were available for 149 of the 160 time loss injuries (93.1% of all injuries), 122 match and 27 training injuries. The frequency (% of injuries) and incidence (per 1000 player-hours) for all injuries, match injuries and training injuries by grades of severity is depicted in Table 3.7.

Table 3.7: The frequency (% injuries) and incidence (per 1000 player-hours) of injuries by grades of severity of injuries (all, match and training)

	Injury severity	n	%	IR	95% CI	
All injuries	Minimal (2-3 days)	49	32.9	2.8	2.1	3.7
	Mild (4-7 days)	37	24.9	2.1	1.5	2.9
	Moderate (8-28 days)	41	27.5	2.4	1.7	3.2
	Severe (> 28 days)	22	14.8	1.3	0.8	1.9
Match injuries	Minimal (2-3 days)	43	35.2	28.4	20.6	38.3
	Mild (4-7 days)	32	26.2	21.2	14.5	29.9
	Moderate (8-28 days)	30	24.6	19.8	13.4	28.3
	Severe (> 28 days)	17	13.9	11.2	6.6	18.0
Training injuries	Minimal (2-3 days)	6	22.2	0.4	0.1	0.8
	Mild (4-7 days)	5	18.5	0.3	0.1	0.7
	Moderate (8-28 days)	11	40.7	0.7	0.3	1.2
	Severe (> 28 days)	5	18.5	0.3	0.1	0.7

n=Number of injuries (missing data in 11 injuries)
%: % of injuries
IR: Incidence rate per 1000 player-hours

All injuries

The majority of injuries were of minimal or mild severity (> 57%). Moderate and severe injuries accounted for 27.5 % and 14.8% of all injuries respectively.

Match injuries

The majority of match injuries were also of minimal or mild severity (> 60%) and moderate or severe match injuries accounted for 24.6 and 13.9% of all match injuries respectively. The incidence of moderate and severe match injuries was 19.8/1000 player-hours (95% CI 13.4-28.3; 1 in 51 match player-hours) and 11.2/1000 player-hours (95% CI 6.6-18.0; 1 in 89 match player-hours) respectively.

Training injuries

Although the overall incidence of training injuries was low (2.1; 95% CI: 1.5-3.0), the majority of all training injuries, in contrast to match injuries, were of moderate or severe nature (> 59.2%). Moderate and severe training injuries accounted for 40,7 % and 18,5% of all training injuries respectively.

The frequency (% of injuries) and incidence (per 1000 player-hours) for all injuries and match injuries by severity in the main anatomical locations are depicted in Table 3.8.

Table 3.8: The incidence (per 1000 player-hours) and frequency (% injuries) of grades of severity of injuries (all, match) by main anatomical location

		Injury severity	n	%	IR	95% CI	
All injuries	**Head / neck**	Minimal (2-3 days)	9	42.9	0.5	0.2	1.0
		Mild (4-7 days)	6	28.6	0.3	0.1	0.8
		Moderate (8-28 days)	5	23.8	0.3	0.1	0.7
		Severe (> 28 days)	1	4.8	-	-	-
	Upper limb	Minimal (2-3 days)	9	24.3	0.5	0.2	1.0
		Mild (4-7 days)	14	37.8	0.8	0.4	1.4
		Moderate (8-28 days)	3	8.1	0.2	0.0	0.5
		Severe (> 28 days)	11	29.7	0.6	0.3	1.1
	Trunk	Minimal (2-3 days)	12	60.0	0.7	0.4	1.2
		Mild (4-7 days)	4	20.0	-	-	-
		Moderate (8-28 days)	3	15.0	-	-	-
		Severe (> 28 days)	1	5.0	-	-	-
	Lower limb	Minimal (2-3 days)	19	26.8	1.1	0.7	1.7
		Mild (4-7 days)	13	18.3	0.7	0.4	1.3
		Moderate (8-28 days)	30	42.3	1.7	1.2	2.5
		Severe (> 28 days)	9	12.7	0.5	0.2	1.0
Match injuries	**Head / neck**	Minimal (2-3 days)	8	42.1	5.3	2.3	10.4
		Mild (4-7 days)	6	31.6	4.0	1.5	8.6
		Moderate (8-28 days)	5	26.3	3.3	1.1	7.7
		Severe (> 28 days)	0	-	-	-	-
	Upper limb	Minimal (2-3 days)	9	25.7	6.0	2.7	11.3
		Mild (4-7 days)	13	37.1	8.6	4.6	14.7
		Moderate (8-28 days)	3	8.6	-	-	-
		Severe (> 28 days)	10	28.6	6.6	3.2	12.2
	Trunk	Minimal (2-3 days)	10	58.8	6.6	3.2	12.2
		Mild (4-7 days)	4	23.5	-	-	-
		Moderate (8-28 days)	2	11.8	-	-	-
		Severe (> 28 days)	1	5.9	-	-	-
	Lower limb	Minimal (2-3 days)	16	31.4	10.6	6.0	17.2
		Mild (4-7 days)	9	17.6	6.0	2.7	11.3
		Moderate (8-28 days)	20	39.2	13.2	8.1	20.4
		Severe (> 28 days)	6	11.8	4.0	1.5	8.6

n=Number of injuries
%: % of injuries
IR: Incidence rate per 1000 player-hours
Incidence rates and 95%CI are only reported for n ≥ 5

All injuries

The majority of all injuries to the head and neck, upper limb, and trunk were of minimal or mild severity (> 57%). However, 55% of all lower limb injuries were graded as moderate (42.3%) or severe (12.7%).

Match injuries

Similarly, the majority of match injuries to the head and neck, upper limb, and trunk were of minimal or mild severity (> 50%). However, 51% of all lower limb injuries were graded as moderate (39.2%) or severe (11.8%).

Training injuries

The number of training injuries in each sub-category of severity was too small for meaningful statistical analysis.

3.3.8. Match injuries at different periods in the match

The frequency (%) of match injuries during different periods in the match, and by severity of the injury, is depicted in Table 3.9. The period was reported for 125 of the 126 match injuries.

Table 3.9: The frequency (% match injuries) during different quarters of matches and for different severity of injury

Period in match	All match injuries	%	Minimal	%	Mild	%	Moderate	%	Severe	%
1st quarter	22	17.6	3	7.0	7	22.6	7	23.3	4	23.5
2nd quarter	33	26.4	8	18.6	11	35.5	10	33.3	4	23.5
3rd quarter	29	23.2	13	30.2	6	19.4	6	20.0	4	23.5
4th quarter	39	31.2	18	41.9	7	22.6	6	20.0	5	29.4
Cool-down	2	1.6	1	2.3	0	0.0	1	3.3	0	0.0

%: % of injuries

The majority of match injuries (> 50%) occurred in the third and fourth quarter of the match. In general, this trend holds for all degrees of severity of injuries, with the exception of match injuries classified as mild and moderate severity. Very few injuries (< 2%) occurred during the cool down phase after a match.

3.3.9. Mechanism of injuries

The mechanism associated with all injuries, match injuries and training injuries (%) is depicted in Table 3.10.

Table 3.10: Main mechanisms of all injuries, match injuries and training injuries (training activity at the time of a training injury) in all players

	Main mechanisms	n	%
All injuries (n=160)	Kicking	3	1.9
	Collision	9	5.6
	Ruck	13	8.1
	Running	18	11.3
	Scrum	6	3.8
	Tackled	32	20.0
	Tackling	37	23.1
	Other *	42	26.3
Match injuries (n=126)	Kicking	2	1.6
	Collision	6	4.8
	Ruck	11	8.7
	Running	9	7.1
	Scrum	5	4.0
	Tackled	31	24.6
	Tackling	36	28.6
	Other *	26	20.6
Training injuries (n=34)	Kicking	1	2.9
	Collision	3	8.8
	Ruck	2	5.9
	Running	9	26.5
	Scrum	1	2.9
	Tackled	1	2.9
	Tackling	1	2.9
	Other *	16	47.1

n=Number of injuries
%: % of injuries
*: Includes “Other non-contact”, “Other contact”, “Not known” or “Not identified”

The most common specified mechanism for all injuries and match injuries was tackling (all=23.1%; match=28.6%) or being tackled (all=20.0%; match=24.6%). Other mechanisms, not listed, were associated with the majority of training injuries (47.1%) and also accounted for a significant proportion of all injuries (26.3%) and match injuries (20.6%).

3.3.10. Intercontinental travel and playing in locations $\geq$ 6 hours time difference

In this study, a crude analysis of the effects of travelling across $\geq$ 6 time zone differences on the incidence of all time-loss injuries, match injuries and training injuries could be explored (Table 3.11).

Table 3.11: The incidence of injuries (per 1000 player-hours) for all injuries, match injuries and training injuries at a home location (matches and training in the home country) or an away location (matches and training in a location $\geq$ 6 time zone differences; Australia or New Zealand)

	Home location					Away location				
	Player-hours	n	IR	95% CI		Player-hours	n	IR	95% CI	
All	13967	126	9.0	7.5	10.7	3373	34	10.1	7.0	14.1
Matches	1100	100	90.9	74.0	110.6	412	26	63.1	41.2	92.5
Training	12867	26	2.0	1.3	3.0	2961	8	2.7	1.2	5.3

n: number of injuries
IR: Incidence rate per 1000 player-hours

There were more home location vs. away location player-hours because the South African teams played all matches (matches in their own city and the opponents' city) against each other in the home country (South Africa). All matches against New Zealand or Australian teams consisted of at least one match in the home country and one match in the away (foreign) location. There was no significant difference in the incidence of all injuries (expressed as per 1000 player-hours), match injuries or training injuries when play took place in the home country compared with a foreign location ($\geq$ 6 time zone differences).

The incidence of injury (expressed as injuries per 1000 player days) when playing at the home locations (9.0; 95% CI: 7.5 to 10.7) was not significantly different to playing at the away locations (10.1; 95% CI: 7.0 to 14.1).

3.4. Discussion

The main findings of this study in the 2012 Super Rugby tournament over ≈ 16 weeks were as follows: a) almost 55% of all players sustained a time-loss injury during the tournament, and 25% of players sustained more than one time-loss injury, b) the overall incidence of time-loss injuries was 9.2 per 1000 player-hours, and the incidence of match injuries (83.3) was significantly higher compared with training injuries (2.1), c) the incidence of injuries in forwards and backs was not significantly different, d) the main anatomical location of injuries was the lower limb (48.1%) followed by the upper limb (25.6%), e) the specific anatomical location with the highest incidence of injury was the shoulder/clavicle followed by the knee and thigh, f) soft tissue injuries to the muscle/tendon (50% of injuries) or joints/ligaments (32.7%) accounted for >80% of all injuries, g) injuries were classified as moderate (27.5%) or severe (14.8%) in 42% of all injuries, and these were mainly in the lower limb (62%), h) most match injuries occurred in the latter stages of a game, and i) tackling (26.3%) and being tackled (23.1%) were the most common mechanisms of injury. Finally, preliminary data show that the incidence of time-loss injuries (all, match injuries and training) was not related to playing and training at the home country location compared with an away location (following intercontinental travel to play in different locations ≥ 6 hours' time difference).

3.4.1. Injured player proportion (IPP)

In this study, there was an IPP of almost 55%. This means that 55% of all the players starting the tournament sustained a time-loss injury during this tournament, This finding is of concern, particularly as 20.4% of players will sustain a moderate injury (8-28 days lost) (6-7 players in a squad of 3-34 players) and 14.5% of players will sustain a severe injury (> 28 days lost) (4-5 players in a squad of 3-34 players). Furthermore, 25% of players sustained more than one injury (about 8 players in a squad of 30-34 players). The injured player proportion (IPP) has not been reported in previous studies during tournaments. However, IPP can be estimated from raw data presented in these studies. In the two previous Super Rugby studies, the estimated IPP varies between 64% of the 75 players in the 1999 Super Rugby tournament (14 weeks) [4] to 82% of the 441 players in the 2008 Super Rugby tournament (16 weeks)[5]. In the 7-week Rugby World Cup tournaments, only 2% of 416 players were injured in the 1995 Rugby World Cup, while the IPP is estimated as 26-34% of the approximately 615 players in the 2003 [57], 2007 [3], and 2011 [13] Rugby World Cup competitions (7 weeks). These estimates are likely to overestimate the IPP as the number of players with more than one injury was not reported in these studies. Even if there is an overestimation of the IPP in these studies, the data from this study indicate that there is at least a two times higher proportion of players who will sustain an injury in the Super Rugby tournament compared with a player in the Rugby World Cup.

The reason for this is largely related to the duration of the tournament, but there is not necessarily a linear relationship between the number of exposure weeks, and the proportion of injured players. Other factors such as progressive player fatigue, repeated injuries in the same player (25% in our study) and other factors may contribute to the increased proportion of players that are injured in more prolonged tournaments. Indeed, evidence for this comes from one of the earliest study in the Super Rugby tournament, where it was reported that injuries that caused a player to miss a game occurred almost exclusively in the pre-season program or the final third of the season [6]. Therefore, it is important to report the IPP (for all injuries and for different grades of injury severity) in tournaments of different durations, and this is of value and needs to be explored in future studies. More specifically, the IPP has important practical clinical value to the team physician who is responsible for planning how many players are likely to be injured during a tournament so that injury prevention and management strategies for rehabilitation and return to play can be instituted. Finally, team coaches and team managers will benefit from knowing the IPP for tournaments of different durations so that the squad size and logistical arrangements for rehabilitation or transport of injured players can be planned.

3.4.2. Incidence of match injuries

In the recently published meta-analysis, the overall incidence of match injuries in senior men's professional Rugby union was reported as 81 per 1000 player-hours [2]. Data from this study are consistent with this reported overall incidence of match injuries in senior men's professional rugby union. However, data from this study can only be compared to the data from two of the three studies during the Super Rugby tournament [4, 5]. In the one study, the definition of injury is substantially different from the definition that we used, and a true comparison is not strictly valid [6]. Data can only be compared to the incidence of match injuries reported in two Super Rugby studies. The incidence of match injuries in our study (83.3) was considerably higher than that reported by Hotzhausen et al. (55) [4], but lower than that reported by Fuller et al. (96) [5]. The precise reasons for this wide discrepancy are not clear. However, there have been changes to rules and their application, the number of teams competing in the tournament, the scheduling of the tournament, and individual team strategies for injury prevention during the last five to six years. It is not possible to accurately interpret the differences in the incidences of injury in these three studies.

3.4.3. Incidence of training injuries

In this study, the incidence of training injuries was also documented. The incidence of training injuries in this study (2.1 per 1000 player-hours) is very consistent with the incidence of training injuries that was reported in the meta-analysis of injuries in men's professional Rugby union (2-4 per 1000 player-hours). The data from the study reported in this dissertation could only compared to the incidence of training injuries in one other study in Super Rugby (4 per 1000 player-hours) [4]. Finally, data from the study in this dissertation are consistent with all the published data showing a considerably higher incidence of injuries in matches compared with training [11]. It is suggested that an on-going surveillance programme to document injuries (mainly match injuries) during this tournament be instituted so that risk factors for injury can be identified, injury prevention strategies can be planned, and outcomes of implementation strategies be measured.

3.4.4. Injuries by player position, anatomical region and type of injury

The data from this study showed that more injuries occurred in the lower limb region (48.1%), than in the upper limb region (25.6%). These data are similar for match injuries alone, and when forwards are compared with backs. This observation is also very consistent with the data reported in the meta-analysis on injuries in men's professional rugby union [11]. Knee and thigh injuries were the most common lower limb injuries, and this is also consistent with most previous studies of injuries in men’s professional rugby union [11].

The majority (>80%) of all injuries in our study affected soft tissue structures, particularly the muscles/tendons (50% of injuries) and joints/ligaments (32.7%). These data are similar if match and training injuries are analysed separately. Once again, these data are consistent with the majority of studies published on injuries in men's professional rugby union [11].

3.4.5. Injury severity

The incidence (per 1000 match player-hours) of injuries classified as of minimal severity (28.4) in this study appears to be slightly higher that that reported for minimal injuries in the meta-analysis (17; 95% CI: 15-19). The incidence of mild (21.2) match injuries is similar to that reported in the meta-analysis of injuries in men's professional rugby union (23; 95% CI: 20-26), while the incidence of moderate (19.8), and severe (11.2) injuries in this study is lower than that reported in the meta-analysis for moderate (28; 05% CI: 25-31), and severe (15; 95% CI: 13-17) injuries [83]. Therefore, the overall profile of the severity of injuries in this study indicated a spectrum of less severe injury compared with that reported in the meta-analysis. The severity of training injuries has never been reported in the Super Rugby tournament. Although the overall number of training injuries (and the incidence) in our study was low, it should be noted that 59.2% of the training injuries resulted in more than 8 days lost to training or competition. Therefore, in this study, training injuries, when they occur, tended to be more severe, and this has been reported in some [17] but not in other studies [13]. In a recently published meta-analysis, it was concluded that differences in injury severity between match and training injuries were trivial [82] and it is suggested that this requires further study. The majority of upper limb injuries were minimal to moderate (62.2%), and the majority of lower limb injuries were moderate (42.3%) or severe (12.7%). In this study there was a higher proportion of upper limb injuries that were more severe (29.7% of upper limb injuries). The lower and upper limb areas constituted most of the injuries (73%), and also constituted most of the moderate/severe injuries (84%) and these data are consistent with reports from other studies in rugby union on anatomical location [13;14, 5] and severity of injuries [13; 17, 19, 14; 11]. Strategies to reduce the incidence and severity of injuries in these two main anatomical areas require further study.

3.4.6. Timing and mechanism of injuries

As has previously been reported, most match injuries in this study also took place in the third and fourth quarters of matches. The lowest percentage of injuries occurs in the first quarter of a match. Furthermore, as has been documented in most studies in rugby union, data from this study also showed that tackling, and being tackled, were the two most frequent mechanisms responsible for match injuries [11]. As most training sessions do not involve contact, it is not surprising that in this study, mechanisms such as running, and other mechanisms were responsible for the occurrence of training injuries. It can be noted that in 47.1% of training injuries and a 20.6% of match injuries the mechanism of injury was classified as “Other”. This finding of a high proportion of a “non-specific” category is not unique to this study. In many other studies, categories with no known specific mechanisms were often also classified as “Other”, or reported separately as “Other non-contact”, “Other contact”, “Not known” or “Not identified” [13, 17 ,19, 14]. When these “non-specific” categories are combined into one, they also consistently represent a relatively high proportion (or in some cases incidence, when these data were reported as such) of injuries that is similar to our data. This can be regarded as a limitation of current methodology in epidemiology of rugby injury studies in general, and this requires investigation.

3.4.7. Injuries and intercontinental travel

Finally, to our knowledge, for the first time, we were able to explore whether travelling across multiple time zones, and playing in a foreign location away from home is associated with an increased risk for injury. Preliminary data show that there was no significant difference in the incidence of time-loss injuries, match injuries, or training injuries whilst playing at home, or at a location away from home ($\geq$ 6 time zones difference). This is of particular clinical relevance to team physician travelling with the team, as we have previously shown that the effects of travelling away from home can affect illness rate [73].

3.5. Strengths and limitations of the study

The main strengths of this study are that a) it represents a large prospective cohort study in rugby union that was conducted in a tournament of a long duration played at a very high level, b) team physicians recorded daily data with a very high compliance rate, c) incidence rates were accurately documented for matches and training, and d) injury definitions, data collection and reporting was consistent with the consensus statement on rugby injury epidemiology research.

A limitation of the study was that a further detailed exploration of subgroups was not possible due to small sample sizes, particularly for training injuries, and that even for this large cohort some of the reported statistics are based on small numbers. It should also be acknowledged that in one team (Team A) only 18/34 (53%) players gave consent to participate in the study. However, this was taken into account in all calculations of the incidence rates (per 1000 player-hours). Finally, the location specific incidence rates can at most be considered as preliminary and this would require further investigation.

3.6. Summary and clinical implications

In summary, the main clinical implications of the data presented in this study are:

- A team physician can also expect 1.67 injuries per match played during the Super Rugby tournament, and most of these injuries will occur in the latter stages of a game
- 25% of injuries will be of sufficient severity that players will not be able to play for 1-4 weeks, while 11% of match injuries will be of sufficient severity that players will not be able to play for $\geq$ 4 weeks
- As matches are played every week, it means that a) after every 3 games, at least one player in the squad will be unfit to play for 1-4 weeks, and b) after every 6 games, at least one player in the squad will be unfit to play for $\geq$ 4
- The majority of injuries occur in the lower limb (mainly the knee and thigh), and the upper limb (shoulder and clavicle), and these are mostly musculotendinous injuries followed by joint or ligament injuries
- In contrast to illness, preliminary data indicate that intercontinental travel and playing in a foreign destination is not associated with an increased risk of injury

In conclusion, epidemiological studies of this nature are very important to a) identify factors associated with injury, b) design intervention strategies for the reduction of injury risk, and c) measure the outcome of any intervention strategies. Therefore, a program of on-going surveillance of injuries in the Super Rugby tournament is necessary and steps to implement this have been initiated.

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Chapter 4

Summary and conclusion

As described in Chapters 2 and 3, epidemiological studies in sport are important in order to a) identify factors associated with injury, b) design intervention strategies for the reduction of injury risk, and c) measure the outcome of any intervention strategies. Therefore, a programme of on-going surveillance of injuries in the Super Rugby tournament is necessary.

The main strengths of this study are that a) it represents a large cohort study in rugby union that was conducted in a tournament of long duration played at a very high level, b) team physicians documented match injuries and training accurately and with a very high compliance rate, c) exposure rates were accurately documented for matches and training and, d) injury definitions, data collection and reporting was consistent with the consensus statement on rugby injury epidemiology research. A limitation of study was that a further detailed exploration of subgroups was not possible due to the small sample sizes, particularly for training injuries, and that even for this large cohort some of the reported statistics are based on small numbers.

A new concept that was revealed in this thesis was, the injured player proportion (IPP), which has been introduced as a result of the study. This concept, never previously reported on in rugby union tournaments, is believed to have a bearing in terms of predicting the overall injury risk of players in rugby union tournaments of prolonged duration. The 2007 consensus document does not propose or recommend reporting the IPP of injuries. In this study, we have shown an IPP of almost 55%. This means that 55% of all players starting the tournament sustained a time-loss injury during the tournament, and that 25% of players sustained more than one injury. This finding is of concern, particularly as 20.4% of players will sustain a moderate injury (8-28 days lost, 6-7 players in a squad of 30-34 players) and 14.5% of players will sustain a severe injury (>28 days lost, 4-5 players in a squad of 30-34 players). Although the IPP has not been reported in previous studies, an estimate can be ascertained from the raw data in these studies. In the two previous Super Rugby studies, the estimated IPP varies between 64% of the 75 players in the 1999 Super Rugby tournament (14 weeks) to 82% of the 441 players in the 2008 Super Rugby tournament (16 weeks).

In the 7-week Rugby World Cup tournaments, only 2% of 416 players were injured in the 1995 Rugby World Cup, while the IPP is estimated at 26-34% of the approximately 615 players in the 2003, 2007 and 2011 Rugby World Cup competitions (7 weeks). These estimates are likely to overestimate the IPP as the number of players with more than one injury was not reported in these studies. Even if there is an overestimation of the IPP in these studies, our data indicate that there is at least a two times higher proportion of players who will sustain injury in the Super Rugby tournament compared with a player in the Rugby World Cup. The reason for this is largely related to the duration of the tournament, although there appears not to be a linear relationship between the number of exposure weeks and the proportion of injured players. Other factors such as progressive player fatigue, repeated injuries in the same player (25% in our study) and other factors may contribute to the increased proportion of players injured in more prolonged tournaments. Therefore, we believe that to report the IPP (for all injuries and for different grades of injury severity) in tournaments of different durations is of value and needs to be explored in further studies. Furthermore, we believe the IPP has important practical clinical value for the team physician who is responsible for planning how many players are likely to be injured during a tournament, so that injury prevention and management strategies for rehabilitation and return to play can be instituted. Finally, team coaches and team managers will benefit from knowing the IPP for tournaments of different durations so that the squad size and logistical arrangements for rehabilitation or transport of injured players can be planned.

As a result of this study the following new findings were documented:

- Almost 55% of all players in the Super Rugby tournament sustained a time-loss injury and 25% of players sustained more than one injury and we suggest that the reporting of the IPP (injured player proportion) is an important development in future epidemiological study of rugby-related injuries

- There is a high incidence of match injuries sustained during the Super Rugby tournament (83 per 1000 match hours or 1.67 injuries per game), that is similar to that reported for men's professional rugby. The overall incidence of time-loss training injuries was 9.2/1000 player hours.
- A team physician can therefore expect 1.67 injuries per match played during the Super Rugby tournament, and most of these injuries will occur in the latter stages of the game.
- 25% of injuries will be of sufficient severity that players will not be able to play for 1-4 weeks, while 11% of match injuries will be of sufficient severity that players will not be able to play for 4 weeks or more.
- Injuries were classified as moderate (27.5%) or severe (14.8%) in 42% of injuries, involving mainly the lower limb (62%).
- Therefore, after every three games in the tournament, at least one player in a team will be unfit to play for 1-4 weeks, and after every six games at least one player in the squad will be unfit to play for 4 weeks or more.
- The majority of injuries occur in the lower limb (48.1%- knee and thigh), and the upper limb (25.6%-shoulder and clavicle), mostly musculotendinous injuries followed by joint or ligament injuries (50% and 32.7% respectively).
- Most injuries occur in the tackling phase of the game (tackling or being tackled).
- Injury risk is similar in forwards and backs.
- These abovementioned findings allow team physicians serving the Super Rugby teams to anticipate the injury risk, nature and type of injuries in their teams during a prolonged tournament such as the Super Rugby tournament and can therefore plan appropriate medical care.
- Prevention strategies to reduce injury risk in this tournament are urgently required and should be targeted towards certain areas, for example, lower limb soft tissue (muscle/tendon) injuries.

- Team management and coaches can now anticipate how the effects of injuries are likely to alter squad composition during the 4-month tournament and allow for advanced planning of medical and rehabilitative support staff.

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APPENDIX A

PARTICIPANT INFORMATION SHEET

ILLNESS, INJURY AND CIRCADIAN RHYTHM IN ELITE RUGBY PLAYERS DURING THE 2012 SUPER 15 TOURNAMENT

Background

The UCT/MRC Research Unit for Exercise Science and Sports Medicine together with colleagues from New Zealand and Australia (team physicians of participating teams) would like to study (i) the incidence and nature of medical illness and (ii) the influence of inter-individual variation in circadian rhythm on performance and incidence of illness and injury in rugby players during this tournament. This particular tournament is of interest since the strenuous schedule sees matches spanning 16 weeks (February to May 2012), during which 15 international rugby teams compete at different venues in South Africa, Australia and New Zealand. The competition is also unique in that the players are required to travel between venues in South Africa, Australia and New Zealand - often up to 9 hours across different time zones.

Firstly, we are interested in determining how common injuries and a variety of medical conditions and illness are in rugby players during the tournament. For example, it is known that athletes, who train hard and then participate in strenuous competition, have increased respiratory tract symptoms (runny nose, sore throat, sinusitis, enlarged lymph glands in the neck, and even cough and chest pain with fever and headaches). However, these symptoms may not always be due to an infection but could be as a result of allergies or pollution. It has also been shown that apart from respiratory tract illness, other illnesses are very most common during competitions such as at the Olympic Games. These illnesses include gastro-intestinal symptoms, allergies, skin conditions, and other infections. These patterns of illness have not been studied in rugby players, particularly during competitions.

Secondly, one of the unique aspects of the Super 15 tournament is that the players are required to travel across many time zones between matches. Such travel is known to disrupt circadian (24-hour) rhythm – experienced as jet lag. This is turn may impact performance. Your body's 24-hour rhythm is also partially determined by your genetic makeup. For example, a variant in one of your "clock" genes may determine whether you are a morning or evening person (also known as diurnal preference). We are interested in whether rugby players tend to be morning or evening types, and how travel across time zones might affect performance and/or incidence of injury and illness in rugby players.

Aims of the research

1. To document (i) the incidence of injuries and (ii) the incidence of medical illness in rugby players participating in the 2012 Super 15 Rugby tournament.
2. To relate the incidence of injuries and medical conditions/illness to 1) past medical history, 2) training history and load, and 3) environmental conditions (time zone changes, temperature, humidity, pollen counts, and atmospheric pollution) at the time of the 2012 Super 15 Rugby tournament.
3. To describe the chronotype distribution of the rugby players participating in the 2012 Super 15 Rugby tournament.
4. To describe the distribution of circadian rhythm gene polymorphisms (such as *Per3* VNTR) of the rugby players participating in the 2012 Super 15 rugby tournament.
5. To compare the differences in performance of the morning and evening-type rugby players travelling in both East-West and West-East directions
6. To compare the differences in the incidence of illness and injury of the morning and evening-type rugby players travelling in both East-West and West-East directions.

Your possible involvement

The UCT Research Office has provided your team doctor with all the information regarding the study, the details of which are explained in this document. As a participant in the 2012 Super 15 Rugby tournament, you are given the choice to participate in this research effort. Your participation is entirely voluntary.

Should you agree to participate, you would be asked to do the following:

<u>Prior to the beginning of the tournament:</u>

- Complete a medical questionnaire (this can be done together with your team doctor). This questionnaire, which deals with medical, training and circadian rhythm information, will be anonymous and only a coding system will be used to identify your team.
- Donate a 5ml (1 teaspoon) blood sample from a vein in your arm. This will be used for the extraction and analysis of genetic material (DNA). The DNA will only be used for scientific

research purposes relating to circadian rhythm. All data will be analysed anonymously and DNA samples will be destroyed on completion of the study

During the competition:

- Every day your team doctor will ask you about possible medical conditions and injuries. This information will be recorded anonymously on a sheet (or in electronic format) that will be sent to the investigators. If you suffer form any injury or disease/condition, your team doctor will treat it in the usual fashion.

Potential risks of this study

- The completion of a questionnaire is not associated with any risk. Questionnaire and other clinical data (paper and electronic) will be kept confidential and secure, and will not be made available to any party other than the research team without the consent of the individual participants.
- The potential risks to participants of blood collection are minimal and are related to 1) blood sample collection technique, and 2) the volume of blood collected prior to a match and the potential risk of a decreased performance in a subsequent match. The potential risks associated with blood collection technique from the ante-cubital veins are: infection, delayed healing, haematoma, physical pain, mental discomfort and injury to a nerve or a vessel. These risks are small and will be minimized by the use of trained phlebotomists, use of sterile techniques and the use of disposable, single-use materials. The risk of decreased performance as a result of blood collection will be reduced by not subjecting any participant to the collection of a blood volume exceeding 15ml prior to a match.
- Your personal genetic information will not be made known to you, your team mates, team medical team, coaches, trainers or management. The information will only be used for research purposes.
- All medical conditions and injuries will be treated by the team doctor.
- You may withdraw from this study at any time without question.

Potential benefits of this study

The research questions that will be addressed by this study have been identified to have a direct impact on improving medical care to rugby players in general, and specifically those who visit South Africa during future Super 15 Rugby competitions. The anticipated benefits of this study are that the results will further our understanding of the possible cause/s of medical conditions and injuries, and relationship between circadian rhythm and performance in rugby players who travel to participate in international competitions.

Contact

Please feel free to contact your team doctor, the UCT Research Office or members of the research team should you have any questions related to the study. Your team doctor has the contact details of the UCT Research Office and the research team. You can also call the following numbers of the principal investigators Prof Martin Schwellnus (+27-83-4543783) or Dr Dale Rae (+27-72-1413143).

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University of Cape Town Research Ethics approval number: REC REF 008/2011

APPENDIX B

INFORMED CONSENT FORM

ILLNESS, INJURY AND CIRCADIAN RHYTHM IN ELITE RUGBY PLAYERS DURING THE 2012 SUPER 15 TOURNAMENT

I understand that a study entitled "Illness, Injury and Circadian Rhythm in Elite Rugby Players During the 2012 Super 15 Rugby tournament" will be conducted by the UCT/MRC Research Unit for Exercise Science and Sports Medicine (University of Cape Town).

I understand that my participation in this research project has no direct benefits to me during the 2012 Super 15 Rugby tournament. However, I understand that my participation will advance the medical and scientific knowledge related to rugby. Therefore, information gathered through my participation in this project could advance the future medical care, training advice and performance of rugby players.

I have read the Participant Information Sheet and understand that the study involves the following components:

<u>Completion of a medical questionnaire before the tournament</u>

The completion of the questionnaire is not associated with any risk. All the questionnaire data and other clinical data (paper and electronic) will be kept confidential, secure and will not be made available to any party other than the research team without the consent of the individual concerned.

I agree that the all the information, which will be collected by my team doctor before the tournament, may be used to answer scientific questions about (i) the medical conditions associated with the participation in and completion of a rugby tournament and (ii) inter-individual variation in circadian (24-hour) rhythms of rugby players.

<u>Blood sample collection for genetic studies before the tournament</u>

Prior to the tournament, I have agreed to donate 5mL (1 teaspoon) of venous blood. The sample will be used for the extraction and analysis of genetic material (DNA).

The potential risks associated with the blood collection technique from the veins on my arm (ante-cubital veins) are: infection, delayed healing, blood clot (haematoma), physical pain, mental discomfort and injury to a nerve or a vessel. These risks are small and will be minimized by the use of staff that are trained to take blood samples (trained phlebotomists), use of sterile techniques and the use of disposable, single-use materials. The risk of decreased performance as a result of blood collection will be reduced by not subjecting any participant to the collection of a blood volume exceeding 15 ml prior to a match.

The genetic material (DNA) that is extracted from my blood will only be used for scientific research purposes. I understand that the DNA will be analysed for variations within genes related to circadian rhythm. I also understand that all data will be analysed without revealing any of my personal details (anonymously) and my DNA sample will be destroyed on completion of the study. I realise that I have the right to request that my DNA sample be destroyed at any time.

I understand that whilst there is no direct benefit to myself if a genetic predisposition for diurnal (morning/evening) preference in rugby players can be established, this research may lead to improved adaptation techniques available to travelling sports people to new time zones in the future. I understand that I will receive only the overall results of this part of the study.

Daily information during the rugby tournament

I agree that the all the information, which will be collected by my team doctor on a daily basis during the tournament, may be used to answer scientific questions about the medical conditions and injuries that are associated with the participation in and completion of a rugby tournament.

I have read (or, where appropriate, have had read to me) and understood the information about this study provided in the preceding Participant Information Sheet. Any questions I have asked have been answered to my satisfaction. I agree that research data provided by me or with my permission during the study may be included in a thesis, presented at conferences and published in journals on the condition that neither my name nor any other identifying information is used. I understand that the medical staff and the research team have professional medical insurance.

I understand that I may withdraw from this study at any time without further question.

I hereby consent to participate in this study.

Player accreditation number:	Name of the team doctor:
Signature of the player	Signature of the team doctor:
Date:	Date:

Name of the investigator:	Signature of the Investigator:	Date:

APPENDIX C
RESEARCH ETHICS APPROVAL

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27 January 2011

HREC REF: 008/2011

Prof M Schwellnus
Human Biology
Sport Science Institute

Dear Prof Schwellnus

PROJECT TITLE: ILLNESS AND INJURY IN ELITE RUGBY PLAYERS DURING THE 2011 SUPER 15 RUGBY TOURNAMENT.

Thank you for addressing the queries raised by the Faculty of Health Sciences Human Research Ethics Committee.

It is a pleasure to inform you that the Ethics Committee has **formally approved** the above-mentioned study.

Approval is granted for one year till the 28 January 2012.

Please submit an annual progress report if the research continues beyond the expiry date. Please submit a brief summary of findings if you complete the study within the approval period so that we can close our file.

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

Please quote the HREC REF in all your correspondence.

Yours sincerely

Signed by candidate

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

S Thomas

This serves to confirm that the University of Cape Town Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC SA), Food and Drug Administration (FDA USA), International Convention on Harmonisation Good Clinical Practice (ICH GCP) and Declaration of Helsinki guidelines.

The Research Ethics Committee granting this approval is in compliance with the ICH Harmonised Tripartite Guidelines E6: Note for Guidance on Good Clinical Practice (CPMP/ICH/135/95) and FDA Code Federal Regulation Part 50, 56 and 312.

S Thomas