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Preseason risk factors associated with hamstring injuries in club rugby players

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Declaration

I, Rene Lombard, 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.

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List of abbreviations

AFL (Australian Rules Football League)
BMI (body mass index)
C.I (confidence interval)
Con. (Concentric)
CTPE (Crouch Touch Pause Engage)
deg/sec (degrees per second)
Ecc. (Eccentric)
EMG (Electromyography)
F -test (Fisher exact test)
Ham (hamstring muscle)
I (Injured group)
IRB (International Rugby Board)
L (left)
Method. (methodology)
Min/session (minutes per session)
MRI (magnetic resonance imaging)
N (frequency)
N.m (Nanometer)
N.m/kgBW (nanometer per kilogram bodyweight)
NA (not applicable)
NI (non-injured group)
OR (odds ratio)
Pros. (prospective)
Quad (quadriceps muscle)
R (right)
Rep. (repetition)
Rep/session (repetitions per session)
Retro. (retrospective)
RIPP (The New Zealand Rugby Injury and Performance Project)
RR (relative risk)
SLR (straight-leg-raise)
SANFL (South Australian National Football League)

SD (standard deviation)
Sec. (seconds)
Sessions/wk (sessions per week)
Sign. (Significant)
V.A.S. (visual analogue scale)

Abstract

Background

Club rugby has a significant role to play in the development of the sport at all levels. There is however limited data on the incidence and risk factors of rugby injuries in South Africa. Hamstring injuries are one of the most common muscle injuries affecting all rugby players. There is inconclusive evidence to identify the preseason risk factors associated with hamstring injuries.

Objectives

The aims of the literature studies were to:

1) describe the nature of injuries affecting school boy, club and professional rugby and
2) identify the risk factors associated hamstring muscle injuries.

The aims of the prospective cohort study was to:

1) identify the seasonal incidence and nature of injuries in club rugby players;
2) identify preseason risk factors for rugby injury;
3) identify preseason risk factors associated with hamstring injuries.

Methods

102 club rugby players underwent preseason testing. Preseason testing included a preseason medical questionnaire; hamstring and quadriceps isokinetic muscle strength testing; flexibility testing (the slump test, the straight leg raise test, the sit and reach test); strength endurance testing (2-minute sit-up test and 1-minute push-up test); anthropometric measurements (weight, height and skinfold measurements); agility testing (Illinois test); the vertical jump test and endurance testing (20m multistage shuttle run).

All players were monitored throughout the season to document their exposure to rugby and details of any injuries sustained. Diagnosis of injury was based on clinical criteria. Injury report forms were completed that contained the following information: date, player position, injury during match or practice session, anatomical site of injury, type and mechanism of injury, first or recurrent injury to the same structure, and the number of sessions missed as a result of the injury.

Statistical analysis was used to determine the injury incidence rate and possible predictors of rugby injuries and all lower limb injuries. The cohort was divided into quartiles for each physical parameter or test. Chi-square analysis was used to determine whether there was any significant difference between the quartiles. Paired t-tests and univariate F-tests were also used to identify predictors for hamstring injury. A significance level of $p < 0.05$ was set for all the tests.

Results

The literature review describes an increase in rugby injuries since the inception of professionalism for schoolboy, club and professional rugby. The prospective study found that there was a seasonal incidence of 37.5 injuries per 1000 hours of player match hours; 4.6 injuries per 1000 player training hours and overall exposure showed 13.9 injuries per 1000 hours in the cohort of club rugby players. The tackle was the most dangerous phase of play affecting the flanks, wings and centres. The most common site of injury was the thigh of which a hamstring injury was the most common.

There were no strong predictors for a rugby injury or specifically for a lower limb injury. The physical tests that showed an association with risk of injury in the multivariate analysis were the two-minute sit-up test, the one-minute push-up test, the Illinois agility test and concentric quadriceps and eccentric hamstring strength. A poor performance of between 46 and 60 repetitions on the two-minute sit-up test placed the player at risk of a lower limb injury. Players who had performed less than 32 repetitions ($p=0.03$) or between 32 and 40 repetitions ($p=0.01$) on the one-minute push-up test were at increased risk of sustaining a rugby injury. Players who completed the agility test in less than 15.91seconds, between 15.91 and 16.39 seconds and between 16.4 and 16.89 seconds had increased risk of a rugby injury. The players who had completed the agility test in more 16.4 seconds also had an increased risk of a lower limb injury. Players with less than 150Nm eccentric hamstring strength and between 159.1 and 211.58 Nm torque concentric quadriceps strength were at greater risk of a lower limb injury.

The literature review found the evidence relating to isokinetic weakness and muscle inflexibility as intrinsic risk factors conflicting. There was strong evidence to suggest that age and past history of a hamstring injury or posterior thigh pain are independent risk factors for hamstring injury.

There was a 9% seasonal incidence of hamstring injuries in this cohort. Muscle strength, strength endurance, agility and endurance fitness tested in the preseason was not able to predict the risk of hamstring injury. Rather, players with a past history of a hamstring injury were 8.23 times more likely to sustain a hamstring injury.

Conclusion

There is an increase in the incidence of rugby injuries across all levels. There is a high seasonal incidence of injury in club rugby players. The thigh is the most common site of injury of which hamstring injuries is the most common. There is strong evidence to suggest that increased age and past history of a hamstring injury are independent risk factors for hamstring injury. Isokinetic muscle strength, muscle flexibility and endurance fitness was not able to predict hamstring injury. The strongest predictor for hamstring injury is a past history of hamstring injury which makes the player 8.23 times more likely to sustain a recurrent injury.

Key words

rugby, injury, hamstring injury, past history, strength, flexibility, fatigue

Chapter One

Introduction and scope of the thesis

Rugby is one of the sporting codes in South Africa that enjoys the most popularity among all ages and cultures in terms of participation and spectatorship. Rugby has a history that symbolizes pride and passion for some population groups and discrimination and exclusion to other groups. It has however the potential to unite all South Africans as was seen at the Rugby World Cup in 1995. The rugby fraternity in South Africa has made various steps to "level the playing fields." There has been a great need to allow the process of transformation and development to take its course since unification in 1991 and with the inception of professionalism in 1995. The process has been slow and difficult due to a number of factors. Financial restraints have been one of the main factors.

The value of developing South African club rugby has not been explored to its full potential. The development of rugby at club level has been very slow and in some cases not visible. This has prevented club rugby from making a meaningful contribution to the development of the sport at a professional level. The cornerstone of any sport is knowledge and prevention of injuries particularly in a contact sport where there is a high risk of injury. Epidemiological studies providing a description of the nature and incidence of injuries in South African club rugby players were conducted prior to 1995[1;2]. The International Rugby Board (IRB) has introduced various law changes to assist in injury prevention[3]. These law changes have lead to fundamental changes in the nature in which the game is played. There has been an increase in open play and tackling which may have influenced the nature of the injuries sustained by players. Little is known about the nature of injuries in South African club rugby players particularly players from historically disadvantaged backgrounds.

Epidemiological studies are the first phase in instituting appropriate and effective prevention strategies. All South African rugby players engage in some form of preseason training. The intensity and frequency of preseason training may vary greatly between school, club and professional rugby players. The nature of this preseason training may also vary within these sectors depending on the coaching and training philosophies adopted by the coaching team. However, most rugby selectors utilize similar preseason tests to identify and categorize the fitness levels of the players. The main aim of preseason training is to prepare the player in various areas of fitness, which would include strength, flexibility and endurance. It is also used to develop the skill of the player and introduce the various game plans. It is assumed that a thorough preseason programme will improve performance and prevent injuries. Preseason testing is used to guide the fitness trainer, coach and medical team about the strengths, weaknesses and potential of the team. The use of these preseason tests to predict injury in rugby has not been fully explored. The first part of this thesis will review the nature of rugby injuries in school, club and professional rugby players (Chapter 2); investigate the incidence and nature of injuries in club rugby players during a season (Chapter 3) and identify whether preseason tests predict injury in club rugby players (Chapter 4).

The second part of this thesis will focus on hamstring injuries, which is postulated as the most common muscle strain among rugby players (Chapter 5 and 6). Hamstring injuries have been associated with sport that involve sprinting. A high incidence of hamstring injuries has been reported in various sporting codes, including rugby[4;5;6]. There is also a high incidence of recurrence of hamstring strains[7;8]. The main risk factors that have been identified are muscle weakness[9;7] muscle inflexibility[10;4;11] fatigue, and inadequate warm-up. The increase in hamstring strains may also be associated with the increased pace of the game. Certain characteristics of players have also been investigated namely age[12;13;] past history of injury[13;12;8] anthropometric characteristics[12;7;13] and race[12]. The extrinsic factors that have been highlighted were the use of thermal pants[14], environmental conditions[13] and the nature of the sport. The most widely postulated theory about risk factors for hamstring injuries to date is muscle weakness, muscle inflexibility and fatigue. This will be referred to as the *muscle-strength-flexibility-fatigue model*. It is important that prevention strategies are based on sound evidence that provides a cause–effect relationship. The scientific literature supporting the *muscle-strength-inflexibility-fatigue model* needs to be reviewed. Chapter five provides a review of the literature that investigated risk factors for hamstring injuries.

The *muscle strength-flexibility-fatigue model* must be validated. There are limited data available on risk factors for hamstring injuries in rugby players. It is essential to determine whether preseason factors can be used to accurately predict the players who are likely to sustain a hamstring injury during the season. At present, muscle weakness and muscle inflexibility are the main focus of prevention of injury particularly for recurrent hamstring strains. It is not clear if hamstring injured players did in fact have muscle weakness and inflexibility prior to injury. The testing of this model is presented in Chapter 6.

Chapter Two

An overview of injuries in school, club and professional rugby players.

2.1. Introduction

Rugby is a contact sport characterised by speed and acceleration. It has always been associated with a high incidence of injury due to the amount of physical contact players make during the game. The game consists of a number of set pieces namely the scrum, line-out, ruck, maul and tackling. Injuries can occur in any of these phases of play. Various law changes have occurred in rugby since 1980 to make this a safe, flowing spectator sport. These changes focused on the scrum, line- out, ruck/maul and tackling.

A number of epidemiological studies have been conducted to determine the nature of rugby injuries[1;2;15;16;17]. The methods used in these studies are not consistent thus making comparison between injury rates difficult. These studies have focused on school[18;19;2] club[20;1;15;21] or professional rugby[17;22;23;24]. Most of the studies used a similar definition of injury. In most studies' injuries were defined as those where the player injured himself on the field during a competitive match, during a practice game, or during another training activity associated with rugby and which prevented the player from training or playing rugby from the time of injury or from the end of the match or practice session in which the injury was sustained[21;24;2;19;15]. Some studies however also defined an injury when a player received medical attention[22;1]. It has also become important that all epidemiological studies report the incidence of injury in relation to exposure time[16]. Studies that will be discussed in detail in this chapter are only those that reported the incidence of injury in relation to hours of exposure to rugby. Injuries reported in terms of percentages are of little value without the exposure to rugby reported. The different methods of reporting the nature and types of injury have also complicated the comparison. More recent studies that used the International Classification of Diseases (9th version) for the coding of rugby injuries, has made the comparison easier[21;19].

It was reported that club rugby players have a higher incidence of rugby injuries (306.2 injuries /1000 player seasons) than school rugby players (80.9 injuries/1000 player seasons)[19]. It has also been reported that the incidence of rugby injuries is the highest among professional players[17;22]. The aim of this chapter is to provide an overview of the nature and mechanism of the injuries sustained by rugby players at various levels of play. The following section deals with the type of injuries sustained by rugby players namely concussion, cervical spinal injuries, musculotendinous injuries, contusions, fractures, ligamentous injuries, lacerations, and dislocations.

2.2. The type and nature of rugby injuries:

2.2.1. Concussion injuries:

Concussion is a trauma-induced change in mental state that may or may not involve loss of consciousness[25]. The main clinical signs of concussion are confusion and loss of memory [26]. It is an injury that affects all levels of rugby players. In various studies it was reported as a concussion injury irrespective if the player left the field following injury or not[1; 2;15]. The most recent systematic review of the incidence of concussion in contact sports concluded that there are few good studies on the incidence of concussion. Of all the 63 studies analysed it was reported that ice hockey and rugby have the highest incidence of concussion[27].

2.2.1a School rugby:

A particularly high incidence of concussion injuries has been reported in South African schools rugby. The incidence of concussion during a single rugby season at a South African high school was reported as 22%[28]. In another South African epidemiology study involving 24 schools in the Western Cape, 72 concussion injuries (14.5% of all injuries) were reported occurring at a rate of 18 per 1000 player seasons.

The phase of play in which these concussion injuries most commonly occurred was while being tackled (48.6%), while tackling (27.8%) and during rucks (13.9%)[2]. The lifetime prevalence of concussion in schoolboy rugby players was reported as 50%[2]. The prevalence could be underreported as the majority of mild head injuries are often not recognised and reported, particularly in cases involving schoolboys. In a prospective study[29] the incidence of concussion in high school rugby players over a three-year period was reported as 3.8% per 1000 athlete exposures, which is much higher than previous studies. It was found that the prevalence of concussion injuries was the second highest of all injuries in school rugby players[19]. However, there may be over reporting as players who had a knock against the head could have reported it as a concussion[19]. The mean age of the players that reported concussion in the matches and training sessions was 14.9 years[19]. In a two-year prospective study of relative risk of a second cerebral concussion on high school and college football players, the risk of sustaining a cerebral concussion was nearly six times greater for individuals with a history of concussion than for individuals with no such history[30].

2.2.1b Club rugby

In the New Zealand Rugby Injury and Performance Project, 4.5% of the total injuries sustained during games were concussion injuries. 30 % of these concussion injuries were recurrent injuries. 64% of concussion injuries were sustained during the tackle. Of the injuries sustained during tackles, 46% were sustained by the tackler, 36% by the ball carrier and 18% by support players. It was also found that at the time of the event, 72% of these players were not wearing any protective equipment while 14% wore a headgear and 14% had a mouthguard.

In a prospective epidemiological study of 8 adult South African rugby clubs during the 1988 rugby season there were 13.2 % concussion injuries reported[1]. Closed head trauma without loss of consciousness was the third most common injury with an incidence of 8.8% in an Argentinean study of club rugby players[20]. School rugby players had a lower prevalence of 17.1concussion injuries per 1000 player-seasons compared to 10.6 concussion injuries per 1000 player-seasons in club rugby players[19].

2.2.1c Professional rugby

There are very few studies that report the incidence of concussion injuries in professional rugby. In 1999 the South African Super 12 rugby competition, the incidence of concussion was reported as 1.6% with only one concussion in 75 players for that season. It is important to note that the incidence of concussion could be underreported as a number of mild cases could go undiagnosed[24].

2.2.1d Prevention of concussion

There has been controversy regarding the management of concussion in sport particularly with regard to return to play decisions. Traditionally there has been a lack of universal consensus on a standard definition of concussion, making scientific research difficult. Significant advances have been made in head injury management since the First International Conference on Concussion in Sport, Vienna 2001. It was during this conference that a comprehensive, systematic approach to concussion was formulated for application in sport, which included computer-based neuropsychological testing as an integral part of concussion evaluation[25]. In a prospective cohort of New Zealand rugby players it was found the highest usage of protective equipment was in the forwards male senior players with a high voluntary use of mouthguards[29]. A Canadian study examined the attitudes of rugby players and their coaches regarding the use of headgear and its role in preventing concussion. It was documented that most players believed headgear may prevent concussion but only a minority reported wearing it. Coaches were less convinced than the players that headgear could prevent concussion[31]. A two –year randomised controlled trial of headgear is being conducted in Rugby Union football in Sydney, Australia. The IRB-approved headgear and a modified headgear with increased foam density and thickness was tested with regard to impact attenuations. The modified headgear demonstrated an improvement in this regard compared to the approved IRB headgear. The study is continuing to test if these improvements will translate in reductions in head injuries and if players find these new dimensions comfortable[32].

2.2.2. Cervical spinal injuries:

Cervical spine injuries usually occur as a result of the collapse of the scrum, prolonged rucks or mauls or high tackles[16]. All rugby–playing countries (i.e. England, Wales, Ireland, Australia, New Zealand, Canada, United States and South Africa) reported an increase in the number of cervical spinal injuries to rugby players after 1976[33].

In 1980, New Zealand introduced law changes related to the maul. These changes resulted in a reduction in the number of annual cervical spinal injuries from 3 per season to 1 per season between 1980 and 1986. Alterations in the scrum laws in 1984 reduced cervical injuries from an average of 3 per annum between 1973 and 1984, to 1 per annum from 1984[34;35]. Australia introduced various changes at under-19 level rugby in 1985, specifically to address the incidence of cervical spinal injuries during scrummages. The success of these law changes in New Zealand and Australia, and to some extent United Kingdom, resulted in the International Rugby Board (IRB) issuing a circular in March 1988[36] regarding the set scrum, the tackle and the ruck and maul which inter-alia noted the following:

The set scrum:

- Only appropriately built players should be chosen in the front row,
- Front row forwards should undergo specific upper body, neck and shoulder strength training,
- Players should be aware of the dangers of the uncontrolled or violent scrum engagements, of scrum collapsing, of popping or continuing to push an unstable scrum especially after it had collapsed,
- That the shoulders of the front row players should not dip below their hips,
- That popping of the scrum should be outlawed as an illegal procedure,
- That the scrum should not be allowed to wheel beyond 90 degrees before emergence of the ball,
- That the duration of the scrum be limited, and
- That in the case of a front row forward being replaced; only a specialist front-row forward should be used as a substitute.

To reduce the impact forces of scrum engagement, it was recommended that:

- The front rows first engage by adopting the crouch-touch-pause-engage (CTPE) technique, and only when the front rows were stable should the back 5 players join the scrum.

The tackle:

- Players should be coached to tackle fairly and correctly and taught how to “ride” a tackle and fall correctly,
- The dangers of the crash tackle to both tackler and player being tackled should be stressed to players, and
- In the event of a high ball, the ball should be contested by the attacking player(s), as opposed to attacking player(s) executing high speed tackles on the ball catcher.

The ruck and maul:

- The danger of the player in possession of the ball posting the ball between his legs during a ruck, potentially causing his head to be caught in a flexed position between the attacking and defending players, should be stressed,
- Players should be taught not to dive blindly into the loose scrum either to collect the ball or post it, or add weight to the scrum, and
- Players should keep their heads up and thus their necks extended when entering the loose-scrum.

The law changes were only adopted in South African schools rugby in the middle of the 1990 rugby season. These law changes were introduced because of the highest number of spinal cord injuries due to rugby were admitted (12 spinal cord injuries) to the spinal unit at Conradie Hospital in 1989. This together with media pressure led to South African law changes[2].

The Spinecare Foundation and the Australian Spinal Cord Injury Units report in its most recent review of acute spinal cord injuries, that there has been a decrease in spinal cord injuries in rugby union and an increase in rugby league in Australia. They report a significant decrease in the incidence of adult rugby union injuries. Scrum injuries in rugby union have decreased following law changes in 1985 particularly in schoolboys. However, 39% of the injuries sustained in scrummage occurred in players not in their regular position of play. The injuries sustained in the rucks and mauls are however increasing. The most dangerous phase of play in rugby league was the tackle with the two on one tackle ("gang" tackle) accounting for half of the acute spinal cord injuries. The Foundation recommends that appropriate preventative strategies and law changes are implemented with particularly attention to tackle injuries and players who are expected to play out of position[37].

The three main areas that have been highlighted in a review as the main focus for prevention of neurotraumas and cervical injuries in sport is strength training of the cervical spine; teaching proper sporting techniques and the use of protective sports equipment[38].

A stratified epidemiological study of French rugby players examined the prevalence of trauma to the lower or middle part of the face and the frequency of the usage of the mouthguard. This study documented that the prevalence of trauma to the face has increased for the older forwards. It also increased with the number of yearly competitions and number of hours of weekly training. It was reported that 64.3% of the players in this study used mouthguards. It was found that the usage increased with the increase in the number of yearly competitions and for those who experienced previous trauma and the forward players who have been playing for a long time[39].

2.2.3. Musculo-tendinous injuries

The comparison of various studies with regard to muscle injuries is difficult as different methodological procedures are used and the definition of injuries and classification of muscle injuries are often inconsistent.

2.2.3a School rugby:

In a prospective epidemiological study of 25 South African schools in the Western Cape during 1991 it was reported that 21.5% of all injuries were muscle injuries (26.8 per 1000 player seasons)[2]. Of these, 72.9% were classified as muscle strains or tears, while 27.1% were recorded as muscle bruising. 74% of these muscle injuries were sustained during matches, 26.2% were recurrent muscle injuries of which 60% were hamstring, 50% groin, 40% back and 32% neck muscle injuries. This study reported the risk of muscle injury for individual player positions to be as follows; hookers 45.1 per 1000 player seasons, wings 43.2 per 1000 player seasons and centres as 30 per player seasons[2].

2.2.3b Club rugby

In the New Zealand Rugby Injury and Performance Project[15] of female and male rugby players ranging from under 18, under 19 and under 21 teams, most strains/ sprains were sustained to the lower limb. The strains/sprains in games were reported as 46.7% of the injuries and in practices as 76.1% of the injuries. In games these sprain/strain injuries were 23.9% of the lower limb, 13.1% of the upper limb, 5% neck, 4.3% trunk and 0.4% unidentified. The lower limb sprains/ strains sustained during games were reported according to anatomical structure: knee (12% of all injuries); thigh (8% of all injuries); ankle (5% of all injuries). The lower limb injuries during practices were also reported according to anatomical structure: ankle (14% of all injuries); thigh (13% of all injuries); and hamstring as (11% of all injuries)[15]. The limitation of this study was that there was no random sampling, and all injuries were reported telephonically. The definition of injury included in this study differs from other studies (an injury was defined as such when the player received medical attention even if no rugby time was missed).

In another prospective study the frequency, nature and circumstances of rugby injuries during the 1993-1994 season in the South of Scotland was examined. It was reported that strains and sprains of the knee had the highest incidence and prevalence rates[40]. The lower limb was the site of 42% of the sprains and strains reported[40]. In an Argentinean study, "pulled" muscles of the lower limb was the most common injury with an incidence of 11.7%[20]. In a South African prospective epidemiological study of 8 adult rugby clubs during the 1988 rugby season, muscle injuries were reported as 18.6% all injuries. Of these muscle injuries, 70.2% occurred during match play and were evenly spread between the forward and backline positions. The wings and props with 16%, centres 14.9% and locks 12.8%. Of these muscle injuries, 27.7% were sustained to the head and neck, 27.7% to the upper limb, 9.6% to the thigh and 2.2% to the groin. The mechanism of muscle injuries was reported as tackling (21.3%); ruck /maul (21.3%); scrum (20.2%) and being tackled (19.1%)[1].

2.2.3c Professional rugby

In a study examining the incidence and nature of injuries during the 1995 World Cup a 14% incidence of muscle injuries was reported[17]. This study failed to provide the mechanism of injury specific to muscle injuries or the specific anatomical sites affected. A four-year prospective survey of injuries in English professional rugby league reported the most frequent type of injury to be muscular injuries 34 per 1000 player hours)[41]. In the Super 12 competition during 1999, musculotendinous strains and tears accounted for 24.2% of the injuries recorded[24].

2.2.4. Contusions

The terms contusion and haematoma have been used interchangeably in some studies while in others a distinction between these injuries was made. Contusions and haematomas were defined as injuries caused by direct contact to a body site resulting in local damage and bleeding to that site. In one study a contusion was characterised by minimal pain, tenderness, swelling, and no restriction of movement. This study characterised haematomas by intense pain, tenderness over a wide area, pronounced swelling, and severely restricted range of motion[42].

In an epidemiological study of rugby sevens, the most common injury recorded was a contusion (40% incidence of 113.4 injuries per 1000 playing hours). The mechanism of injury of these contusions was physical collisions and tackles[42]. The New Zealand Rugby Injury and Performance project (RIPP) study[15] of male and female rugby players found the incidence of haematomas to be 23.9% of all injuries occurring during games and the incidence to be 10.7% of all injuries occurring during practices. The site of haematoma injuries occurring during games was reported as 14.1% of the lower limb, 4.3% of the upper limb, 2.9% of the head and face; 1.6% of the trunk; 0.6% of the neck and 0.4% unidentified. The site of haematomas occurring during practices was reported as follows: 5.3% of the upper limb, 1.8% of the head and face and 1.8% of the lower limb and 1.8% unidentified.

In professional rugby of the Super 12 competition a 9.7% of the injuries recorded were contusions /haematomas i.e. 8.1 injuries per 1000 game hours.

2.2.5. Fractures

2.2.5a School rugby

In South African schoolboy rugby the seasonal incidence of fractures was 31.1 per 1000 player seasons, accounting for 24.9% of all injuries and being the second most common injury type in this study. The most common fracture sites were the clavicle (23.4%), forearm and wrist (22.2%) and fingers (15.3%)[2]. Most fractures occurred to the upper limb (71.8%)

followed by the lower limb (15.3%). Backline players were at a 2.1 greater risk of fracture injuries than forwards with the wing and centre being the highest risk positions[2]. Upper limb fractures was found to be the most prevalent injury in school rugby players (16.4 injuries/1000 player seasons[19]. Clavicle and hand fractures were the most common fracture[19].

2.2.5b Club rugby

In adult club rugby the seasonal incidence of fractures has been reported as 29.1%[1]. No incidence rate related to exposure time is provided. In the New Zealand (RIPP) study of female and male rugby union players the fracture incidence during games was found to be 28 injuries (5.7%) of all game injuries. These fractures were 2.9% of the upper limb; 1.2% of the head and face; 0.8% of the lower limb; 0.6% of the trunk; 0.2% unidentified[15]. During practices the incidence of fractures was 2.6% of all practice injuries of which 1.8% was of the lower limb and 0.9% was of the upper limb of all practice injuries.

2.2.5c Professional rugby:

In a large-scale comprehensive audit of rugby injuries of the 1993-1994 rugby season in the South of Scotland it was found that the main site of fractures was the upper limb[40]. Fractures accounted for 8.1% of the injuries in a Super 12 competition of which four of the five fractures occurred during games[24].

2.2.6. Ligamentous injuries

2.2.6a School rugby

The prospective epidemiological studies of schoolboy rugby in South Africa reported a 25.5% seasonal incidence of ligamentous injuries (31.8 per 1000 player-seasons)[43] and 127 ligament injuries were reported in another study of which 85 were not combined with other injuries[2]. In the latter study, the most frequently injured ligaments were the knee (33.9%), ankle (27.6%), shoulder (11.8%), wrist (7.9%) and neck ligaments (7.1%). There was a 25.2% recurrence rate of ligamentous injuries in this cohort. The hookers (48.9 per 1000 player-seasons), wings (43.2 per 1000 player seasons) and flanks (35.7 per 1000 player seasons) were at greatest risk of ligament injuries[2]. It is important to note that 11% of these ligamentous injuries were sustained when players were substituting an unfamiliar position. 68.5% of the 127 ligament injuries occurred during match play, 32 during match practice, 5 during physical exercises and 2 during skills training[2].

2.2.6b Club rugby

In a prospective study of 8 South African adult rugby clubs during the 1988 rugby season, a 30% seasonal incidence of ligamentous injuries as recorded[1]. This incidence was however not related to exposure time to rugby. There are studies that have used the term strains /sprains together to identify muscle and ligamentous injuries. In one of these studies conducted in the south of Scotland during the 1993-1994 rugby season it was found that the highest incidence and prevalence rates of injuries in rugby union was the dislocation, strains and sprains of the knee[16]. In an epidemiological study of the Croatian-Slovenic rugby league it was reported that the most frequent injuries were dislocations, strains and sprains of the ankle and foot[21]. In a study of amateur rugby league sevens the incidence of joint sprains was the second most frequent injury with an incidence rate of 85.0 per 1000 hours[42]. In the Argentinean study the annual incidence of ankle ligament sprains was the second most common injury (11.7%)[20]. Muscular or ligamentous injury of the shoulder had an annual incidence of 4.6% and muscular or ligamentous injury of the cervical column had an annual incidence of 3.7%[20].

2.2.6c Professional rugby

In professional rugby the incidence of ligamentous injuries has been reported as 30% of all injuries during the 1995 World Cup[17] and 25.8% in the 1999 Super 12 competition[24]. Ligamentous injuries were the most common injury in the competition. Most of these ligamentous injuries occurred during games. The injury incidence was reported as 16.2 injuries per 1000 player game hours and 0.8 injuries per 1000 training hours[24].

2.2.7 Lacerations

2.2.7a School rugby

The seasonal incidence of lacerations reported in adult club rugby was 4.9%[1] and in school rugby 4% of all injuries at a rate of 5.0 per 1000 player–seasons[2]. The three phases, which accounted for 90% of all laceration injuries in school players, were tackling (8 injuries), being tackled (3 injuries) and the loose-scrum (7 injuries)[2]. It was also reported that the school players in the A-teams were 5 times a greater risk of laceration injuries than players in lower teams, while under-19 players were 4.8% times at greater risk than lower-team players[2].

2.2.7b Club rugby

The incidence of lacerations in a New Zealand prospective epidemiological study of male and female rugby union players was reported as 8.8% of all injuries sustained during matches and 2.6% of all injuries sustained during practices. The site of injury for lacerations sustained during the matches was reported as 7.8% to the head and face; 0.4% of the trunk; 0.4% of the lower limb and 0.2% unidentified. All lacerations sustained during practices were all to the head and face[15]. The incidence of laceration injuries was reported as 56.7 per 1000 player hours (third most frequent injury in this study) in a study of amateur rugby seven league players[42]. In the Argentinean study lacerations were reported as either a bleeding wound on the face (8.5%) and cut on the head (4.8%)[20].

2.2.7c Professional rugby

In professional rugby the incidence of lacerations was reported as 27% of all injuries[17]. Lacerations accounted for 9.7% of all injuries sustained in the 1999 Super 12 competition (8.1 injuries per 1000 player game hours)[24]. The risk of injury has also been reported to be greatest in the most talented players in the game[17] which could explain the higher incidence of laceration injuries in professional players as opposed to schoolboy and club rugby players.

2.2.8. Dislocations:

In a South African school rugby study twenty dislocation injuries were reported (4% of all injuries, 5.0 injuries per 1000 player seasons)[2]. Three of these injuries were cervical vertebral dislocations but none resulted in paralysis. Forward players were involved in thirteen (65%) of these dislocations 8 occurred during tackling, 5 occurred during the loose-scrums and 4 during scrums[2]. It is not conclusive that these players had true dislocations based on there early return to play following injury. In the New Zealand prospective epidemiological study of male and female union rugby players during the 1993 season, the seasonal incidence of dislocations during matches was reported as 3.7% and 0.9% during practices. The dislocations occurred to the upper limb (3.5%) and to the neck (0.2%) during the matches and to the upper limb (0.9%) during practices[15]. During a study of South African adult club rugby players during the 1988 rugby season, the seasonal incidence of dislocations was reported as 3.6% of all injuries[1]. In the Super 12 competition of 1999 dislocations/ subluxations accounted for 6.5% of all the injuries (4 injuries /1000 hours of player game hours)[24]. In an Argentinean study of club rugby players only 22 of the most common types of injury were reported[20]. Acromioclavicular joint subluxation and shoulder subluxation had 1.6% and 1.5% annual incidence respectively[20].

2.3. Site of injuries

Most studies report that most frequent site of injury in rugby is the lower limb with the most common type of injury is muscle and/or ligamentous type injuries. The sites of the lower limb most commonly affected include the ankle, knee and thighs. In the 1995 World Cup, 42% of all injuries were in the lower limb with 29% in the upper limb and 17% in the face 17%[17]. In the Super 12 competition it was reported that the pelvis and hip area was the most commonly injured site accounting for 12 (19.3% or 2.1 injuries/1000 player hours of total exposure[24]. The next most injured sites were the head and knee with 8 injuries (12.9% or 1.4 injuries/1000 player hours of total exposure) followed by the thigh and ankle with 7 injuries (11.3% or 1.2 injuries /1000 player hours of total exposure each). The conditions affecting the hip and pelvic area were 3 cases of osteitis pubis, two hip adductor strains and one "hip pointer" of which all were classified as intermediate or serious in severity[24]. All the head injuries were minor injuries and included lacerations of the face and scalp. The knee injuries consisted of an anterior cruciate ligament rupture, two medial collateral ligament sprains, one lateral collateral ligament sprain and one avulsion fracture of the tibial plateau. The thigh injuries consisted of three hamstring tears, one quadriceps tear and one haematoma in the quadriceps[24]. In an Argentinean study of club rugby players it was reported that the most commonly affected lesion was the lower limb (42.6%) followed by head and neck (35.1%), upper limbs (15.3%) and trunk (6.8%)[20]. The results of this study support the findings of other studies, which involved club rugby players. In the South African studies that involved club rugby players the lower limb accounted for most of the injuries followed by the head and neck then the upper limbs and trunk[1]. The incidence of injury at different anatomical sites of school, club, and professional rugby players of different countries are presented in Table 2.1-2.3.

Table 2.1. Incidence of injury (%) at different anatomical sites of school rugby players

Region	*Upton[2], 2000 (South Africa)*	*Roux[18], 1987 (South Africa)*	*Lee[19], 1996 (U.K)*
Lower limb	31.6	37	31.1
Upper limb	32.3	20	35.1
Head and Neck	27.7	29	20.3
Trunk	8.4	13	8.1

Table 2.2. Incidence of injury (%) at different anatomical sites of club rugby players

Region	*Bottini[20] 2000 (Argentina)*	*Clark[1] 1990 (South Africa)*	*Bird[15] 1998 (New Zealand)*	*Lee[19] 1996 (U.K)*	*Babic[21] 2001 (Croatia)*
Lower limb	42.6	44	58.4	41.0	47.62
Upper limb	35.1	27	21.3	21.7	20.64
Head and Neck	15.3	23	Head 7.1 Neck 2.6	15.6	23.89
Trunk	6.8	7	7.9	14.4	4.76

Table 2.3. Incidence of injury (%)/ (per 1000 hours rugby exposure) at different anatomical sites of professional rugby players

Region	*Garraway[23] 2000, (U.K) (injury rate/1000hrs)*	*Holtzhausen[24], 2001 (South Africa)*	*Jakoet[17] 1998 (1995 World Cup players)*	*Targett[22] 1998 (New Zealand)*
Lower limb	Hip and thigh 3.99 Knee 3.99 Ankle and foot 3.99	43.6 % (excl. Pelvis)	42%	40,8%
Upper limb	1.99	11.3%	29%	14,3%
Head and Neck	Neck 1.00	Head 12.9% Neck 4.8%	Face 17%	26,5% Neck 6,1%
Trunk	Back 0.00	Trunk 4.8% Lower back 3.2%		Lower back 6.1%

2.4. Mechanism of injuries

2.4.1. Being tackled and tackling:

2.4.1a School rugby

South African epidemiological studies of schoolboy rugby players indicate that 29.4% of injuries occurred while being tackled[43]. In a later study, 37.6% of injuries occurred while being tackled with an incidence rate of 39.1 injuries per 1000 player seasons[2]. In the earlier study[43] it was reported that 41.2% of the injuries occurred to under-14 players and only 21.4% to under-19 players. The latter study[2] reported that 59.6% of these injuries were in under-19, 20.5% were under-15, 10.9% under-14 and 8.9% under-16 age groups. The earlier finding suggested that more injuries occurred in the younger players due to poor tackling techniques. The later study found that most of the injuries while being tackled occurred to A and B teams of all age groups. The players reported to be at the highest risk of injury while being tackled were the wings, fullbacks and scrumhalves. Most of these injuries while being tackled (77.6%) occurred during matches. The injuries sustained by these players while being tackled were as follows: 31.9% fractures, 48.4% of all fracture injuries sustained during all phases of play and 18.6% were concussion injuries (48.6% of all concussion injuries sustained during all phases of play). The manner in which a player can be injured while being tackled is either due to the impact with the other player or contact with the ground. The site of impact (head and neck, shoulders, hip/waist or legs); direction of the impact (front-on side-on or behind); and the speed of impact (high speed or low speed) and the fairness of the tackle are factors that influence the nature of the injury that will result while being tackled[2].

In an epidemiological study in Edinburgh it was documented that most of the match injuries in school rugby occurred during the tackle, and 40% were associated with tackling and 24% with being tackled[19].

In a more recent school rugby epidemiological study, 19.3% of the injuries[2] occurred as a result of tackling while in an earlier study it was reported as 23.4%[43]. In the recent study [2] 83.8% of the tackling injuries occurred during matches with 37.5% of the players injured while tackling sustaining head and neck injuries, 35.0% upper limb and 23.8% lower limb injuries. In this study[2] the tackler was most commonly injured when impacting the ball carrier around the hip/waist (47.5%) and legs (38.8%), and while executing the tackle at high speeds (85.0%).

2.4.1b Club rugby

As early as 1979 a prospective rugby injury survey in New Zealand rugby clubs reported that 44% of all injuries occurred during the tackle, with set play not contributing significantly to the incidence of injury[44].

A prospective study of South African club rugby reported that 85% of all injuries occurred during matches and the most common mechanism was while being tackled accounted for 26% of these injuries[1]. The type of injuries sustained during this phase of play was not reported[1]. In an epidemiological study of the Croatian-Slovenic rugby league it was reported that the most injuries occurred to forward players while being tackled[21]. The details of the nature of the injuries while being tackled as well as the details of the conditions of the tackle were not included.

The New Zealand epidemiological study (RIPP)[15] reported that that the most dangerous phase of play was the tackle, constituting 40% of all injuries that occurred during games. Of these tackle injuries 49% were while being tackled and 47% were tackling at the time of injury and 4% were support players during the tackle. The body sites of injuries sustained during tackling were as follows: head and face (18%), knee (17%), shoulder (14%), arms and hands (10%), thigh (8%), ankle (8%), other leg (7%), trunk (6%), neck (4%), other (8%).

In a large-scale epidemiological study of rugby union players in the south of Scotland it was reported that the tackle was responsible for 49% of the injuries sustained during matches. The injuries sustained by the players while being tackled was reported as 6 of the 11 lower limb fractures; 37% of the knee dislocations, ligament and cartilage tears. There was no significance reported regarding player position with regard to injuries while being tackled or while tackling[23]. Another epidemiological study in the South of Scotland found that being tackled accounted for most of the injuries (28%) followed by tackling (21%)[19].

2.4.1c Professional rugby

In professional rugby, being tackled also constitutes the most dangerous phase of play with a 46.3% incidence according to a four-year prospective survey of professional English rugby league players[41]. The tackle was also responsible for most of the injuries reported in a study of professional rugby players in the 1997 Super 12 competition[22]. During the 1995 World Cup the tackle, was reported as the most dangerous phase of play constituting 56% of all the injuries. The details of the conditions of the tackles were not investigated[17]. A study that investigated the impact of professionalism on injuries in rugby union found that the proportion of injured players had doubled from 1993-1994 to 1997-1998. Instead of an injury episode every 3.4 matches, it was one every 2.0 matches in 1997-1998[23]. There was a tackling injury episode in a professional team every 59 minutes of play. This has been mainly attributed to the increase in open play resulting in more tackle injuries[23]

2.4.1d Factors influencing tackle injuries

A study was conducted that examined the influence of selected factors of the player's lifestyle, personality and other player related factors on injuries sustained during the tackle. It was found that the following factors did not contribute significantly to injuries sustained during the tackle: alcohol consumption before the match; feeling "below par" due to minor illness; extent of match preparation; previous coaching; practicing tackling. In 52% of injuries, the tackle occurred from behind the tackled player out of his peripheral vision. A third of the injuries occurred with players running at differential speeds at the time of impact. The player with the lower momentum was injured in 80% of the cases. The forceful or crunching tackles resulted in injuries mostly to the head or within the tackled players side vision. It was concluded from this study that high speed tackles going in behind the tackled players line of vision was the most dangerous[45].

There is another study that examined 30 tackling injury incidents of provincial and international teams that have reported that tackles to the trunk from the front were responsible for nearly 3 times more injuries than either side-on tackles or tackles from behind. It was found that it was the landing of the tackle that was associated with the injury rather than any particular action such as crouch, arms out, leg drive or wrap arms[46]. It has been suggested that players be coached in falling technique from the front, or that law changes be introduced to reduce the likelihood of front-on tackles to the trunk[46].

The danger of the tackle is evident from the results of these studies. The increase in injuries due to the tackle could be as a result of law changes that encourage open play at high speeds to ensure that it remains a flowing spectator sport. There is not sufficient information regarding the circumstances under which these injuries occur. It is recommended that the danger of the gang tackle be reviewed by the IRB following the increase in dangerous play and injuries as a result of this method of tackling during the 2003 World Cup.

The law changes that have occurred with regard to the tackle have been discussed previously in this chapter with regard to cervical spinal injuries (page 21).

2.4.2. Ruck maul:

In a South African schoolboy rugby study, 20% of injuries occurred during the ruck/ maul of which 56.6% were under –19 players, 75.9% were A and B team players from all age groups and 72.3% were forward players[2]. The forward players most often injured during the ruck/maul were the hookers (37.6%), flankers (35.7%), and locks (32%) and the backline players was the scrumhalf (30.1%). 77.1 % of the ruck /maul injuries were during match play. The nature of the injuries sustained in the ruck and maul were as follows: ligamentous (29.4%), fractures (24.5%), and 16.7% muscle injuries. 70.0% of the ligamentous injuries were of the knees and ankles and the most common fracture site was the arms and hands.

In professional rugby, the second highest frequency of injuries occurred during the ruck/maul with it constituting 23% of the injuries in the 1995 World Cup[17]. In rugby union in the south of Scotland, the ruck was also reported the second highest frequency of injury with 15% and the maul 2% of all injuries sustained[16]. In the New Zealand RIPP of rugby union players rucks and mauls constituted 17% and 12% of the injuries respectively[15]. In the 1999 Super 12 competition it was reported that rucks and mauls accounted for 7 (17% or 23 injuries/1000 player game hours) of game injuries[24].

2. 4.3. Scrum and line-out:

The scrum is the phase of play, which has undergone the most law changes to ensure safety with regard to serious cervical injuries. The changes that have taken place with regard to the scrum are outlined under cervical spinal injuries (page. 21)

In the New Zealand RIPP epidemiological study, it was reported that the scrum was responsible for 7% of the injuries, which was the least amount of injuries compared to other phases of play in this study[15].

The epidemiological study of Scottish rugby union players also revealed a low incidence of injuries in the scrum phase of play. There were only 8% of injuries that were sustained during the scrum and 12% in the line-out[16].

In the 1995 rugby World Cup an incidence of 1% of injuries was reported during the scrum and line-out.

2.4.4. Foul play:

There are a few studies that reported on foul play as a mechanism of injury.

2.4.4a School rugby:

In an epidemiological study of 24 schools in the Western Cape[43], South Africa foul play injuries accounted for 10.1% of all injuries. Foul play was regarded as illegal tackles, illegal scrummaging techniques, punches and kicks. Of all the foul play injuries 47.6% occurred at under-19 level; 42.9% in A teams at all levels of play and 90.5% during match play. Hookers followed by the props had the highest risk of foul play injuries during loose scrums. Wings were the next position with the highest risk of foul play while being tackled. It was reported that 69.0% of the players were involved in situations known as "off the ball incidents".

2.4.4b Club rugby:

The incidence of foul play as a mechanism of injury has not been considered in many epidemiological studies[1;47;16;48]. In one epidemiological study an increase in the number of foul play incidents were reported[49]. In another New Zealand epidemiological study, it was reported that there was a decrease in the incidence of foul play injuries compared with an earlier study[50]. In a more recent New Zealand epidemiological study, it was reported that 13% of the match injuries were as a result of foul play and in 69% of these cases no penalty was called[15]. This study compared the site of injuries of foul play injuries and reported that there were significantly more injuries (p=0.001) to the head (including the face and eye) and significantly more lacerations (p=0.001) than compared with non-foul play injuries. Of the injuries to the head as a result of foul play, 65% were lacerations, 17% concussion, 9% fractures and 9% bruising[15]. This study[15] also made the following recommendations to reduce the incidence of foul play injuries: 1) stricter referring of games 2.) players taking personal responsibility 3.) coaches to instruct players about clean play 4.) administrators forming judicial committees with prizes for fair play in New Zealand. The aim of these recommendations was to reduce the injuries and ensure a cleaner game to increase the popularity and support of the game.

2.4.4c Professional rugby

In the 1999 Super 12 competition of one South African team, foul play accounted for only one injury sustained during the game i.e.1.4 injuries per 1000 player game hours[24]. In the study of a 1997 New Zealand Super 12 team, players were not asked about foul play as a possible mechanism of their injuries[22]. The data on foul play in the professional arena is lacking.

2.5 Summary

The increase in the incidence of rugby injuries since the inception of professionalism is cause for concern[22;24;23]. This increase is not limited to professional rugby players but across all levels (Table 2.1-2.3). It is however difficult to make conclusive statements about the incidence in rugby due to the differences in study designs. Earlier studies failed to report injuries expressed as incidence per 1000 hours but merely reported frequency, which makes interpretation and comparison with other studies difficult. The failure to adhere to the International Rugby Board (IRB) guidelines in terms of definition of injury remains a problem[51]. The differences in data collection by most studies are either flawed by observer or recall bias, which further complicates the validity of the data.

There however appears to be a lower incidence of injuries among school rugby players compared with club and professional rugby players[1;19;2]. This could be due to the lack of medical involvement with school rugby teams. If the injury definition requires a player to miss a match it could also result in underreporting at school level. At professional level, players are able to have better medical management and this may result in players not playing where they may have played if they were club or school level. The confounding variable with school rugby players is unlikely to be age but rather previous injury history and differences in the frequency and nature of training. There are limited data available on school rugby. In terms of professional and club rugby, the increased injury rate could be as a result of the increased intensity of the game being played at a faster pace with a greater number of tackles and fewer breaks in play.

The incidence of concussion still remains a problem, particularly at school level. The lower incidence of concussion at the professional level could be because professional players may disguise and deny symptoms in order to play. Professional players also may also be using better headgear than other players. The incidence of fractures particularly of the upper limb also appears higher at school level. This phenomenon has not been explained. It could be lack of skill and also inappropriate anthropometric characteristics for the sport. This is however speculative.

It has been shown that school and adult rugby players suffer similar rugby injuries in terms of type of injury, anatomical distribution, and mechanism of injury. The lower limb has been shown to be the most affected anatomical site in rugby. Muscle and ligamentous injuries are the most common injuries across all levels of play and across different countries. The tackle had been confirmed as the most dangerous phase of play for all levels of rugby.

The need for effective prevention programmes is crucial for all levels of play. Prevention programmes can only be designed with sufficient and accurate data in terms of epidemiology and risk factors of rugby injuries.

Chapter Three

The incidence and nature of injuries in club rugby players during a rugby season.

3.1. Introduction

Injury is the cause of considerable morbidity for rugby players. Rugby is a contact sport associated with a high risk of injury[15;24;40].

Several epidemiological studies have been conducted on club rugby players to determine the incidence of rugby injuries[21;20;1;15;19]. However few of these studies utilize the same study design, which makes comparison difficult. As a result it is difficult to identify risk factors for injuries in club rugby players. In the contrast, South African epidemiological studies are limited to school, provincial and professional rugby with one study related to club players[1;24;2;17]. Scientific data on the incidence, and the nature of injuries in club rugby players are essential. This information is beneficial to medical professionals, coaching staff, rugby players, team management and policy makers in ensuring appropriate injury prevention and management. Injury prevention intervention at club level is essential to ensure these players are allowed to develop and progress to a higher level of play at provincial or national level.

Earlier epidemiological studies have reported a high incidence of rugby injuries at club level with most injuries occurring during matches[21;1;15;20;19]. There is difficulty in making comparisons between studies due to differences in definition of injury and in reporting of injury incidence by player hours or player games. The most common injury reported is musculo-tendinous strains and ligament sprains[21;15;24;2;52;53;41;17;22;]. The most common anatomical sites of injury were the joints of the lower extremity[40;17; 21;15;1;52;53;41;22;54]. The tackle has been reported as the most dangerous phase of play and that most injuries occurred in the final phase of the match[15;40;1;22;44;21;24;2;17;41;55;13;16].

There is limited data on the description of injuries sustained by South African club rugby players. An earlier epidemiological study of club rugby players was conducted prior to 1995[1]. This study[1] failed to express incidence in relation to exposure time.

Epidemiological data is the basis from which prevention strategies can be designed. It is important that this data be South African to ensure that our prevention strategies are appropriate and effective. There are limited data about the types of injury; the seasonal incidence of injury as well as the mechanism of injuries sustained by South African club rugby players.

3.2. Aim of the study

The aim of this study was to determine the incidence, nature and mechanism of injuries of club rugby players in a competitive season.

3.3. Methods

A prospective cohort study consisting of 102 male club rugby players was conducted for the 2001 rugby season. Players were recruited from four rugby clubs in the Western Province premier A and Super league division. Clubs were selected from these divisions as they represent the highest level of play in club rugby. Convenience sampling was used to select these clubs. There were 12 clubs in the Premier A division and 24 clubs in the Super league. One of the clubs used in this study was from the Premier A division (Silvertree Rugby Fooball club) and three were from the Super league division (Collegians Rugby club; U.C.T Rugby club; Scotteskloof Warmers Rugby club). The inclusion criteria for participation were that all rugby players were aged between 18 and 35 and were medically fit to play at the start the season. Rugby players who have sustained any type of chronic injuries and who would not be starting the season would be excluded from the study. The Research Ethics Committee of the University of Cape Town approved this project and all subjects provided written informed consent (Appendix 1).

All subjects were tested prior to the commencement of the 2001 rugby season. Each subject completed a pre-season medical questionnaire (Appendix 2) to establish past injury history and training history with particular reference to strength and flexibility training. Two subjects were excluded from the cohort; one as he did not play for the season due to study commitments and another player was advised to stop rugby due to a severe previous neck injury. The neck injury occurred prior to the commencement of the season.

All players were followed up throughout the season to document their exposure to rugby and the details of any injury sustained.

The four rugby clubs were involved in 22 matches for the season excluding preseason games, which accounts for 1971.7 player hours of game time. Training hours were calculated at 2 sessions of 2 hours each week for two clubs and 2 sessions of 1.5 hours each week for the remaining clubs. Pre-season training hours were excluded. A total of 5020.8 player-training hours were documented in the study. Injuries sustained during games were documented as injuries per 1000 player game hours, and injuries during training as injuries per 1000 player training hours. The sum of injuries sustained during games and training were documented as injuries per 1000 hours of exposure. Injuries that had not healed since the previous season were not included.

The diagnosis of all injuries was based on clinical criteria. A physiotherapist was present at the matches or practice sessions that would identify injuries. The diagnosis was confirmed by a medical practitioner and/or by diagnostic imaging. All subjects were contacted by telephone during and immediately after the season to ensure no injuries were missed. Injury report forms (Appendix 3) were completed for each injury sustained. The following information was recorded on this form: date, player position, injury during match or practice session, anatomical site of injury, type and mechanism of injury, first or recurrent injury to the same structure, and the number of sessions missed as a result of the injury. An injury was defined as one that prevented the player from participating in a training session or match. Acute and chronic overuse injuries were included if these criteria were met. The severity of the injury was assessed by the number of games and training sessions missed as a result of the injury. A player who was unable to participate for a week was recorded to have missed three sessions (two training sessions and a game).

Injuries were classified as *minor* if three or less sessions were missed, *intermediate* if four to nine sessions were missed and *serious* if 10 or more sessions were missed.

3.4 Results

The mean (SD) age of the subjects was 23.9 (4.5) years, the mean height was 175.4 (6.2) m and mean weight was 78.4 (16.5) kg.

3.4.1. Seasonal injury incidence

The injury incidence according to exposure to rugby is shown in Table 3.1. A total of ninety-seven injuries were recorded in 66 players over a period of 23 weeks. Seventy-four injuries occurred during matches, which represent 37.5 injuries per 1000 player game hours. Thirty-six (18.3 injuries/1000 player game hours) were minor injuries while twenty-two (11.2 injuries/1000 player hours) were of intermediate severity and sixteen (8.1 injuries/1000 player hours) were of a serious nature. Twenty-three injuries occurred during training, which represent 4.6 injuries per 1000 player training hours. Thirteen (2.6 injuries/ 1000 player training hours) were of minor severity while seven injuries (1.4/1000 player training hours) and three injuries (0.6/1000 player training hours) were of intermediate and a serious nature respectively.

Table 3.1. Injury rates [no of injuries (injuries /1000 hours)] of club rugby players during the 2001 rugby season

	Hours Exposure	***Mild Injuries***	***Intermediate Injuries***	***Severe Injuries***	***Total Injuries***
Games*	1971.7	36 (11.2)	22 (11.2)	16 (8.1)	74 (37.5)
Training**	5020.8	13 (2.6)	7 (1.4)	3 (0.6)	23 (4.6)
Total *** Exposure	6992.5	49 (7.0)	29 (4.1)	19 (12.7)	97 (13.9)

Numbers between brackets:

* Injuries per 1000 player game hours

** Injuries per 1000 player training hours

*** Injuries per 1000 hours of total exposure to training and rugby games

3.4.2. Injuries in different player positions

The total number of injuries per player position and the severity of injury is shown in Table 3.2. The column indicating the number of injuries was corrected to reflect that two players in the team represent some player positions, while others have one player. The flank was the position most commonly injured (27.8% of all the injuries). The flanks recorded the most intermediate and serious injuries. The wing and centre are the next most injured positions with 16.5% and 13.4% of all the injuries sustained respectively. The wings sustained 16 (2.3 injuries/1000 hours of rugby) injuries of which 10 were minor injuries. The backs comprising 46.7% of the team sustained 52.6 % of the injuries while the forwards representing 53.3% of the team sustained 47.4% of the injuries. Of the 29 intermediate and 19 serious injuries recorded, 23 (47.9%) were from backline players and 25 (52.1%) were from the forwards. The number 8 player position has the least amount of injuries 2 (0.3 injuries /1000 of rugby) injuries.

Table 3.2. Injuries [No. of injuries (injuries /1000 hours)] to club rugby players by playing position

Position	*No. in team*	*No. of injuries (injuries/1000 hours)*	*Minor (No. of injuries)*	*Intermediate (No. of injuries)*	*Serious (No. of injuries)*
Flank	2	27 (3.9)	13	9	5
Wings	2	16 (2.3)	10	4	2
Centre	2	13 (1.9)	4	4	5
Scrumhalf	1	8 (1.1)	5	1	2
Fullback	1	8 (1.1)	6	2	0
Lock	2	7 (1)	3	3	1
Flyhalf	1	6 (0.9)	3	2	1
Props	2	4 (0.6)	3	0	1
Hooker	1	6 (0.9)	1	3	2
No. 8	1	2 (0.3)	1	1	0
Total	15	97 (13.9)	4.9(50.5%)	29 (29.9%)	1.9 (19.5%)

No., Number

3.4.4. Injury type

The type of injuries sustained during matches and training sessions are shown in Table 3.3. Ligament sprains (39.2%) and muscle strains (38.1%) accounted for 77.3 % of the injuries recorded. Thirty-four of the ligament sprains (17.3 injuries /1000 player game hours) occurred during games and four (0.8 injuries/1000 player training hours) occurred during training. Twenty-six of the muscle strains (13.2 injuries /1000 player game hours) occurred during games and 11 (2.2 injuries/1000 player training hours) occurred during training. The other significant injuries reported were fractures (6.2%), contusions (5.2%) and concussions (4.1%). Of the 6 fractures that were sustained 4 (66.6%) occurred during games and 2 (33.3%) occurred during training. All the contusions occurred during games. Of the 4.1% of concussion episodes, 75% occurred during games and 25% occurred during training sessions.

Table 3.3. Types of injuries sustained by club rugby players during the 2001 rugby season

Injury type	*[Total no. of injuries (injuries /1000 hours)]*	*[No. of match injuries (injuries /1000 hours)]*	*[No. of training injuries (injuries /1000 hours)]*	*% of total injuries*
Ligament Sprain	38 (5.4)***	34 (17.3)*	4 (0.8)**	39.2%
Muscle Strain	37 (5.3)***	26 (13.2)*	11 (2.2)**	38.1%
Fractures	6 (0.9)***	4 (2.0)*	2 (0.4)**	6.2%
Contusions	5 (0.7)***	5 (2.5)*	-	5.2%
Concussion	4 (0.6)***	3 (1.5)*	1 (0.2)**	4.1%
Chronic Overuse	3 (0.4)***	1 (0.5)*	2 (0.4)**	3.1%
Lacerations	2 (0.3)***	1 (0.5)*	1 (0.2)**	2.1%
Internal Organ	1 (0.1)***	-	1 (0.2)**	1.0%
Other	1 (0.1)***	-	1(0.2)**	1.0%
TOTAL:	97 (13.9)***	74	23	

No., Number

Numbers between brackets:

* Injuries per 1000 player game hours

** Injuries per 1000 player training hours

*** Injuries per 1000 player hours of total exposure to training and rugby games

(The chronic overuse injuries were 3 cases of patellofemoral pain syndrome)

3.4.5. Injury site

The distribution of injuries according to anatomical site is shown in Table 3.4. The thigh was the most commonly injured site, accounting for 15 (15.5% or 2.1 injuries/1000 player hours of total exposure) of all injuries. Ten of the thigh injuries occurred during games and Nine of the thigh injuries were mild and six of an intermediate nature. Twelve of the thigh injuries were hamstring injuries of which nine occurred in the player's dominant leg. All of these hamstring strains were of mild or intermediate severity. Eight of the hamstring strains occurred in backline players while 4 occurred in forward players. There were 3 injuries to the quadriceps muscle of which 2 were minor quadriceps strains and one was a haematoma of intermediate severity.

The ankle was the next most commonly injured site with 14 (14.4% or 2.0 injuries/1000 player hours of total exposure) injuries followed by the knee and arm/hand with 13 injuries each (13.45 or 1.9 injuries /1000 player hours of total exposure). Thirteen of the ankle injuries occurred during games (92.8% or 6.6 injuries/1000 player game hours). Eleven of these injuries were of mild or intermediate severity. There was 13 ankle ligament sprains and 1 ankle fracture. Three of the 14 were recurrent ankle injuries. Backline players were involved in 8 of the ankle injuries and 6 forwards sustained ankle injuries.

Ten of the knee injuries occurred during games (76.9 % or 5.1 injuries /1000 player game hours). Nine of the knee injuries were of an intermediate or serious nature (69.2% or 5.7 injuries /1000 hours of total exposure). Seven of the knee injuries were medial collateral ligament sprains of which 1 was serious and 6 of mild or intermediate severity. There were 3 cases of patellofemoral pain syndromes of which 2 were minor and 1 was serious. There was one lateral meniscus tear that was of a serious nature.

The arm and hand injuries consisted of five thumb injuries, three metacarpal fractures, two radial fractures, two finger dislocations and one wrist sprain. No pelvic or hip injuries were reported in this cohort.

Table 3.4. Injuries to club rugby players by anatomical site and severity

Region	***[Total no. of inj. (inj. /1000 hrs)]***	***[No. of match inj. (inj. /1000 hrs)]***	***[No. of training inj. (inj. /1000 hrs)]***	***Minor (No. of inj.)***	***Intermed (No. of inj.)***	***Serious (No. of inj.)***	***% of total***
Head	6 (0.9)***	4 (2.0)*	2 (0.4)**	0	3	3	6.2%
Neck	2 (0.3)***	2 (1.0)*	0	1	0	1	2.1%
Shoulder	11 (1.6)***	9 (4.6)*	2 (0.4)**	7	3	1	11.3%
Arm / Hand	13 (1.9)***	10 (5.1)*	3 (0.6)**	9	1	3	13.4%
Trunk	2 (0.3)***	1(0.5)*	1 (0.2)**	0	0	2	2.1%
Back	9 (1.3)***	8 (4.1)*	1 (0.2)**	4	2	3	9.3%
Groin	6 (0.9)***	5 (2.5)*	1 (0.2)**	4	2	0	6.2%
Thigh	15 (2.1)***	10 (5.1)*	5 (0.9**	9	6	0	15.5%
Knee	13 (1.9)***	10 (5.1)*	3 (0.6)**	4	6	3	13.4%
Lower Leg	5 (0.7)***	2 (1.0)*	3 (0.6)**	4	1	0	5.2%
Ankle	14 (2.0)***	13 (6.6)*	1 (0.2)**	6	5	3	14.4%
Foot	1 (0.1)***	0	1 (0.2)**	1	0	0	1.0%
Pelvis/ Hip	0	0	0	0	0	0	0
TOTAL:		74	23	49	29	19	

Inj., Injury; No., Number

Numbers between brackets:

* Injuries per 1000 players game hours

** Injuries per 1000 player training hours

*** Injuries per 1000 hours of total exposure to training and rugby games

3.4.6. Mechanism of injury

Contact between players accounted for 66 injuries (68% of all injuries). Of these 35.1% were intermediate or serious injuries. The most dangerous phase of play during matches was being tackled, accounting for 28 of the 74 injuries sustained during games (37.8% of the game injuries or 14.2 injuries /1000 player game hours). Thirteen were of an intermediate or serious nature (46.4 % or 6.6 injuries /1000 player game hours). Tackling was responsible for thirteen (17.6% or 6.7 injuries/1000 player game hours) game injuries. Rucks and mauls caused 10 (13.5% or 5.1 injuries/1000 player game hours) of the injuries sustained during games. Open running was the mechanism of 11 injuries (14.9% of the game injuries or 5.6 injuries/1000 player game hours) during games. The distribution of the mechanism of injuries during games is shown in Figure 3.1. Thirteen injuries occurred with contact training (56.5% of the acute injuries during training or 2.6 injuries/1000 player training hours). Speed training was responsible for 5 acute injuries during training (21.7% of the acute injuries during training or 1.0 injuries/1000 player training hours).

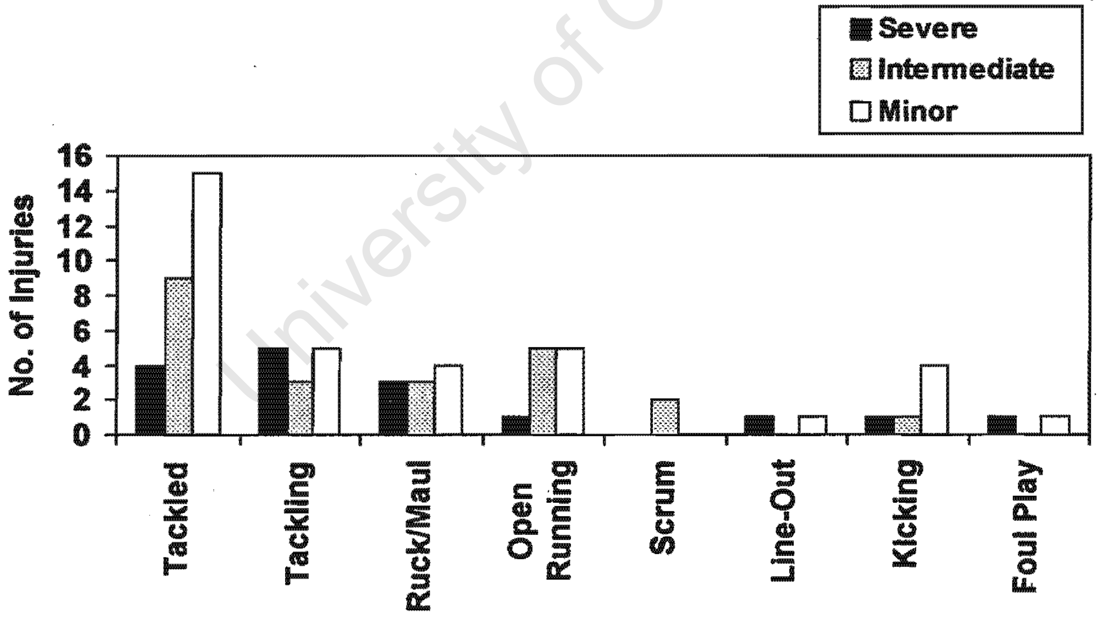


Figure 3.1 Mechanism of injury in club rugby players during matches

Table 3.5. Mechanism of acute injuries to club level rugby players during matches

Matches	*No. of mild injuries*	*No. of intermediate injuries*	*No. of severe injuries*	*Total no. of injuries*	*Percentage*
Tackled	15	9	4	28	38
Tackling	5	3	5	13	18
Ruck/Maul	4	3	3	10	14
Open Running	5	5	1	11	15
Scrum	0	2	0	2	3
Line-out	1	0	1	2	3
Kicking	4	1	1	6	8
Foul Play	1	0	1	2	3

No., Number

Table 3.6. Mechanism of acute injuries to club level rugby players during training

Training	*No. of mild injuries*	*No. of intermediate injuries*	*No. of severe injuries*	*Total no. of injuries*	*Percentage*
Speed Training	2	3	0	5	22
Skills	2	0	1	3	13
Contact	8	4	1	13	57
Endurance	1	0	1	2	9
Strength	0	0	0	0	0
TOTAL	13	7	3	23	100

No., Number

3.4.7. Time of injury during games and during the season

There were 74 match injuries of which fourteen (18.9%) occurred in the first 20 minutes, fourteen (18.9%) in the second 20 minutes, twenty one (28.4%) in the third 20 minutes and twenty-five (33.8%) in the final 20 minutes. This is shown in Figure 3.2. The incidence of injury at different times in the season is shown in Figure 3.3. The highest incidence of injury was during the first part of the season i.e. April and May and then again in August which follows the mid season break.

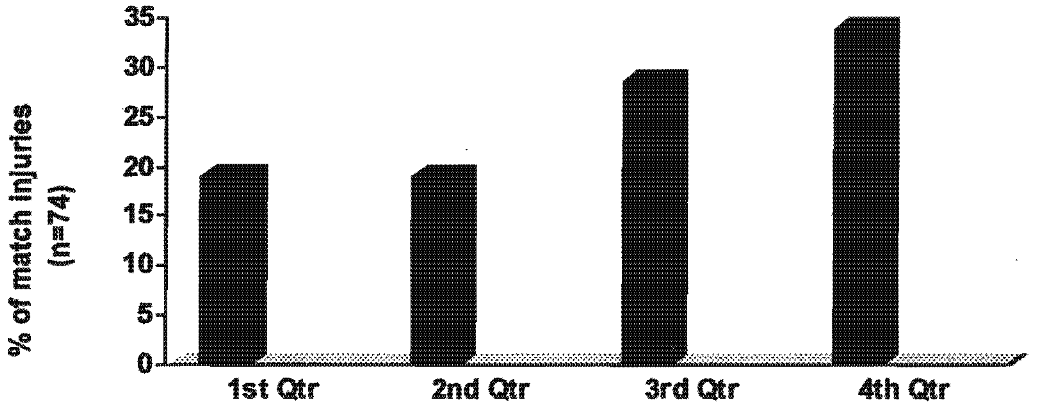


Figure 3.2: Injury incidence during different quarters of the game

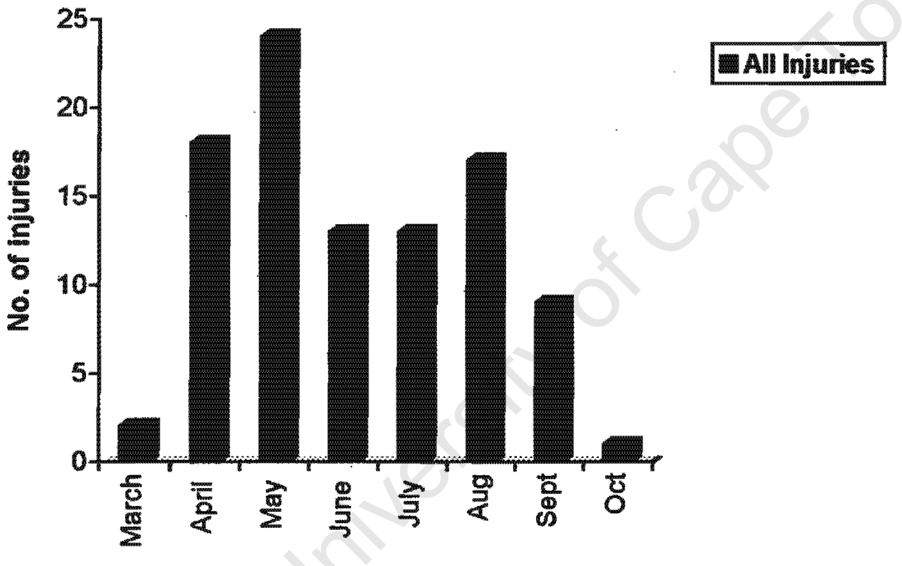


Figure.3.3 Injury incidence during the club rugby season

3.5. Discussion

3.5.1. Methodology

Most epidemiological studies of rugby injuries have been conducted at amateur club level. However, differences in study design with regard to data collection, definition of injury and differences in expression of injury incidence makes comparison between studies difficult. A measurement instrument for injury data collection has been validated which allows comparison of injury data[16]. The methodology of this study is consistent with this validation and allows comparison with a few studies of club level and professional level rugby players [21;24;15;16;41;22].

The classification of injury in this study could have resulted in under-reporting. Many players are injured but are pressurized to play due to the constraints of their club in terms of substitute players. Most prospective studies determining rugby injuries used the number of players in a training squad or the number of players on the field during the game, as a basis to express player exposure to rugby. In these studies new players joining the team or squad were included in the cohort while players leaving the team or squad were automatically excluded. The cohort of players in this study remained fixed. Players who had not undergone preseason screening were automatically excluded from the cohort. The rates per time of exposure to rugby in the cohort of players were documented.

3.5.2. Injury Incidence

This study documented 37.5 injuries per 1000 hours of player match hours; 4.6 injuries per 1000 player training hours and an overall incidence of injury showed 13.9 injuries per 1000 hours of exposure. In comparison to other epidemiological studies that utilised similar methodology, 28.22 injuries per 1000 match hours[21] and 25.7 injuries per 1000 match hours[53] were recorded. It is difficult to compare this study to other South African epidemiological studies of club rugby players, as the incidence of injury in other studies was not recorded in terms of player hours[1].

A study on professional rugby recorded 120 injuries per 1000 player game hours[22]. This New Zealand study of a single Super 12 team had a different definition of injury, which could explain the higher incidence of injury. If a player had sought medical attention on the field or after the game it would be classified as an injury. The present study only classified an injury if the player missed a training session or match. The other explanation that was given for the high incidence of injuries in the New Zealand study was that the researcher was the full time medical practitioner of the team, which facilitated injury reporting and documentation. The most recent South African epidemiological study of professional rugby reported 55.4 injuries per 1000 player hours; 4.3 injuries per 1000 training hours and an overall injury incidence of 11 injuries per 1000 hours[24]. The present study reports a lower incidence of injuries during matches, similar incidence during training sessions and a slightly higher overall incidence of injuries in club rugby players compared to professional rugby players. The higher injury incidence in club rugby players compared to professional rugby players supports the hypothesis held by many that injury rates are related to overall physical conditioning and fitness i.e the less fit the player the higher the risk of injury. However this cannot be concluded from the incidence of injuries. The differences between club and professional rugby in terms of the nature, mechanism and severity of injuries and playing conditions are factors that need to be considered. The lack of adequate facilities, poor field conditions, and poor medical care for majority of the players in this cohort could influence the results of the present study.

This study reported that club rugby injuries were mostly of a mild or intermediate severity. The epidemiological study of South African professional club rugby players participating in the Super 12, reported a higher incidence of severe injuries during games[24]. The severity of an injury was determined by the amount of time missed from rugby as a result of the injury. This could mean that injuries would be classified as severe at a professional level, which may not have been the case at an amateur level. In the Super 12 competition key players could be rested with minor injuries to ensure they are match fit for important games later in the season. There could also be underreporting of injuries as club players are often forced to play with injury due to pressure from the coach or team players. Most injuries at club level were of mild or intermediate severity, which could be as a result of the culture of playing with injury that exists at this level. All studies at school, club or professional level report a higher incidence of injuries during games compared to training sessions[17;21;15;53;55;19;24;2;41;1;22]. There are studies that have reported a much higher incidence of injuries compared to the studies previously discussed i.e 283.5 injuries per 1000 player hours[54] and 367.0 injuries per 1000 player seasons[19]. The main reason for this was differences in study design as injuries were reported according to player seasons.

South African club rugby players had a slighter higher overall seasonal incidence of injury compared to studies of South African professional rugby players[24]. However, South African professional rugby players reported injuries of a more serious nature than South African club rugby players[24]. South African club rugby players had a similar seasonal injury incidence as club rugby players in other countries[20,21,15].

3.5.3. Injuries in different player positions

The most commonly injured player positions were flanks, wings and centres. This finding correlates with the most common mechanism of injury, which is being tackled or tackling. The flanks and centres have the most contact with the opposition due to their role in attacking and defence. Wings are required to out play their opposition with their speed and strength[24]. This study reports that the backline players sustained 52.6% of the injuries while the forwards sustained 47.4% of the injuries. This finding differs from earlier studies of club rugby players that report a higher incidence of injuries among forwards[5;1;21]. The epidemiological study of Croatian club rugby players found a higher incidence of injuries among the forwards of 35 injuries per 1000 game hours and the backs with 20 injuries per 1000 game hours[21]. The South African study of club rugby players found the highest incidence of injury among the hookers 19%, wings 15% and fullbacks 11%[1]. The epidemiological study of the senior rugby clubs in the Scottish Rugby Union reported the highest incidence of injuries among centres and wings as in this study[19]. A more recent study of Argentinean club rugby players found the highest incidence of injuries was the flanker[20]. The comparison in this Argentinean study of senior and younger players with regard to incidence of injury by player position found that senior players in the second row ($p<0.001$), at flyhalf ($p< 0.01$), fullback ($p=0.02$) and number 8 ($p=0.03$) had a statistically higher risk of injury than the younger players[20]. The findings of the present study, however correlates with the studies of South African professional rugby players that report the highest incidence among flanks, centres and wings[17] and centres[24]. The latter study[24] found a high incidence among fullbacks, which is not found in other studies which could be related to the style of play where the fullback is used to break the line with fast running. In a study of a 1997 Super 12 team of New Zealand it was found that positions number 8, full backs and locks had the highest incidence of injuries followed by flankers and centres[22]. Recent studies show a trend that there is a decrease in injuries among the forwards that could be related to rule changes regarding the scrum[19]. It appears that the variable that has to be considered with position of play would be the amount of physical contact or tackles the player is involved in.

More recent studies of club and professional rugby players find the most commonly injured positions to be the flanker, centres and wings[21;20;17;24] while earlier studies found a high risk of injury for the forward player positions[1;21;15].

3.5.4. Mechanisms of injury

Being tackled accounted for 37.8%; tackling as 17.6%; open running 14.9% and rucks and mauls 13.5% of match injuries. This finding supports the findings of all comparable studies that the tackle is the most dangerous phase of the game[56;21;15;1;40;44;22;17;41;55;24;2;13;16]. In a study that measured the frequency and nature of injuries occurring in competitive matches since professionalism was introduced in rugby union it was found that more professional players (37%) were injured while being tackled than amateurs (26%)[23]. Most tackle injuries occurred when tackled players were attacked from behind or within their peripheral vision. The tackled or tackling player is usually sprinting or running in most injury episodes. There are occasions where players are in differential speeds (one player traveling much faster than the other at impact). The player with the lower momentum gets injured. Information on circumstances of vast majority of tackles in which no injury occurs is required before any changes are considered to decrease injuries in the tackle[40]. Fewer injuries occurred in the set phases of play such as the line out and scrums that are characterized with more control and low velocity. The rule changes around the scrum have contributed to a decrease in injuries in this phase of play. Recent law changes have encouraged open play conducted at higher speeds to enhance the game as a flowing spectator sport, which may have contributed to the high incidence of tackle injuries. The factors for that may influence the rugby player would be the frequency of tackles he is involved in, the intensity of the game and his tactical sense as a player. The challenge remains to decrease the high-velocity contact in the tackle and still maintain popularity of the game[40;24;2].

Most of the hamstring injuries occurred during open running. During running the hamstring muscles become active in the last third of the swing phase undergoing eccentric contraction to decelerate the knee extension and oppose the activity of the quadriceps. At ground contact the hamstrings switch from maximal eccentric to concentric activity and develop the greatest force of the lower extremity muscles[8].

The ruck and maul accounted for 13.5% of all the injuries sustained during games. In the study of South African Super 12 players it was reported that the ruck/maul accounted for 11.3% of all the match injuries. In the study, which involved the New Zealand Super 12 players the ruck/maul accounted for 35.89% of all the match injuries. Recent law changes have aimed at making this a safer phase of play (page 24-25). However, the adherence of players to these laws is not known. At club level in particular the discipline may be a problem with regard to this phase of play however this has not been documented.

Most of the injuries sustained in this cohort during the training sessions were during contact sessions (56.5%) while in the South African Super 12 most of the injuries during training sessions were speed training (33.3%)[24] and in the New Zealand Super 12 it was during team training (40%). The New Zealand Super 12 team failed to provide details of the activities involved in this type of training session. There were also very few injuries sustained during this New Zealand's team's Super 12 season (10 injuries during the season) to be able to observe trends in training injuries[22]. It is clear that more preventative measures need to be considered when players are involved in contact training sessions. Contact sessions during training may be an integral part of preparation in conditioning the player for contact sessions. The reduction of contact training sessions may reduce the number of training injuries but the effect on player performance and the frequency of match injuries would need to be investigated. Studies which involved club rugby players failed to provide details of the mechanism of injury during the training sessions.

3.5.5. Injury type and anatomical site

The most common anatomical site of injury was the thigh with 12 of the 15 injuries being hamstring strains. This was followed by ankle and knee injuries. This study confirms previous findings that the most common anatomical sites of injury in rugby players are the joints of the lower limb[55;21;15;1;40;17;52;41;53;22]. The most common injury type is also confirmed by previous studies as musculo-tendinous strains and ligament sprains[21;1;17;52;53;22;41;24;2].

The incidence of muscle strains and ligamentous strains were also the most common type of injury in South African Super 12 players[24]. Club rugby players in the present study had a higher incidence of ligamentous (5.4 /1000 hours of rugby exposure) and muscular injuries (5.3/1000 hours of rugby exposure) compared to ligamentous (2.8 injuries/1000 rugby exposure) and muscular (2.7 injuries /1000 hours of rugby exposure) injuries compared with the Super 12 squad[24]. The level of physical fitness in terms of flexibility and muscle strength, and aerobic fitness may be factors that have resulted in a higher incidence of ligamentous and muscular injuries in club rugby players. The level of physical fitness of this cohort will be addressed in Chapter 4. The role of environmental factors and medical care availability are areas that are of poor quality to club rugby players in this cohort that may play a role in the incidence of ligamentous and muscle strains. The absence of medical care could equate the absence of adequate prevention strategies however this is speculative.

Hamstring strains were the most common muscle strain in this cohort. The risk factors associated with hamstring strains will be addressed in Chapter 5 and 6. There were 14 ankle injuries sustained in the games of which 13 were ankle sprains and 1 was an ankle fracture. There was no significant difference between the players who sustained ankle injuries and those without any ankle injury in terms of demographics, strength, flexibility, agility or cardiovascular fitness tests or use of protective equipment or strapping. There was no correlation found between ground conditions in terms of dry or wet grass and ankle sprains at the time of injury. The ground conditions in terms of potholes was not determined in this study which could be another factor responsible for the high incidence of ankle sprains. Two of the clubs of this cohort have training sessions at night without any proper lighting, which could influence the incidence of ankle injuries. However, only one of the ankle injuries occurred during a training session.

Contusions and lacerations have a higher incidence in professional players than in club rugby players with an incidence of 0.7 injuries/1000 hours of rugby exposure and 0.3 injuries/1000 hours of rugby exposure respectively. The professional players had an incidence of 1.0 injury/1000hours of rugby exposure for contusions and lacerations[24]. The incidence among club rugby may not be an accurate account as very few players rest from play as a result of contusions or lacerations.

The incidence of fractures among club rugby players has been reported to be lower than school rugby. Fractures in rugby players mostly affect the upper limb and hand or wrist across all levels of play. The incidence of concussion in this cohort was 4.1% (0.6/1000 hours of rugby exposure) compared to professional rugby that reported an incidence of 1.4% (0.2/1000 hours of rugby exposure)[24]. The incidence of concussion in the New Zealand Super 12 team was 12.8% of the total game injuries (14.8/1000 game hours)[22]. Concern has been expressed regarding the reporting of concussion injuries in professional players[22]. Professional player may disguise symptoms or fail to report concussion as playing rugby is their occupation[22]. There could be underreporting of concussion at all levels of senior rugby, as concussion may not be viewed as a serious injury to coaches or to rugby players. The knowledge and attitude of players and coaches to concussion injuries needs to be investigated. There is a need to investigate the management of concussion at club level.

3.5.6. Time of injury during games and during the season

There were fewer injuries in the first quarter of the game and most of the injuries occurred in the final half of the game, which correlates with previous findings[56;20]. Muscle fatigue has been considered as an important etiological factor that could be responsible for injuries to occur as the game progresses. Fatigue could result due to decreased physical fitness, poor hydration or nutrition, or lack of substitute players. Professional rugby studies do not report a high incidence of injury in the final 20 minutes, which could be due to the player changes that occur and improved player conditions and fitness. The results of this study correlates with most studies that the highest incidence of injuries is in the first few weeks of the season and again after the midseason break[1;21;19].

3.6. Summary:

There was a high incidence of injuries during the 2001 club rugby season. The tackle was the most dangerous phase of play affecting the flanks, wings and centres. The most common site of injury was the thigh of which hamstring strains were the most common. Ankle sprains were the second most common injury in this cohort. The highest incidence of injury was at the beginning of the season and most injuries occurred in the final half of the game.

There is an urgent need for epidemiological studies of similar design at all levels of South African rugby. The results of the present study need to be compared to studies of South African club rugby players with better playing conditions. Preventative programmes can only be instituted once there is clarity on the incidence, nature and risk factors associated with rugby injuries.

Chapter Four

The role of preseason testing in injury prediction in club rugby players.

4.1. Introduction

Rugby is a contact sport associated with a high risk of injury. There is extensive documentation on the nature of rugby injuries however there is limited research on key risk factors and injury prediction. Injury risk factors can be classified as intrinsic or extrinsic. Intrinsic risk factors are specific to the individual sportsperson and include age, anthropometric characteristics, fitness, psychological considerations and injury history[13]. Extrinsic factors are external to the individual and include the nature of the sport, environmental conditions and equipment[13]. A prospective cohort study conducted as part of the New Zealand Rugby Injury and Performance Project (RIPP) identified potential risk factors in relation to the proportion of the season missed due to injury. A multiple regression model identified grade of play and previous injury experience as risk factors for injury in the season. A second model identified previous injury experience, hours of strenuous physical activity, playing position, cigarette smoking status, body mass index, years rugby participation, stress, aerobic and anaerobic performance and number of push-ups as risk factors in terms of the proportion of the season missed due to injury[57]. The influence of pre-season fitness, existing injury and pre-season rugby training on subsequent injury has been investigated[58]. It was documented that injury risk was more likely related to rugby training than to overall player fitness. Players who were injured at the end of season were more likely to be injured in the following season[58]. This study failed to scientifically test the physical fitness of the players. Most rugby teams have a protocol of physical tests that are used to determine the preseason fitness level and "match fitness" of players. The accuracy of the fitness tests, as predictors of injury risk in rugby have not being verified. Preventative strategies and activities are paramount as sports injuries are costly and time-consuming. In order to develop efficient prevention strategies the aetiology, risk factors and exact mechanisms of injuries need to be identified before initiating a programme[59].

4.2. Aim of the study

The aim of this study was to determine if preseason clinical factors and tests could be used to determine potential risk factors for rugby injuries and specifically lower limb injuries in club players as measured by the injury incidence rate.

4.3. Methods

A prospective cohort design was used in this study. The same rugby players that were involved in the epidemiology study were involved in this study (Chapter 3). A total of 102 male club rugby players were recruited from four rugby clubs in the Western Province premier A and Super league division. Convenience sampling was used in the selection of the clubs that participated in this study. Inclusion criteria for preseason testing were all rugby players aged between 18 and 35 from these clubs who would start the season. Rugby players who have sustained any type of chronic injuries and who would not be starting the season were excluded from preseason testing. The project was approved by the Research Ethics Committee of the University of Cape Town and all subjects provided written informed consent.

4.3.1. Preseason measurements

All subjects were tested prior to the commencement of the 2001 rugby season at the South African Sport Science Institute, Cape Town, South Africa. Each subject completed a pre-season medical questionnaire (Appendix 2) to establish age, years of rugby participation, and past injury history. In addition the following physical tests were conducted. All subjects underwent the tests in the following order.

4.3.1a The slump test

The slump test combines cervical flexion, trunk flexion and straight leg raise with ankle dorsiflexion[60;61]. The Kin-Com System isokinetic dynamometer (Chattanooga Group, Inc., Chattanooga, USA) was used as a fixation device. Electromyography (EMG) surface electrodes (The Prometheus Group, 1 Washington Street, Dover, USA) were placed in series with their centres 3cm apart, between the center of the innervation zone of the biceps femoris and its distal tendon. All three electrodes were placed on a line joining the origin and insertion of the muscle.

The settings of the Kin-Com (Chattanooga Group, Inc., Chattanooga, USA) unit as described for the isokinetic testing was used. The subject was seated with the backrest firmly pushed to the sacrum and secured while the subject leans forward. A base level EMG reading was recorded. The right ankle was secured in 15 degrees dorsiflexion with a rigid brace (Corflex, Manchester, North America, United States of America). The knee was secured at the subject's maximum tolerable pain limit or full range of extension movement using the knee piece of the Kin-Com unit (Chattanooga Group, Inc., Chattanooga, USA). The electromyography (EMG) reading was repeated once the ankle and knee was secure. The subject was then instructed to 'slump'. Velcro straps were used to stabilize the patient in his full range of thoracic flexion at the level of the xiphoid. The EMG reading was repeated. The subject was then instructed to flex the cervical spine onto the chest, which was manually maintained. End range cervical flexion was followed by end range extension. EMG activity was recorded with the cervical spine flexed and extended. The EMG readings assisted the investigator in determining end range of movement during testing. The EMG reading would spike at the end of range. The subject was asked to rate their pain intensity of the posterior thigh at each end range position on a V.A.S (0-10) with 0 = least amount of pain and 10 = the maximal amount of pain. The slump test was repeated for the left lower limb.

Prior to the onset of the study, a pilot study of 14 subjects (8 females and 6 males mean age 25.14 years) was conducted to determine the reliability of the slump test. The subjects were tested on two occasions 2 days apart. The subjects were advised not to engage in any unusual strenuous physical activity prior to and on the day of testing. The mean correlation coefficient for the different variables between tests on day 1 and day 3 of the slump test was 0.85, indicating good reliability.

The outcome variable for the slump test in this study was the amount of pain experienced by the subject as measured on the visual analog scale (V.A.S.) in cm. The pain was recorded for cervical flexion and cervical extension during both right and left leg extension. The cervical component of the slump has been reported to influence the hamstring muscle tension[62].

4.3.1b Concentric and eccentric hamstring and quadriceps strength

Quadriceps and hamstrings muscle function was assessed in an upright, seated position using a Kin-Com System isokinetic dynamometer (Chattanooga Group, Inc., Chattanooga, USA) at an angular velocity of 60 deg/sec. Subjects were positioned according to the Kin-Com users' manual. Subjects were assessed after a thorough warm up which included at least 5 minutes of low-level aerobic work and stretching. Once the subject was positioned he performed 4-6 warm-up repetitions using minimal effort. The subject was asked to give a 60% and subsequent 80% effort before a maximal effort. Three maximal efforts were then requested. A minimum of a minute's rest was allowed between maximal efforts. The effort with the highest peak torque (N.m) was recorded as the final score. The hamstring to quadriceps ratio that was measured was concentric quadriceps and eccentric hamstring.

4.3.1c The straight leg raise test

This test measured the subjects hamstring flexibility in both legs. The subject was in a supine position on a plinth. The pelvis was placed in a posteriorly tilted position to allow the lumbar spine to come into contact with the plinth. This position was maintained using a belt around the anterior superior iliac spines and the plinth. EMG electrodes (The Prometheus Group, 1 Washington Street, Dover, USA) connected to a recorder was placed on the hamstring muscle to measure electrical activity in the muscle as it is stretched. The electrodes were placed in series with their centres 3cm apart, between the center of the innervation zone of the biceps femoris and its distal tendon. All three electrodes were placed on a line joining the origin and insertion of the muscle.
The ankle joint was placed in 15 degrees of plantarflexion and maintained in this position with a rigid hinge brace (Corflex, Manchester, NA, United States of America). A flexible

goniometer (South African Sport Science Institute of South Africa, Newlands, Cape Town, South Africa) was secured to the lateral side of the fibula to measure the angle of hip flexion. The subject's leg was lifted into hip flexion with the knee extension being maintained. The degree of hip flexion was measured at either of these 4 end points: as the tester felt the knee starting to flex; as the subject reported a feeling of marked discomfort, but no pain; when the tester determined the end feel of movement and as a spike in the EMG activity from the electrodes was displayed on the monitor. The values read out by the tester were recorded[63]. The subject's leg was then returned to neutral and the test was repeated with the ankle in 15 degrees dorsiflexion.

Prior to the onset of the study, a pilot study of 14 subjects (8 females and 6 males mean age 25.14 years) was conducted to determine the reliability of the straight leg raise test. The subjects were tested on two different occasions 2 days apart. The subjects were advised not to engage in any unusual strenuous physical activity prior to or on the day of testing. The mean correlation coefficient between tests conducted on day 1 and day 3 for the different variables of the straight leg raise test was 0.97, indicating excellent reliability.

The degree of hip flexion measured at either of the 4 points described in the procedure of the straight leg raise test was used as an outcome variable. A small degree of hip flexion would indicate less flexibility.

4.3.1d The sit and reach test

The sit and reach test was used to determine the flexibility of the lower back and lumbar spine. A research assistant who was a physiotherapist administered this test. The subject sat with the soles of their feet against a sit-reach box and with their knees fully extended. A ruler was fixed on top of the sit-reach box, such that the 22.5cm mark is in line with the vertical line of the feet. The subject was instructed to flex maximally at both hips and lower back with both hands together and outstretched. The furthermost point reached by the subject's fingertips was measured from the ruler. The subject is expected to be able to maintain the furthermost point for 2 seconds. The best of three attempts was recorded in centimetres (cm). A test-retest reliability co-efficient of 0.94 and an inter-tester reliability of 0.99 has been documented for this test[64].

4.3.1e Body composition

The body composition of the subjects was assessed by measuring skinfold thickness of the following sites: triceps, biceps, subscapular, suprailiac, calf, thigh and abdominal[65].

The skinfold caliper reading is a measurement of the compressed thickness of a double layer of skin and underlying subcutaneous tissue, which is assumed to be adipose tissue. The skin fold thickness is measured by grasping a fold of skin and the underlying subcutaneous tissue between the thumb and forefinger, 1-2 cm above the site, which is to be measured. The fold is pulled away from the underlying muscle and the jaws of the calipers are placed on either side of the site, at a depth of approximately 1cm. The skinfold is held firmly throughout the application of the caliper and the reading is taken when the needle becomes steady after the full pressure of the caliper jaws has been applied. The calipers must be applied at right angles to the fold at all times. All measurements will be performed on the subject's right side except for the abdominal skinfold, which is recorded on the subject's left side[66]. The measurement is recorded in mm. The body fat of the subjects will be described as the sum of the skinfold of the following sites: triceps, biceps, subscapular, suprailiac, calf, thigh and abdominal.

(i) Triceps

The triceps skinfold was measured from the back on the posterior surface of the arm midway between the top of the shoulder (acromion process) and the elbow (olecranon process). The upper limb should hang loosely by the side with the subject in the standing position. The inter-tester and intra-tester technical errors have been documented to vary from 0.8 to 1.89mm[67;68] and 0.4 and 0.8mm[67;69;70] respectively.

(ii) Biceps

The biceps skinfold was measured from the front on the anterior surface of the arm midway between the top of the shoulder and the elbow. The subject stands as for the triceps measurement. The standard deviations of differences for repeated measurements of biceps skinfold thicknesses by one investigator and between three testers was documented as 1.9mm[71]. The intra-tester technical errors have been documented as 0.2 to 0.6mm[72;73].

(iii) Subscapular

The subscapular skinfold was measured just below the inferior angle of the scapula with the fold in an oblique plane descending laterally (outwards) and downwards at an angle of approximately 45° to the horizontal. Repeatability reliability of the subscapular skinfold measurement is good with intra-tester errors ranging from 0.88[74] to 1.16mm[75]. Inter-tester errors range from 0.88[76] to 1.53mm[77].

(iv) Suprailiac

The suprailiac skinfold was measured 5cm above the iliac crest with the fold oblique, descending medially (inwards) and downwards at an angle of about 45° to the horizontal. The subject should stand erect with the upper limbs by the side and the abdominal muscles relaxed. A test-retest correlation of 0.97 for the suprailiac skinfold measurements for testing one day apart in young men has been documented[75].

(v) Calf

The calf skinfold was measured on the medial surface of the calf at the level of the greatest calf circumference. The subject's weight must be placed on the leg, which is not measured. A test-retest correlation coefficient of 0.98 has been reported for the calf skinfold measurement[78].

(vi) Thigh

The thigh skinfold was measured at the mid-point on the anterior surface of the thigh with the fold parallel to the long axis of the thigh. The subject's weight should be placed on the leg, which is not measured so that the knee joint of the measured leg forms an angle of about 120°. Intra-tester reliability coefficients are very high ranging from 0.91 to 0.98[79;75;80].

(vii) Abdominal

The abdominal skinfold was measured in a vertical plane 5cm to the left of the subject's umbilicus[65]. A test-retest correlation of 0.979 for abdominal skinfold measurements done

one day apart in young men has been documented[75] and intra-tester errors of 0.89mm has been reported[81].

4.3.1f Vertical jump

This test was to assess the subjects' instantaneous explosive leg power. The subject stood in athletic shoes with his right hip against the wall onto which a calibrated measuring board is mounted. The subject reached with the right hand to touch the board at the highest point possible with the heels on the ground. This height was recorded as standing height. The subject then placed chalk on his fingertips and then from a two-footed take off position the subject flexed at the hip and knee joints and used his arms as momentum to extend as high as possible. At the top of the jump the subject touched and marked the board with his fingertips. The score for the jump is the difference between the standing height and the jump height. The highest of three separate trials was recorded as the subjects' maximum score. If the subject took any step or shuffle prior to the jump the score was rendered invalid[82; 83]. A coefficient of variation of 2.4% and an intraclass correlation coefficient of 0.91 has been documented indicating a high test-retest reliability for the vertical jump test[84].

4.3.1g Muscle endurance:

4.3.1g (i) The 2- minute sit-up test

A research assistant administered this test. The sit-ups was performed with the knees flexed and feet fixed. The subject's hands was expected to touch his ears, and elbows touched the knees at the end of the sit up and then descended in a controlled manner. The tester's hand was placed palm side up on the bench such that the wrist makes contact with the spine in line with the inferior border of the scapulae. If the subject's hands were taken off the ears, or elbows did not touch the thighs or the back did not touch the tester's hand the sit-up was not counted. The maximum number of sit-ups performed in two minutes was recorded. The subject could rest within the two-minute period and then re-start[85]. A reliability co-efficient of 0.94 has been documented for the sit-up test[64].

4.3.1g (ii) The 1-minute push-up test

The subjects were in a prone position with their thumbs placed on the floor shoulder width apart. The subjects back and body had to be maintained in a straight posture as he descended to the tester's fist, placed below the sternum and then ascend until the elbows are fully extended. If the subjects did not adhere to these specifications the repetition was not counted. The maximum number of push-ups performed correctly in one minute was recorded. The subject could rest within the one-minute period. An objectivity coefficient of 0.99 has been documented for this test[64] but no reliability coefficient was reported.

4.3.1h Agility testing

The Illinois agility test was used to assess the subject's agility and speed[85;82]. A rectangle measuring 9.14m by 3.65m was clearly marked and divided by half along its length by four cones positioned at equidistant intervals. On the command "go" the stop watches started and the subject would rise from the lying position and run as quickly as possible to the end and back to the starting line. The subject repeated two time trails; and the best time was recorded. The subject was disqualified if he touched a cone while running, or if he failed to follow the prescribed course. No reliability tests have been documented for this test.

4.3.1i The multistage shuttle run

The multistage shuttle run or bleep test was used to test the maximum aerobic power of the subjects[86]. Two lines were marked 20m away on a non-slippery surface. The subjects ran between these 2 lines touching each line with their foot and turning quickly at the moment the sound signal was emitted from an audio- tape .The initial running speed was 8.5 km/hr, and increased at 0.5 km/hr each minute. The subject would continue running until he could not maintain the prescribed pace. The subject would receive 2 warnings regarding not reaching the line in time before the test would be ended with his third warning. At this stage the number of shuttles was recorded. Excellent reliability (r=0.97) and validity (r=0.84) has been reported for this test[91].

The players and their coaches were not given the results of the tests and no specific rehabilitation programme was implemented on the basis of the deficits detected from the testing.

4.3.2. Diagnosis of injuries

Players were monitored throughout the 2001 rugby season from April to October 2001. The physiotherapist was present at the matches or practice sessions and made the diagnosis of all injuries. In addition all subjects were contacted by telephone during and immediately after the season to ensure no injuries were missed. A specific injury report form was used to standardize clinical examination and diagnosis of the injuries (Appendix 2). The player reported whether the injury occurred during a training session or during a match and the mechanism of injury was obtained. The player reported on the site of the injury by anatomical region and the type of injury. The definition of an injury was it had to be severe enough to cause the player to miss a practice or match. An injury was classified as minor if less than 3 sessions were missed; intermediate if more than 3 and less than 10 sessions were missed; and severe if more than 10 sessions were missed.

4.3.3. Outcome measures

The injury incidence rate was used as an outcome measure to examine the influence of preseason factors. The incidence rate provides a measure of the number of injuries sustained per unit of exposure to rugby games. The four rugby clubs were involved in 22 matches for the season excluding preseason games, which accounts for 1971.7 player hours of game time. Training hours were calculated at 2 sessions of 2 hours each week for two clubs and 2 sessions of 1.5 hours each week for the remaining clubs. Pre-season training hours were excluded. A total of 5020.8 player-training hours were included in the study. Injuries sustained during games were documented as injuries per 1000 player game hours, and injuries during training as injuries per 1000 player training hours. The sum of injuries sustained during games and training were documented as injuries per 1000 hours of exposure. Injuries that had not healed since the previous season were not included.

4.3.4. Statistical analysis

The cohort was divided into quartiles for each physical parameter or test. Chi-square analyses were then used to determine whether there was any significant difference between the quartiles in respect of injury rate per 1000 hours. In addition logistics regression analyses were used to identify quartiles that were significantly at risk. These analyses were used for 1) all injuries sustained and 2) lower limb injuries sustained.

4.4. Results

4.4.1. Age, years playing rugby, previous injury history

There was no significant difference (p>0.05) between the quartiles with reference to age, years of playing rugby or previous injury status and their injury incidence for all injuries and for lower limb injuries (Table 4.1 and 4.2). The logistic analysis of years playing rugby found that players in the quartile of 8-12 years rugby experience were at greater risk of any rugby injury (p=0.03 95%CI 0.01-0.77) (Table 4.3). The multivariate regression analysis of age, and previous injury did not reveal any significant predictors for risk of any rugby injury or a lower limb injury (p>0.05) (Table 4.3 and Table 4.4).

Table 4.1. Age, years of playing rugby, past injury status with injury incidence for all injuries

	Total hours	*Total Injuries*	*Injury rate per 1000 hours*	*Chi-square*	*Sign.*
Age (years)					
< 21	904.60	23	25.43		
21 – 24	1351.70	24	17.76		
25 – 28	1295.60	32	24.70		
29 >	819.70	15	18.30	2.32	p > 0.05
Years Playing					
< 8	1035.5	25	24.14		
8 – 12	975.7	24	24.60		
13-17	1672.4	29	17.34		
17 >	778	17	21.85	1.51	p > 0.05
Previous injury					
No	1290.70	30	23.24		
Yes	3285.50	66	20.25	0.21	p > 0.05

Table 4.2. Age, years playing rugby, past injury status with injury incidence for lower limb injuries

	Total hours	*Total Injuries*	*Injury rate per 1000 hours*	*Chi-square*	*Sign.*
Age (years)					
< 21	661.90	14	21.15		
21 – 24	855.50	13	15.20		
25 – 28	855.80	17	19.86		
29 >	466.30	8	17.16	1.17	p > 0.05
Years Playing					
< 8	734.30	13	17.70		
8 – 12	602.2	15	24.91		
13-17	1087.6	15	13.79		
17 >	505.4	10	19.79	3.38	p > 0.05
Previous lower limb injury					
No	1298.10	30	23.11		
Yes	1719.00	24	13.96	2.26	p > 0.05

Table 4.3. Logistic analysis of age, years playing rugby and previous injuries with injury incidence of all injuries

	N	*Regression coeffcient (B)*	*Chi-square*	*p-value*	*Odds ratio*	*95% CI*	
						Lower	*Upper*
Age							
< 21	28		5.13	0.16			
21 – 24	29	-0.36	0.33	0.57	0.70	0.21	2.37
25 – 28	22	-0.01	0.00	0.99	0.99	0.29	3.35
29 >	17	1.15	2.40	0.12	3.15	0.74	13.45
Years Playing							
< 8	30		6.73	0.08			
8 – 12	26	-2.44	4.81	*0.03	0.09	0.01	0.77
13-17	30	-1.99	3.16	0.08	0.14	0.02	1.23
17 >	11	-1.46	1.68	0.19	0.23	0.03	2.10
Previous injury		-0.11	0.05	0.83	0.89	0.32	2.51

$*p<0.05$

Table 4.4. Logistic analysis of age, years playing rugby, previous injury history with incidence of all lower limb injuries

	N	*Regression coeffcient (B)*	*Chi-square*	*p-value*	*Odds ratio*	*95% CI*	
						Lower	*Upper*
Age							
< 21	28		1.57	0.67			
21 – 24	29	0.02	0.00	0.98	1.02	0.29	3.59
25 – 28	22	-0.04	0.00	0.96	0.97	0.28	3.39
29 >	17	0.61	0.84	0.36	1.83	0.50	6.72
Years Playing							
< 8	30		3.95	0.27			
8 – 12	26	-1.25	2.89	0.09	0.29	0.07	1.21
13-17	30	-1.37	3.27	0.07	0.25	0.06	1.12
17 >	11	-.83	1.29	0.26	0.44	0.10	1.82
Previous lower limb injury		.027	0.00	0.95	1.03	0.46	2.30

4.4.2 Anthropometric factors

The anthropometric factors that were analyzed include height, body mass, body mass index, and the sum of skin folds (Table 4.5 - Table 4.8). There was no significant difference between quartiles for all injuries (Table 4.5) and for lower limb injuries (Table 4.6) for height, body mass, the body mass index, and the sum of skin folds (p>0.05). In the logistic analysis of anthropometric variables no significant injury predictors were found (p>0.05)(Table 4.7-4.8).

Table 4.5: Anthropometric factors with injury incidence for all injuries

	Total hours	*Total Injuries*	*Injury rate per 1000 hours*	*Chi-square*	*sign.*
Height (m)					
<171.03	932.6	23	24.66		
171.03-175.2	1285.1	23	17.90		
175.3-177.9	991.3	22	22.19		
178 >	1163.00	24	20.64	1.13	p > 0.05
Body Mass (kg)					
<67.9	1249.20	25	20.01		
70-75	860.60	20	23.24		
75.1-83.1	970.30	23	23.70		
83.2 >	1205.00	25	20.75	0.45	p > 0.05
Body Mass Index (BMI)					
<22.65	1309.70	24	18.32		
22.66 – 24.10	1021.30	22	21.54		
24.11 – 27.97	1004.70	24	23.89		
27.98 >	1036.30	22	21.23	0.74	p > 0.05
Sum of Skinfolds (mm)					
<52.55	1193.70	22	18.43		
52.56 – 69.8	910	23	25.27		
69.91-90.40	868.10	21	24.19		
90.41>	1294.2	24	18.54	1.83	p > 0.05

Table 4.6 Anthropometric factors with injury incidence for lower limb injuries

	Total hours	*Total Injuries*	*Injury rate per 1000 hours*	*Chi-square*	*sign.*
Height (m)					
<171.03	523	12	22.94		
171.03-175.2	886.5	13	14.66		
175.3-177.9	817.7	15	18.34		
178 >	678.6	11	16.21	2.16	p > 0.05
Body Mass (kg)					
<67.9	723.3	12	16.59		
70-75	541.1	8	14.78		
75.1-83.1	626.1	14	22.36		
83.2 >	948.4	18	18.98	1.77	p > 0.05
Body Mass Index (BMI)					
<22.65	797.6	13	16.30		
22.66 - 24.10	278.8	6	21.52		
24.11 - 27.97	962.7	15	15.58		
27.98 >	866.7	17	19.61	1.29	p > 0.05
Sum of Skinfolds (mm)					
<52.55	659.3	10	15.17		
52.56 - 69.8	529.6	11	20.77		
69.91-90.40	780.2	15	19.23		
90.41>	971.7	17	17.50	0.96	p > 0.05

Table 4.7. Logistic analysis of anthropometric variables with incidence of all injuries

	N	*Regression coefficient (B)*	*Chi-square*	*p-value*	*Odds ratio*	*95% CI*	
						Lower	*Upper*
Sum of Skinfolds (mm)							
<52.55	22		4.66	0.19			
52.56 – 69.8	23	0.68	1.19	0.28	1.96	0.58	6.62
69.91-90.40	23	1.19	3.32	0.07	3.30	0.91	11.93
90.41>	23	0.00	0.00	1.00	1.00	0.31	3.18
Height (m)							
<171.03	23		2.49	0.48			
171.03-175.2	23	0.07	0.02	0.90	1.07	0.36	3.17
175.3-177.9	17	0.43	0.59	0.44	1.55	0.51	4.69
178 >	31	0.98	2.12	0.15	2.68	0.71	10.07
Body Mass (kg)							
<67.9	28		4.59	0.20			
70-75	13	0.61	1.27	0.26	1.85	0.63	5.38
75.1-83.1	28	1.57	3.41	0.07	4.81	0.91	25.52
83.2 >	30	0.01	0.00	0.99	1.01	0.36	2.84
Body Mass Index (BMI)							
<22.65	24		2.67	0.45			
22.66 – 24.10	15	0.20	0.12	0.73	1.22	0.39	3.80
24.11 – 27.97	29	1.08	2.02	0.16	2.93	0.67	12.95
27.98 >	26	-0.10	0.03	0.85	0.90	0.31	2.63

Table 4.8. Logistic analysis of anthropometric variables with incidence of all lower limb injuries

	N	*Regression coefficient (B)*	*Chi-square*	*p-value*	*Odds ratio*	*95% CI*	
						Lower	*Upper*
Sum of Skinfolds (mm)							
<52.55	22		4.66	0.19			
52.56 - 69.8	23	0.68	1.19	0.28	1.96	0.58	6.62
69.91-90.40	23	1.19	3.32	0.07	3.30	0.91	11.93
90.41>	23	0.00	0.00	1.00	1.00	0.31	3.18
Height (m)							
<171.03	23		4.13	0.25			
171.03-175.2	23	-0.09	0.02	0.89	0.92	0.29	2.95
175.3-177.9	17	0.48	0.71	0.40	1.62	0.53	4.93
178 >	31	1.09	3.09	0.08	3.00	0.88	10.21
Body Mass (kg)							
<67.9	28		2.07	0.56			
70-75	13	-0.32	0.35	0.55	0.73	0.25	2.09
75.1-83.1	28	0.42	0.40	0.53	1.53	0.41	5.64
83.2 >	30	-0.48	0.77	0.38	0.62	0.21	1.81
Body Mass Index (BMI)							
<22.65	24		1.57	0.67			
22.66 - 24.10	15	-0.36	0.38	0.54	0.70	0.23	2.17
24.11 - 27.97	29	-0.86	1.49	0.22	0.42	0.11	1.69
27.98 >	26	-0.19	0.13	0.72	0.82	0.28	2.39

4.4.3 Flexibility tests

There were no significant differences between the quartiles of the flexibility tests in terms of injury incidence rate for all rugby injuries and lower limb injuries ($p>0.05$). These flexibility tests include the slump test (Table 4.9- 4.10); the straight leg raise test (Table 4.13 - 4.14) and the sit and reach test (Table 4.17- 4.18). The multivariate regression analysis found no significant predictors for rugby injury or lower limb injury in terms of the slump test, straight leg raise test or the sit and reach test ($p>0.05$) (Table 4.11- 4.18).

Table 4.9 Slump test measurements with injury incidence for all injuries

	Total hours	*Total Injuries*	*Injury rate per 1000 hours*	*Chi-square*	*sign.*
R cervical flexion (cm)					
<1.00	1336.4	31	23.20		
1.10 - 4.89	942.5	17	18.04		
4.90 - 6.79	1284.3	28	21.80		
6.8 >	967	19	19.65	0.76	$p > 0.05$
R cervical extension (cm)					
<0.40	1204.1	27	22.42		
0.41 - 1.04	1073.5	21	19.56		
1.05 - 2.19	1366.5	27	19.76		
2.20 >	905.1	21	23.20	0.48	$p > 0.05$
L cervical flexion (cm)					
<1.05					
1.06 - 4.99	1210.6	30	24.78		
5.00 - 7.04	1325.4	27	20.37		
7.05 >	1109.1	22	19.84		
L cervical extension (cm)	904.1	17	18.80	1.00	$p > 0.05$
<0.20	1149.2	27	23.49		
0.21 - 0.79	1342.3	26	19.37		
0.80 - 1.69	1282.6	26	20.27		
1.70 >	775.10	17	21.93	0.47	$p > 0.05$

L left; R right

Table 4.10 Slump test measurements with injury incidence for lower limb injuries

	Total hours	*Total Injuries*	*Injury rate per 1000 hours*	*Chi-square*	*Sign.*
R cervical flexion (cm)					
<1.00	1018.1	23	22.59		
1.10 - 4.89	366.6	5	13.64		
4.90 - 6.79	927.2	16	17.26		
6.8 >	705.2	10	14.18	2.99	$p > 0.05$
R cervical extension (cm)					
<0.40	727.3	14	19.25		
0.41 - 1.04	886.9	16	18.04		
1.05 - 2.19	936.6	16	17.08		
2.20 >	466.3	8	17.16	0.17	$p > 0.05$
L cervical flexion (cm)					
<1.05	978.6	22	22.48		
1.06 - 4.99	659.2	11	16.69		
5.00 - 7.04	913.5	14	15.33		
7.05 >	465.8	7	15.03	2.09	$p > 0.05$
L cervical extension (cm)					
<0.20	720.7	14	19.43		
0.21 - 0.79	837.2	14	16.72		
0.80 - 1.69	879.2	16	18.20		
1.70 >	580	10	17.24	0.24	$p > 0.05$

L left; R right

Table 4.11 Logistic analysis of the slump test results with injury incidence of all injuries

	N	*Regression coefficient (B)*	*Chi-square*	*p-value*	*Odds ratio*	*95% CI*	
						Lower	*Upper*
R cervical flexion (cm)							
<1.00	24		2.83	0.42			
1.10 - 4.89	21	0.96	2.64	0.10	2.62	0.82	8.34
4.90 - 6.79	27	0.56	0.89	0.34	1.75	0.55	5.58
6.8 >	27	0.61	1.19	0.28	1.83	0.62	5.43
R cervical extension (cm)							
<0.40	26		3.27	0.35			
0.41 - 1.04	26	0.13	0.05	0.82	1.14	0.38	3.55
1.05 - 2.19	24	-0.34	0.35	0.56	0.71	0.23	2.18
2.20 >	24	0.76	1.48	0.22	2.14	0.63	7.33
L cervical flexion (cm)							
<1.05	24		3.00	0.39			
1.06 - 4.99	25	0.59	1.03	0.31	1.81	0.58	5.64
5.00 - 7.04	26	1.03	2.93	0.09	2.79	0.86	9.01
7.05 >	25	0.55	0.94	0.33	1.73	0.57	5.28
L cervical extension (cm)							
<0.20	25		3.90	0.27			
0.21 - 0.79	25	0.74	1.61	0.20	2.10	0.67	6.60
0.80 - 1.69	26	0.57	0.98	0.32	1.77	0.57	5.51
1.70 >	24	1.17	3.74	0.05	3.21	0.99	10.45

L left; R right

Table 4.12 logistic analyses of the slump test with injury incidence of all lower limb injuries

	N	*Regression coefficient (B)*	*Chi-square*	*p-value*	*Odds ratio*	*95% CI*	
						Lower	*Upper*
R cervical flexion (cm)							
<1.00	24		4.86	0.18			
1.10 - 4.89	21	0.86	2.21	0.14	2.36	0.76	7.34
4.90 - 6.79	27	-0.47	0.52	0.47	0.63	0.17	2.26
6.8 >	27	0.47	0.69	0.40	1.60	0.53	4.82
R cervical extension (cm)							
<0.40	26		2.49	0.48			
0.41 - 1.04	26	0.25	0.17	0.68	1.29	0.39	4.25
1.05 - 2.19	24	0.58	0.93	0.34	1.78	0.55	5.77
2.20 >	24	0.89	2.14	0.14	2.43	0.74	7.98
L cervical flexion (cm)							
<1.05	24		4.10	0.25			
1.06 - 4.99	25	1.15	3.44	0.06	3.17	0.94	10.70
5.00 - 7.04	26	0.58	0.85	0.36	1.78	0.52	6.09
7.05 >	25	0.99	2.67	0.10	2.71	0.82	9.00
L cervical extension (cm)							
<0.20	25		1.81	0.61			
0.21 - 0.79	25	0.12	0.04	0.85	1.12	0.35	3.65
0.80 - 1.69	26	0.12	0.04	0.85	1.12	0.35	3.65
1.70 >	24	0.69	1.41	0.24	2.00	0.64	6.29

L left; R right

Table 4.13 Straight leg raise measurements with injury incidence for all injuries

	Total hours	*Total Injuries*	*Injury rate per 1000 hours*	*Chi-square*	*Sign.*
R Dorsiflexion (°)					
<67.25	1248.5	22	17.62		
67.26 - 75.99	1001.9	20	19.96		
76.00 - 90.74	1105.5	30	27.14		
90.75 >	1193.3	24	20.11	2.40	p > 0.05
R Plantarflexion (°)					
<71.25	1264.3	24	18.98		
71.26 - 83.99	1056	25	23.67		
84 - 95.99	1029.7	24	23.31		
96 >	1199.2	23	19.18	0.92	p > 0.05
L Dorsiflexion (°)					
<70	1270	21	16.54		
70.1 - 80.9	1018	27	26.52		
81 - 94.9	969.1	21	21.67		
95 >	1292.1	27	20.90	2.34	p > 0.05
L Plantarflexion (°)					
<72	1373.3	29	21.12		
72.1 - 82.99	1173.3	27	23.01		
83 - 97.74	820.6	19	23.15		
97.75 >	1182	21	17.77	0.89	p > 0.05

R right; L left

Table 4.14 Straight leg raise measurements with injury incidence for lower limb injuries

	Total hours	*Total Injuries*	*Injury rate per 1000 hours*	*Chi-square*	*sign.*
R Dorsiflexion (°)					
<67.25	741.7	11	14.83		
67.26 - 75.99	721.7	11	15.24		
76.00 - 90.74	729	17	23.32		
90.75 >	824.7	15	18.19	2.57	p > 0.05
R plantarflexion (°)					
<71.25	824	14	16.99		
71.26 - 83.99	803.3	14	17.43		
84 - 95.99	596.1	13	21.81		
96 >	793.7	13	16.38	1.01	p > 0.05
L Dorsiflexion (°)					
<70	745.5	9	12.07		
70.1 - 80.9	937.1	21	22.41		
81 - 94.9	511.9	9	17.58		
95 >	822.6	15	18.23	3.08	p > 0.05
L plantarflexion (°)					
<72	919.7	15	16.31		
72.1 – 82.99	934.5	19	20.33		
83 - 97.74	521.4	9	17.26		
97.75 >	641.5	11	17.15	0.53	p > 0.05

R right; L left

Table 4.15 Logistic analysis of the straight leg raise test with injury incidence of all injuries

	N	*Regression coefficient (B)*	*Chi-square*	*p-value*	*Odds ratio*	*95% CI*	
						Lower	*Upper*
R Dorsiflexion (°)							
<67.25	28		0.51	0.92			
67.26 - 75.99	24	-0.34	0.34	0.56	0.71	0.23	2.22
76.00 - 90.74	25	-0.29	0.24	0.63	0.75	0.23	2.43
90.75 >	23	-0.05	0.01	0.93	0.95	0.29	3.10
R plantarflexion (°)							
<71.25	25		0.48	0.92			
71.26 - 83.99	27	0.07	0.01	0.91	1.07	0.33	3.41
84 - 95.99	24	-0.29	0.25	0.62	0.75	0.24	2.30
96 >	24	0.00	0.00	1.00	1.00	0.31	3.22
L Dorsiflexion (°)							
<70	26		2.62	0.46			
70.1 – 80.9	27	-0.12	0.04	0.84	0.89	0.28	2.85
81 - 94.9	22	-0.83	2.06	0.15	0.44	0.14	1.35
95 >	25	-0.19	0.09	0.75	0.82	0.25	2.76
L plantarflexion (°)							
<72	25		2.59	0.46			
72.1 – 82.99	27	0.32	0.26	0.61	1.37	0.40	4.66
83 - 97.74	25	-0.41	0.48	0.49	0.67	0.21	2.06
97.75 >	23	-0.55	0.86	0.36	0.58	0.18	1.85

R right; L left

Table 4.16 Logistic analysis of the straight leg raise test with incidence of all lower limb injuries

	N	*Regression coefficient (B)*	*Chi-square*	*p-value*	*Odds ratio*	*95% CI*	
						Lower	*Upper*
R Dorsiflexion (°)							
<67.25	28		0.82	0.85			
67.26 – 75.99	24	-0.49	0.69	0.41	0.62	0.19	1.93
76.00 – 90.74	25	-0.07	0.02	0.90	0.93	0.29	2.95
90.75 >	23	-0.14	0.06	0.81	0.87	0.28	2.73
R plantarflexion (°)							
<71.25	25		0.44	0.93			
71.26 - 83.99	27	-0.07	0.01	0.91	0.93	0.29	2.92
84 - 95.99	24	-0.04	0.00	0.95	0.93	0.32	2.94
96 >	24	-0.36	0.35	0.55	0.70	0.22	2.27
L Dorsiflexion (°)							
<70	26		1.28	0.73			
70.1 – 80.9	27	-0.39	0.47	0.49	0.67	0.22	2.09
81 - 94.9	22	0.02	0.00	0.97	1.02	0.34	3.05
95 >	25	-0.52	0.73	0.39	0.59	0.18	1.96
L plantarflexion (°)							
<72	25		1.28	0.73			
72.1 – 82.99	27	0.39	0.42	0.52	1.47	0.46	4.74
83 - 97.74	25	0.41	0.48	0.49	1.50	0.48	4.72
97.75 >	23	-0.13	0.04	0.84	0.88	0.27	2.93

R right; L left

Table 4.17 Sit and reach test results and injury incidence for all injuries and lower limb injuries

	Total hours	*Total Injuries*	*Injury rate per 1000 hours*	*Chi-square*	*Sign.*
Sit & Reach (cm) (all injuries)					
<23.5	950.6	21	22.09		
23.51 - 29.19	1192.4	22	18.45		
29.2 - 33.49	974.1	21	21.56		
33.50 >	1432.1	32	22.34	0.46	p > 0.05
Sit & Reach (cm) (lower limb injuries)					
<23.5	613.9	12	19.55		
23.51 - 29.19	753.6	12	15.92		
29.2 – 33.49	712.6	12	16.84		
33.50 >	937	18	19.21	0.53	p > 0.05

Table 4.18. Logistic analysis of the sit and reach test for all injuries and lower limb injuries

	N	Regression coefficient (B)	Chi-square	P-value	Odds ratio	95% CI	
						Lower	Upper
Sit & Reach (cm) (all injuries)							
<23.5	25		4.15	0.25			
23.51 - 29.19	26	-1.25	3.81	0.05	0.29	0.08	1.00
29.2 – 33.49	23	-0.87	1.80	0.18	0.42	0.12	1.49
33.50 >	24	-1.07	2.68	0.10	0.34	0.09	1.24
Sit and reach (cm) (lower limb injuries)							
<23.5	25		1.68	0.64			
23.51 - 29.19	26	-0.75	1.62	0.20	0.47	0.15	1.50
29.2 – 33.49	23	-0.47	0.67	0.41	0.63	0.20	1.92
33.50 >	24	-0.44	0.56	0.46	0.64	0.20	2.05

4.4.4 Concentric and eccentric hamstring and quadriceps strength

There were no significant differences between the quartiles of all the isokinetic variables of concentric and eccentric quadriceps and hamstring strength in terms of injury incidence for all rugby injuries and lower limb injuries (p>0.05) (Table 4.19 and 4.20). In the multivariate regression analysis the players with a dynamic ratio of the right leg of more than 1.087 were found to be at greater risk of rugby injury (p=0.05 95%CI 1.0-20.5) (Table 4.21). The logistic analysis found that players with between 159.1 and 187.99 N.m torque (p=0.02 95%CI 0.05-0.80) and between 188 and 211.58 Nm torque (p=0.01 95%CI 0.05-0.07) of the right concentric quadriceps contraction had a significantly greater risk of a lower limb rugby injury (Table 4.22). The players with between 150.1 and 174.9 Nm torque (p=0.03

95%CI 0.05-0.87) and less than 150 Nm torque (p=0.03) of the right eccentric hamstring contraction had a greater risk of a lower limb injury (Table 4.22).

Table 4.19 Concentric and eccentric hamstring and quadriceps strength with injury incidence of all injuries

	Total hours	*Total Injuries*	*Injury rate per 1000 hours*	*Chi-square*	*sign.*
R Con. Quad (N.m)					
<159	826.6	16	19.36		
159.1 – 187.99	1031.2	21	20.36		
188-211.58	924.2	22	23.80		
211.59>	956.7	22	23.00	0.62	p > 0.05
L Con. Quad (N.m)					
<156	924.5	24	25.96		
156.1 – 191.99	990.2	17	17.17		
192 – 219.99	968.9	19	19.61		
220>	855.1	21	24.56	2.34	p > 0.05
R Con. Ham (N.m)					
<107.25	1033.4	20	19.35		
107.26 - 122.99	834.2	18	21.58		
123 – 141.24	828.5	22	26.55		
141.25>	976	20	20.49	1.37	p > 0.05
L Con. Ham (N.m)					
<102.5	910.9	20	21.96		
102.6 – 123.99	754.7	14	18.55		
124 – 131.99	1202.4	28	23.29		
132>	870.7	19	21.82	0.57	p > 0.05
R Ecc. Quad (N.m)					
<221.5	924	16	17.32		
221.6 – 263.99	955.9	18	18.83		
264 – 303.4	1165.1	27	23.17		
303.5 >	693.7	20	28.83	3.63	p > 0.05
L Ecc. Quad (N.m)					
<214.5	1081.8	22	20.34		
214.6 – 277.99	882.1	18	20.41		
278 – 308.99	1018.7	24	23.56		
309 >	756.1	17	22.48	0.35	p > 0.05
R Ecc. Ham (N.m)					
<150	744.4	13	17.46		
150.1 – 174.99	1061.5	22	20.73		
175 – 197.99	1163.9	29	24.92		
198 >	768.9	17	22.11	1.35	p > 0.05
L Ecc. Ham (N.m)					
<142	935.4	16	17.11		
142.1 – 167.99	989.1	23	23.25		
168 – 202.99	719.1	15	20.86		
203 >	1095.1	27	24.66	1.52	p > 0.05
R dynamic ratio					
<0.80	1177	22	18.69		
0.81 – 0.99	656.6	13	19.80		
1 – 1.086	1010.8	30	29.68		
1.087 >	894.3	16	17.89	4.22	p > 0.05
L dynamic ratio					
<0.80	1406.8	26	18.48		
0.81 – 0.89	789.2	15	19.01		
0.90 – 1.09	666.8	22	32.99		
1.10 >	875.9	18	20.55	6.24	p > 0.05

Table 4.20. Concentric and eccentric hamstring and quadriceps strength with injury incidence for lower limb injuries

	Total hours	Total Injuries	Injury rate per 1000 hours	Chi-square	sign.
R Con. Quad (N.m)					
<159	477.2	9	18.86		
159.1 – 187.99	542.6	8	14.74		
188-211.58	539.3	11	20.40		
211.59>	849.5	16	18.83	0.97	$p > 0.05$
L Con. Quad (N.m)					
<156	550.8	11	19.97		
156.1 – 191.99	506.5	7	13.82		
192 - 219.99	792	14	17.68		
220>	559.3	12	21.46	1.82	$p > 0.05$
R Con. Ham (N.m)					
<107.25	491.1	7	14.25		
107.26 – 122.99	688.7	11	15.97		
123 - 141.24	571	14	24.52		
141.25>	591.2	11	18.61	3.30	$p > 0.05$
L Con. Ham (N.m)					
<102.5	488.6	10	20.47		
102.6 – 123.99	482.9	7	14.50		
124 - 131.99	773.2	14	18.11		
132>	663.9	13	19.58	1.14	$p > 0.05$
R Ecc. Quad (N.m)					
<221.5	487.3	8	16.42		
221.6 – 263.99	584.2	9	15.41		
264 - 303.4	687.6	14	20.36		
303.5 >	649.5	13	20.02	1.05	$p > 0.05$
L Ecc. Quad (N.m)					
<214.5	830.7	11	13.24		
214.6 – 277.99	215.5	5	23.20		
278 - 308.99	733.1	16	21.83		
309 >	629.3	12	19.07	3.02	$p > 0.05$
R Ecc. Ham (N.m)					
<150	281.9	4	14.19		
150.1 – 174.99	519.1	9	17.34		
175 - 197.99	952.9	19	19.94		
198 >	654.7	12	18.33	1.01	$p > 0.05$
L Ecc. Ham (N.m)					
<142	539.2	7	12.98		
142.1 – 167.99	705.9	13	18.42		
168 - 202.99	445.9	9	20.18		
203 >	717.6	15	20.90	2.12	$p > 0.05$
R Dynamic ratio					
<0.80	568.5	9	15.83		
0.81 – 0.99	405.8	6	14.79		
1 - 1.086	714.9	17	23.78		
1.087 >	719.4	12	16.68	2.81	$p > 0.05$
L Dynamic ratio					
<0.80	698.7	11	15.74		
0.81 – 0.89	723.3	12	16.59		
0.90 – 1.09	475.5	12	25.24		
1.10 >	511.1	9	17.61	3.04	$p > 0.05$

R, right; L, left; Quad, quadriceps muscle; Ham, Hamstring muscle; Con, concentric torque; Ecc, eccentric torque

Table 4.21 Logistic analysis of concentric and eccentric hamstring and quadriceps strength with injury incidence of all injuries

	N	Regression coefficient (B)	Chi-square	p-value	Odds ratio	95% CI Lower	95% CI Upper
R Con. Quad							
<159	21		2.28	0.52			
159.1 – 187.99	22	-1.00	2.20	0.14	0.37	0.09	1.38
188-211.58	20	-0.73	1.18	0.28	0.48	0.13	1.81
211.59>	20	-0.69	1.01	0.32	0.50	0.13	1.93
L Con. Quad							
<156	22		1.07	0.79			
156.1 – 191.99	21	-0.67	1.05	0.31	0.52	0.14	1.84
192 – 219.99	20	-0.36	0.29	0.59	0.69	0.19	2.56
220>	20	-0.44	0.44	0.51	0.64	0.17	2.38
R Con. Ham							
<107.25	22		2.76	0.43			
107.26 – 122.99	21	-0.09	0.02	0.89	0.92	0.25	3.41
123 – 141.24	19	-0.94	2.07	0.15	0.39	0.11	1.45
141.25>	20	-0.53	0.62	0.43	0.59	0.16	2.22
L Con. Ham							
<102.5	21		2.61	0.46			
102.6 – 123.99	22	-0.49	0.54	0.46	0.62	0.178	2.25
124 – 131.99	21	-0.77	1.41	0.24	0.46	0.13	1.66
132>	19	0.14	0.04	0.84	1.15	0.29	4.47
R Ecc. Quad							
<221.5	21		3.56	0.31			
221.6 – 263.99	22	-0.63	0.97	0.33	0.53	0.15	1.88
264 – 303.4	21	-0.17	0.07	0.79	0.84	0.24	2.98
303.5 >	19	0.62	0.79	0.37	1.87	0.47	7.35
L Ecc. Quad							
<214.5	21		0.71	0.87			
214.6 – 277.99	22	-0.05	0.01	0.94	0.95	0.26	3.42
278 – 308.99	21	-0.36	0.31	0.58	0.70	0.20	2.45
309 >	19	0.15	0.05	0.82	1.17	0.32	4.28
R Ecc. Ham							
<150	21		3.56	0.31			
150.1 – 174.99	22	-0.63	0.97	0.33	0.53	0.15	1.89
175 – 197.99	21	-0.17	0.07	0.79	0.84	0.24	2.98
198 >	19	0.62	0.79	0.37	1.87	0.05	7.35
L Ecc. Ham							
<142	21		3.17	0.37			
142.1 – 167.99	21	-1.00	2.20	0.14	0.37	0.09	1.38
168 – 202.99	21	-0.41	.34	0.56	0.67	0.17	2.59
203 >	20	-1.00	2.20	0.14	0.37	0.09	1.38
R Dynamic ratio							
<0.80	28		4.79	0.19			
0.81 - 0.99	16	0.34	0.34	0.56	1.41	0.45	4.41
1 - 1.086	18	-0.09	0.02	0.89	0.91	0.25	3.34
1.087 >	21	1.51	3.88	***0.05**	4.55	1.01	20.50
L Dynamic ratio							
<0.80	36		2.87	0.41			
0.81 - 0.89	13	-0.65	1.08	0.30	0.52	0.15	1.79
0.90 - 1.09	17	0.33	0.15	0.69	1.39	0.26	7.29
1.10 >	17	-0.76	1.11	0.29	0.47	0.11	1.93

R, right; L, left; Quad, quadriceps muscle; Ham, Hamstring muscle; Con, concentric torque; Ecc, eccentric torque

$^*p \leq 0.05$

Table 4.22 Logistic analysis of concentric and eccentric hamstring and quadriceps strength with injury incidence of lower limb injuries

	N	Regression coefficient (B)	Chi-square	p-value	Odds ratio	95% CI Lower	95% CI Upper
R Con. Quad							
<159	21		7.49	0.06			
159.1 - 187.99	22	-1.54	5.20	***0.02**	0.22	0.06	0.81
188-211.58	20	-1.60	5.70	***0.01**	0.20	0.05	0.75
211.59>	20	-1.24	3.49	0.06	0.290	0.08	1.06
L con. Quad							
<156	22		2.83	0.42			
156.1 - 191.99	21	-0.78	1.41	0.24	0.46	0.13	1.66
192 - 219.99	20	-0.49	0.58	0.45	0.61	0.17	2.16
220>	20	0.20	0.10	0.75	1.22	0.35	4.24
R Con. Ham							
<107.25	22		1.60	0.66			
107.26 – 122.99	21	-0.78	1.41	0.24	0.46	0.13	1.66
123 - 141.24	19	-0.29	0.20	0.65	0.75	0.23	2.61
141.25>	20	-0.12	0.03	0.86	0.89	0.25	3.16
L Con. Ham							
<102.5	21		4.28	0.23			
102.6 - 123.99	22	-1.02	2.35	0.13	0.36	0.09	1.33
124 – 131.99	21	-1.09	2.68	0.10	0.34	0.09	1.24
132>	19	-0.20	0.10	0.75	0.82	0.24	2.84
R Ecc. Quad							
<221.5	21		3.59	0.31			
221.6 - 263.99	22	-1.27	3.39	0.07	0.28	0.07	1.08
264 – 303.4	21	-0.67	1.09	0.29	0.51	0.15	1.79
303.5 >	19	-0.39	0.38	0.54	0.68	0.19	2.35
L Ecc. Quad							
<214.5	21		4.95	0.18			
214.6 - 277.99	22	-0.18	8.08	0.78	0.83	0.24	2.90
278 – 308.99	21	-1.39	3.78	0.05	0.25	0.06	1.01
309 >	19	0.01	0.00	0.99	1.01	0.29	3.50
R Ecc. Ham							
<150	21		8.66	***0.03**			
150.1 - 174.99	22	-1.55	4.63	***0.03**	0.21	0.05	0.87
175 - 197.99	21	-1.09	2.68	0.10	0.34	0.09	1.24
198 >	19	0.18	0.08	0.78	1.20	0.34	4.18
L Ecc. Ham							
<142	21		2.36	0.50			
142.1 - 167.99	21	-0.92	1.94	0.16	0.40	0.11	1.45
168 - 202.99	21	-0.29	0.21	0.65	0.75	0.22	2.57
203 >	20	-0.69	1.16	0.29	0.50	0.14	1.77
R Dynamic ratio							
<0.80	28		3.79	0.29			
0.81 - 0.99	16	-0.63	1.07	0.30	0.53	0.16	1.76
1 - 1.086	18	-0.50	0.52	0.47	0.61	0.16	2.37
1.087 >	21	0.51	0.62	0.43	1.67	0.47	5.93
L Dynamic ratio							
<0.80	36		6.37	0.09			
0.81 - 0.89	13	-0.59	0.94	0.33	0.55	0.16	1.84
0.90 - 1.09	17	1.17	2.26	0.13	3.21	0.70	14.74
1.10 >	17	-0.25	0.12	0.72	0.78	0.19	3.12

R, right; L, left; Quad, quadriceps muscle; Ham, Hamstring muscle; Con, concentric torque; Ecc, eccentric torque

***p<0.05**

4.4.5 Strength endurance; agility; aerobic fitness; vertical jump

There were no significant differences between the quartiles for strength endurance in terms of the sit-ups and push-ups tests in relation to injury incidence for any rugby injury or a lower limb injury (p>0.05) (Table 4.23-4.24). The multivariate regression analysis found that a player who performed less than 32 repetitions (p=0.03) or between 32 and 40 repetitions (p=0.01 95%CI 0.04-0.59) on the push-up test were at greater risk of a rugby injury (Table 4.25). The multivariate analysis found that the player who performed between 46 and 60 repetitions on the sit-up test was found to be at a greater risk of a lower limb injury (p=0.01 95%CI 0.03-0.62)(Table 4.26). There were no significant differences between quartiles in terms of agility and injury incidence for any rugby injury or for a lower limb injury (p> 0.05) (Table 4.23 - 4.24). However, the multivariate analysis did show a significant predictor for rugby injury for players who had completed the agility test in between 15.91 and 16.39sec (p=0.01 95%CI 1.48-18.66) and between 16.4 and 16.89sec (p=0.03 95%CI 1.16-13.86)(Table 4.25). Players who had completed the agility test between 16.4 and 16.89 seconds (p=0.04 95%CI 1.06-16.03) or more than 16.89sec (p=0.02 95%CI 1.29-18.15) were at greater risk of a lower limb injury (Table 4.26). There were no significant differences between the quartiles in terms of the multistage shuttle run (bleep) test and vertical jump in relation to injury incidence for any rugby injury or for lower limb injury (p>0.05) (Table 4.23- 4.24). The multivariate regression analysis did not find any predictors for rugby injury or lower limb injury in terms of the vertical jump and multistage shuttle run (bleep) tests results (p>0.05) (Table 4.25-4.26).

Table 4.23 Strength endurance; agility; aerobic fitness; vertical jump with injury incidence for all injuries

	Total hours	*Total Injuries*	*Injury rate per 1000 hours*	*Chi-square*	*Sign.*
Sit-ups (rep)					
<45.75	894.2	18	20.13		
45.76 - 59.99	1260.9	20	15.86		
60 - 69.99	1312.8	26	19.81		
70 >	972.3	30	30.85	5.72	$p > 0.05$
Push ups (rep)					
<32	917.4	16	17.44		
32.1 - 39.99	1137.6	28	24.61		
40 - 46.99	1083.9	18	16.61		
47 >	1251	32	25.58	3.13	$p > 0.05$
Agility (sec)					
<15.9	1366	30	21.96		
15.91 - 16.39	1144.5	28	24.46		
16.4 - 16.89	1295.9	25	19.29		
16.9 >	564.9	10	17.70	1.28	$p > 0.05$
Bleep (no)					
<62.5	870.5	17	19.53		
62.51 - 78.99	1185.8	26	21.93		
79 - 93.49	866.3	18	20.78		
93.5 >	1151.6	28	24.31	0.57	$p > 0.05$
Vertical Jump (cm)					
<43.35	946.9	21	22.18		
43.36 - 47.24	1158.5	21	18.13		
47.25 - 51.19	929.8	19	20.43		
51.2 >	889.5	23	25.86	1.47	$p > 0.05$

Table 4.24 Strength endurance; agility; aerobic fitness; vertical jump with injury incidence for lower limb injuries

	Total hours	*Total Injuries*	*Injury rate per 1000 hours*	*Chi-square*	*sign.*
Sit-ups (rep)					
<45.75	282.4	6	21.25		
45.76 - 59.99	898.9	13	14.46		
60 - 69.99	945.4	14	14.81		
70 >	800.4	20	24.99	4.19	p > 0.05
Push ups (rep)					
<32	557.8	7	12.55		
32.1 – 39.99	730	17	23.29		
40 - 46.99	856.5	12	14.01		
47 >	713.5	16	22.42	5.16	p > 0.05
Agility (sec)					
<15.9	736.8	14	19.00		
15.91 - 16.39	847.6	16	18.88		
16.4 – 16.89	1122.3	18	16.04		
16.9 >	220.4	5	22.69	1.16	p > 0.05
Bleep (no)					
<62.5	533.7	11	20.61		
62.51 - 78.99	767.3	13	16.94		
79 - 93.49	605.5	12	19.82		
93.5 >	794.5	14	17.62	0.49	p > 0.05
Vertical Jump (cm)					
<43.35	611.5	13	21.26		
43.36 - 47.24	811.7	14	17.25		
47.25 - 51.19	610.6	9	14.74		
51.2 >	506.7	10	19.74	1.35	p > 0.05

Table 4.25 Logistic analysis of strength endurance, agility, aerobic fitness, vertical jump with injury incidence of all injuries

	N	Regression coefficient (B)	Chi-square	P-value	Odds ratio	95% CI	
						Lower	Upper
Sit-ups (rep)							
<45.75	25		3.12	0.37			
45.76 - 59.99	23	-0.93	2.16	0.14	0.39	0.12	1.36
60 – 69.99	27	-0.02	0.00	0.98	0.98	0.27	3.61
70 >	20	-0.32	0.25	0.62	0.73	0.21	2.50
Push ups (rep)							
<32	28		8.69	***0.03**			
32.1 – 39.99	21	-1.85	7.59	***0.01**	0.16	0.04	0.59
40 – 46.99	21	-0.64	0.77	0.38	0.53	0.13	2.21
47 >	23	-1.07	2.28	0.13	0.34	0.09	1.38
Agility (sec)							
<15.9	24		7.81	0.05			
15.91 - 16.39	23	1.66	6.57	***0.01**	5.25	1.48	18.66
16.4 – 16.89	27	1.39	4.78	***0.03**	4.00	1.16	13.86
16.9 >	22	1.09	3.35	0.07	2.98	0.93	9.57
Bleep (no.)							
<62.5	24		4.85	0.18			
62.51 - 78.99	26	-1.32	3.62	0.06	0.27	0.07	1.04
79 – 93.49	22	-0.69	0.97	0.33	0.50	0.13	1.98
93.5 >	19	-1.32	3.51	0.06	0.27	0.07	1.06
Vertical Jump (cm)							
<43.35	20		1.21	0.75			
43.36 - 47.24	20	-0.15	0.05	0.82	0.86	0.23	3.26
47.25 - 51.19	26	-0.15	0.05	0.82	0.86	0.23	3.26
51.2 >	19	-0.62	0.96	0.33	0.54	0.16	1.86

Table 4.26 Logistic analysis of strength endurance, agility, aerobic fitness, vertical jump with incidence of all lower limb injuries

	N	Regression coefficient (B)	Chi-square	p-value	Odds ratio	95% CI	
						Lower	Upper
Sit-ups (rep)							
<45.75	25		7.73	0.05			
45.76 - 59.99	23	-1.86	6.92	***0.01**	0.16	0.04	0.62
60 – 69.99	27	-0.29	0.22	0.64	0.75	0.23	2.49
70 >	20	-0.42	0.51	0.48	0.66	0.21	2.09
Push ups (rep)							
<32	28		3.64	0.30			
32.1 – 39.99	21	-0.84	1.90	0.17	0.43	0.13	1.42
40 - 46.99	21	0.17	0.08	0.78	1.18	0.36	3.88
47 >	23	0.17	0.08	0.78	1.18	0.36	3.88
Agility (sec)							
<15.9	24		6.11	0.11			
15.91 - 16.39	23	0.99	2.04	0.15	2.70	0.69	10.55
16.4 – 16.89	27	1.42	4.19	***0.04**	4.13	1.06	16.03
16.9 >	22	1.58	5.49	***0.02**	4.85	1.29	18.15
Bleep (no)							
<62.5	24		0.94	0.82			
62.51 – 78.99	26	-0.59	0.87	0.35	0.56	0.16	1.92
79 – 93.49	22	-0.37	0.36	0.55	0.69	0.21	2.30
93.5 >	19	-0.45	0.51	0.48	0.64	0.18	2.22
Vertical Jump (cm)							
<43.35	20		0.56	0.91			
43.36 - 47.24	20	0.13	0.04	0.84	1.14	0.314	4.16
47.25 - 51.19	26	0.34	0.27	0.61	1.40	0.39	5.06
51.2 >	19	-0.09	0.02	0.88	0.91	0.26	3.12

***p<0.05**

4.5 Discussion

4.5.1 Age; years playing rugby; previous injury

4.5.1a Age

This study did not find age to be a significant predictor for rugby injury. The quartile with players aged less than 21 years had the highest injury incidence rate of rugby injuries (25.43 injuries /1000 hours) (Table 4.1) and for lower limb injuries (21.15 injuries/1000 hours) (Table 4.2). This was however not statistically significant ($p>0.05$). This finding may not be statistically significant but it supports the findings of the prospective New Zealand study that found that an age between 20 and 22 had greater risk of injury in rugby ($p<0.01$)[57]. This study also found players aged 23 and older were at greater risk of rugby injury[57]. These findings are not conclusive and studies with larger samples need to confirm age as a risk factor for injury in rugby. The confounding variable would be level of experience and skill and years of participation in rugby. The younger player could be more at risk to injury due to his inexperience or lack of skill. The younger may also play at a higher intensity or have a greater "will to win" than more experienced players. The older player could be at greater risk with previous injury history and physical fitness as confounding variables. A study that investigated risk factors for training-related injuries among men and women in basic combat training did not find age to be a significant predictor for injury ($p>0.05$)[87]. To date, there is no conclusive evidence to suggest age as a significant predictor for rugby injury.

4.5.1b Years of participation in rugby

There was no significance found between years of rugby participation and injury incidence. The players with 8-12 years of rugby participation had the highest injury incidence was for all rugby injuries and for lower limb injuries but it was not significant ($p>0.05$) in the univariate analysis (Table 4.1 and 4.2). In the multivariate analysis players with between 8 and 12 years rugby participation were a greater risk of rugby injury ($p=0.02$) (Table 4.3). This does not support other findings, as the years of rugby participation was not found to be a significant predictor of injury incidence in rugby ($p>0.05$)[57]. In the New Zealand study players with 4-5 years of rugby participation missed less play due to injury during the season than players with 3 or less years of rugby participation ($p=0.02$)[57]. This was confirmed in the multivariate analysis ($p<0.01$)[57]. It has been postulated that the experienced player is better conditioned for the game and would therefore return from injury sooner than the inexperienced player. The confounding variable with the experienced player would be previous injury status. To date, there is no conclusive evidence to suggest that the years of participation in rugby is a significant predictor of injury in rugby.

4.5.1c Previous injury history

In this cohort previous injury was not found to be a significant risk factor for injury in rugby or for a lower limb rugby injury ($p>0.05$) (Table 4.1 and 4.2). This does not support the findings of the New Zealand study, which found that players with a preseason injury were at greater risk ($p<0.01$) of sustaining injury than players who had no injuries in the previous 12 months[57]. This was confirmed by the findings of another study that found a 61% relative increase risk of injury for players who had been injured in the preseason or carried a injury from the previous season[58]. The current study did not classify players with injuries at the time of preseason testing as a previous injury but it was classified as current injuries. These preseason injuries were not included in this previous injury variable. The theory is that previous lower limb injuries may be a risk factor for subsequent lower limb injuries. Inadequate rehabilitation, weakness, inflexibility and changes in the biomechanical factors could all be related to a previous lower limb injury. The limitation of the New Zealand study is that muscle strength and flexibility were not tested in this cohort and could therefore not be confirmed as possible confounding variables in the multivariate analysis. The current study's failure to identify a history of a previous injury, as a significant risk factor could be valid or the sample size of this cohort was too small.

It was reported that the history of a previous injury (OR=9.41 95%CI2.80-31.58) is a risk factor for the occurrence of sport injuries in young people[88]. However, this is influenced by the personality trait dominance[88]. It was found that subjects with a high dominance score had a significantly smaller chance of sustaining an injury as a result of a previous injury compared to the person who had a less dominant personality[88].

There is conflicting evidence with regard to history of a previous injury being a significant risk factor for rugby injury. There is also evidence to suggest that a dominant personality trait may reduce an athlete with a previous injury, risk of sustaining another injury.

4.5.2 Anthropometric factors: height, body mass, BMI, sum of skinfolds

4.5.2a Height

This study supports the findings of the New Zealand study where height was not a significant risk factor for rugby injury incidence. In another study involving combat trainers stature of the subjects was not identified as a risk factor for injury[87]. In the current study the highest injury incidence was in the quartile of players with a height less than 171.03 cm for all rugby injuries (24.66 injuries/1000hours) ($p>0.05$)(Table 4.5) and for lower limb injuries (22.94 injuries/1000 hours) ($p>0.05$) (Table 4.6). This could demonstrate that being too short may increase the chances of sustaining a rugby injury but this was not confirmed. In club rugby players it was found that the injured forwards were on average taller than the non-injured forwards (183.0cm versus 181.1cm) but this was not statistically significant[89]. The injured backs were also on average taller than the non-injured backs (180.0cm versus 178.3cm) but it was not statistically significant[89]. To date there is no conclusive evidence to suggest that height is a significant risk factor for injury in rugby.

4.5.2b Body mass

The players with a body mass of between 75.1 and 83.1kg had the highest incidence of injury (22.36 injuries/1000 hours) for lower limb injuries (Table 4.6) and but this was not statistically significant. In the New Zealand study, players with a body mass of greater than 81kg had a higher injury incidence rate compared with players with a body mass less than 74kg, but it was not statistically significant[57]. The body mass of combat trainers was not found to be a significant predictor of injury[87]. The players with a body mass of between 75.1and 83.1kg were associated with an increased injury incidence. The confounding variables would be position of play and physical fitness. The positions of play with a higher body mass may be involved in more body contact and tackles, which is the most dangerous phase of play. Physical fitness also plays a role with body mass and the amount of power the player can generate i.e. the bigger and faster player may have an increased risk of lower limb injury. The significance of this finding needs to be confirmed by future studies as it may be due to chance. In club rugby players it was found that the injured forwards were on average heavier than the non-injured forwards (95.2kg versus 90.8kg) and injured backs were on average heavier than the non-injured backs (83.7kg versus 81.9kg) but these differences were not statistically significant[89]. However, there is no evidence to identify body mass as a significant risk factor for rugby injury.

4.5.2c Body Mass Index (BMI)

There was no significant relationship between BMI and injury risk. The New Zealand study found that players with a BMI of greater than 26.5 sustained more injuries than the reference group with a BMI of less than 23[57]. In multivariate analysis of the New Zealand study it was found that the players who have a BMI was less than 23 had a higher risk of missing a proportion of the rugby season due to injury ($p<0.01$)[57]. In the study of combat trainers BMI was not found to influence the time lost to training as a result of injury[87]. In a study that investigated the risk factors for sport injuries in young people it was reported that BMI was not a significant predictor ($p>0.05$)[88]. The Croatian study of club rugby players found the injured forwards to have a larger BMI in comparison to the non-injured forwards (28.7 versus 27.9) while injured and non-injured backs had the same BMI[89]. There are other studies that found that the players who had reported injuries had an age adjusted mean BMI of 25.4 compared with non-injured players who had an age adjusted mean BMI of 24.6[90]. However, in this study[90] the BMI was not measured but self-reported. The confounding variable for BMI would be the level of play and position of play as it could indicate the number of tackles the player is involved in. However, there is no conclusive evidence to suggest that BMI is a significant risk factor for rugby injury.

4.5.2d Sum of skinfolds

This study supports the findings of the New Zealand study that did not find the calculation of sum of skinfolds as a significant risk factor for rugby injury[57]. The Croatian study of club rugby players found that injured forwards had on average a greater body fat percentage (21.0% versus 20.5%) while injured backs had on average a lower body fat percentage in comparison to non-injured backs[89]. It has not been confirmed if subcutaneous fat tissue and other anthropometric characteristics represent risk factors or protective factors in contact sports[89].

4.5.3 Flexibility measurements

4.5.3a The slump test

The slump test assessed the amount of pain experienced by the player in cervical flexion versus cervical extension with both the right leg and the left leg. The visual analog scale results were used in the analysis. No trends were obvious with respect to the visual analog scale recordings of the slump test and injury incidence in relation to all rugby injuries. The results with regard to lower limb injuries revealed an inverse relationship between the visual analog scale results and injury incidence. The players with the least pain during the slump test had the highest lower limb injury incidence rate (Table 4.10). No other studies used the slump test to predict risk of rugby injuries. The one study that involved the slump test found that it might be involved in repeated grade 1 hamstring strains in rugby players[10]. There is however, no conclusive evidence to identify the results of a slump test as a risk factor for injury in rugby.

4.5.3b The straight leg raise test

There was no significance between range of motion during the straight leg raise test and injury incidence for all rugby injuries (Table 4.13) and for lower limb injuries (Table 4.14). There are no studies that have used the straight leg raise test to identify risk factors for rugby injury. The straight leg raise was one of the tests that were used to identify risk factors for muscle injuries in soccer players[11]. In this study it was found that soccer players who had less than 90 degrees of hip range of motion on the straight leg raise test had a higher risk of sustaining a hamstring strain ($p=0.02$)[11]. This finding applied to players who not had any previous hamstring injuries. There is no evidence to suggest that decreased range of motion on the straight leg raise test is a risk factor for rugby injury or a lower limb injury. However, soccer players who had no previous muscle injuries and less than 90 degrees of hip range of motion on the straight leg raise test had a higher risk of sustaining a hamstring injury.

4.5.3c The sit and reach test

This study did not reveal any trends in terms of the sit and reach test results and risk for rugby injury. The players who could reach the furthest, i.e. greater then 33.5cm had the highest incidence for rugby injury ($p>0.05$) (Table 4.17). The players in the quartile with the least flexibility could reach less than 23cm and had the highest injury incidence for lower limb injuries but it was not statistically significant ($p>0.05$). There were no significant predictors for rugby injury identified in the multivariate analysis. It could be that the sample size was too small. The sit and reach test was used to determine risk factors associated with hamstring injuries in Australian Rules footballers and it was not found to be a significant predictor test[7;8]. The male combat trainers were found to be at risk of injury if they had the highest or the lowest results on the sit and reach test[87]. The sit and reach had not been used in a study, which involved rugby players. At present, there is no evidence to suggest that the results on the sit and reach test can be used a predictor for injury in rugby.

4.5.4 Concentric and eccentric hamstring and quadriceps strength

There was no relationship between the different isokinetic variables as predictors for rugby injury or lower limb injury. In all of the variables with the exception of 2 variables (left concentric quadriceps strength -Table 4.15 and left concentric hamstring strength- Table 4.16) the third quartile had the highest injury incidence rate ($p>0.05$). In the logistic analysis the players with a dynamic ratio (concentric quadriceps and eccentric hamstrings) of greater than 1.087 were found to be at greater risk of an injury in rugby ($p=0.05$) (Table 4.21). The dynamic ratio was particularly designed to test imbalances between the quadriceps and hamstrings that could indicate predisposition to injury[91]. However the evidence to indicate validity of this ratio for injury prediction is sparse. It was postulated that a dynamic ratio less than 1.0 could increase hamstring injury risk[7]. This will be discussed in chapter five.

The logistic analysis found that a right concentric quadriceps peak torque of between 159.1- 187.99 Nm ($p=0.02$) and between 188 -211.58 Nm ($p=0.01$) was a significant predictor of a lower limb injury in rugby ($p=0.02$)(Table 4.22). These were not the strongest players of the quartiles but rather the weaker players. The logistic analysis also showed that players who had a right eccentric hamstring contraction of less than 150 Nm or between 150.1 and 174.99 Nm torque were at greater risk of a lower limb injury in rugby ($p=0.03$) (Table 4.22). These findings support the results of some studies that have identified isokinetic weakness as a risk factor for hamstring injury[7;9;6;4]. The studies that have identified isokinetic muscle weakness as a risk factor were investigating hamstring injuries and it was not done on rugby players[7;9;6;4]. Findings from the present study's findings support the hypothesis that weak concentric quadriceps or weak eccentric hamstring strength or imbalance (as identified by the dynamic ratio) places players at greater risk of injury of a lower limb injury. Since these findings were not consistently shown in all the analyses of the current study future studies with a larger sample are needed to confirm this.

In conclusion, it can be documented that there is some evidence to suggest that weak concentric quadriceps or weak eccentric hamstring strength can be used as a predictor for lower limb injury in rugby.

4.5.5 Strength endurance, agility, aerobic fitness, vertical jump

4.5.5a Strength endurance: the 2- minute sit-up test

There were no significant findings with regard to sit-ups and prediction of injury in rugby. It was found that the players who performed more than 70 sit-ups had the highest injury incidence for any rugby injury (Table 4.18) and for lower limb injuries (Table 4.18). This means that the players who performed the best in the sit-up test had the highest injury incidence which could once again demonstrate that the players with the better physical conditioning may be at more risk of injury but confounding variables have to be considered. However the multivariate analysis showed that a poor performance of between 46 and 60 repetitions on the sit-up test placed the player at risk of a lower limb injury (p=0.01)(Table 4.26). This could indicate that players on either end of the spectrum i.e. the best physically conditioned or the worst physically conditioned players could be at risk of injury. There are no other studies that used the (2minute) sit-up test as a predictor for rugby injury or specifically for lower limb injuries. The sit-up test was included in the protocol of a study that aimed at identifying risk factors for hamstring injury in Australian Rules footballers[7]. The performance of a player on the sit-up test was not found to have any predictor value for hamstring injury[7]. The performance of combat trainers on the sit up test was not found to influence the trainer's risk of injury or time that might be lost from training due to injury[87].

There is no conclusive evidence to indicate that the results on the sit-up test can be used as a predictor for rugby or more specifically for lower limb injury.

4.5.5b Strength endurance: the 1-minute push-up test

It was found that the players who performed more than 47 repetitions during the push-up test had the highest injury incidence rate for any rugby injury but it was not statistically significant ($p>0.05$) (Table 4.23). The players who performed between 32.10 and 39.99 repetitions had a 0.77 higher incidence rate of lower limb injuries than those who performed more than 47 repetitions (Table 4.23). The multivariate analysis found that players who performed less than 32 repetitions ($p=0.03$) or between 32.1 and 39.99 repetitions ($p=0.01$) on the push-up test were at risk of a rugby injury (Table 4.25). This finding supports other studies that found poor performance on the push-up test as a risk factor for injury[87;57]. In the study, which involved combat trainers it was found that those who performed less push-ups were at greater risk of losing training time as a result of injury ($p<0.01$)[87]. In the New Zealand study it was found that players who performed between 20 and 33 push-ups missed a greater proportion of their rugby season than those who performed fewer than 19 push-ups[57]. The patterns of association in the multivariate analysis were not linear, making interpretation difficult. This finding could mean that the less strength endurance a player has places him at greater risk of a rugby injury or missing proportion of the season. However, it could also be argued that the more strength endurance a player has the more at risk he is to sustaining a rugby injury. The fitter players may also more likely to be involved in more body contact and tackles in the game.

There is however, some evidence to suggest that poor performance on the push-up test (less than 40 repetitions) can increase injury risk in rugby.

4.5.5c Agility

The players that performed the agility test between 15.91 and 16.39 seconds had the highest injury incidence rate for any rugby injury (24.46 injuries /1000 hours) (Table 4.23.). The fastest players had an injury incidence of 21.96 injuries/1000 hours indicating a difference of 2.5 compared with the players with the highest injury incidence rate. In the univariate analysis of lower limb injuries the players who had the slowest times i.e more than 16.9 seconds had the highest incidence of lower limb injuries (Table 4.24) but it was not statistically significant ($p>0.05$). In the multivariate analysis the fastest players that took less than 15.9 seconds ($p= 0.05$) or between 15.9 and 16.39 seconds ($p=0.01$) and 16.4 and 16.89 sec ($p=0.03$) were found to be at greater risk of rugby injury (Table 4.25). The players with the slowest times on the agility test i.e between 16.4 –16.89sec (p=0.04) and greater than 16.9sec (p=0.02) were found to be at risk of a lower limb injury (Table 4.26). This finding does not support the New Zealand study that found the fastest players that completed a 30 m sprint in 3.76 seconds had the highest injury rate (p=0.05)[57]. The validity of agility and 30m sprint test results as predictors of rugby injury needs to be confirmed by future studies. At present it appears that players at either end of the spectrum i.e. the slowest and the fastest players are at risk of a higher injury incidence.

4.5.5d Aerobic fitness: the multistage shuttle run test

The players who completed more than 93.5 shuttles of the 20m multistage shuttle run had the highest injury rate (24.31 injuries/1000 hours) for any rugby injury (p>0.05) (Table 4.18). The players who had completed the least number of shuttles i.e. less than 62.5 shuttles of the 20m multistage shuttle run test had the highest incidence of lower limb injuries (20.61 injuries /1000 hours) (p>0.05) (Table 4.19). The multivariate analysis did not reveal the 20m multistage shuttle run as a significant predictor of any rugby injury. These findings support the results of the New Zealand study that did not find the 20m multistage shuttle run test as a significant predictor of injury in rugby[57]. A prospective study of Australian Rules footballers confirmed that this test could not be a predictor of hamstring injury[7]. The results of the current study highlight the possibility that players on either end of the spectrum may be at risk of a higher incidence of rugby injuries i.e the fittest and the least fit players.

4.5.5e The vertical jump test

The players who could jump the highest i.e. more than 51.2cm also had the highest injury incidence for all rugby injuries (25.86 injuries /1000 hours) (p>0.05) (Table 4.23). The players who jumped the lowest i.e. less than 43.35cm had the highest injury incidence of lower limb injuries (21.26 injuries/1000 hours) (p>0.05) (Table 4.24). The multivariate analysis did not show the vertical jump test results as a significant predictor of rugby injury or lower limb injury. (p>0.05) (Table 4.25 and Table 4.26). The results of the New Zealand study confirm these findings that the results of the vertical jump test cannot be used to predict risk of injury (p>0.05)[57]. This was also the finding in the study, which involved basic combat trainers[87].

The vertical jump test was not identified as a predictor for injury in rugby.

4.6 Summary

The physical tests that demonstrated an association with risk of injury in the multivariate analysis were the two-minute sit-up test, the one-minute push-up test, the Illinois agility test and the isokinetic concentric quadriceps and eccentric hamstring strength. A poor performance of between 46 and 60 repetitions on the two-minute sit-up test placed the player at risk of a lower limb injury. Players who had performed less than 32 repetitions ($p=0.03$) or between 32 and 40 repetitions ($p=0.01$) on the one-minute push-up test were at increased risk of sustaining a rugby injury (Table 4.25). Players who completed the agility test in less than 15.91seconds, between 15.91 and 16.39 seconds and between 16.4 and 16.89 seconds had increased risk of a rugby injury. The players who had completed the agility test in more 16.4 seconds also had an increased risk of a lower limb injury. Players with less than 150Nm eccentric hamstring strength and between 159.1 – 211.58 Nm torque concentric quadriceps strength were at greater risk of a lower limb injury. This would need to be confirmed by studies with a larger sample size.

The value of other physical tests as predictors for rugby injury needs to be investigated. These tests used in the current study may not be suited to test the unique combination of skill, strength, speed and fitness required in rugby. Rugby is a sport that involves short episodes of power i.e. the ability to develop force at a high rate. It is also important to address the conditioning of the player to sport specific tasks. The tackle is the most important aspect that needs to be addressed in training. Most injuries in this cohort (as described in chapter three) involved being tackled. Tests need to be designed to assess the ability of the player to withstand the force associated with the tackle. The other factors that need to be addressed to make tackles safer are the use of protective equipment and law changes. The tests that were investigated in this study have validity to test one aspect of the players' fitness. The risk for injury in rugby may be multifactorial and may be position specific. It may be necessary to design tests that are specific to position of play that could be used as predictors for injury in these players. Each position has a certain set of skills required which usually cumulates into a certain set of anthropometric characteristics. The tests used may need to reflect this and the norms for various positions of play need to be validated.

The present study did not analyze the influence of preseason training on subsequent injury. It has been documented that players have a 3.9% relative increase in risk of injury for each additional preseason training week attended[58]. These players were from 25 rugby clubs in the Scottish Rugby Union and the details of the preseason training were not provided. It appears that an increased amount of training could increase risk of injury in the season if the player develops an injury during the preseason. The present study did not use the proportion of time missed from the season as an outcome variable as in the New Zealand study[57]. The reason is that the interpretation of this may be difficult because injuries that occur in the preseason or early in the season would reflect as causing more time missed from rugby than injuries that occurred later in the season. The results of the New Zealand study should be viewed with caution due to the method of statistical analysis. Each quartile of a particular variable was only compared to one other quartile (the reference group)[57]. The statistical significance reflects the comparisons of two quartiles rather than a comparison of four.

4.7 Conclusion

There were no strong predictors for rugby injury or lower limb rugby injuries. The comparison of the studies may highlight the possibility that players on either end of the spectrum may have a greater risk of rugby injury i.e. the fittest versus the most unfit. More research needs to be conducted to investigate these findings with a larger sample size and with more rugby and positional specific tests.

Chapter Five

A review of risk factors associated with hamstring injuries

5.1. Introduction
5.2. Methods
5.3. Results
5.4. Discussion
5.5. Summary

5.1. Introduction

Hamstring injuries have been identified as a common injury in sports, that involve sprinting, changing direction with speed, and kicking[8;11;92;7;93;94]. In particular, it has been identified that hamstring injuries are common in a number of sporting codes including rugby[4;5;6]. Previous epidemiological studies of South African rugby players report a seasonal incidence of 4.3% in school rugby players; 11% in club rugby players and 4% in professional rugby[2;1;24]. Comparisons between studies are difficult as few studies relate incidence to exposure time. In Australian Rules football, hamstring injuries account for 16% of missed playing time and have a recurrence rate of 25% in intercollegiate football players[8;7]. The most common injuries reported during the 1987/1988 soccer football league season were hamstring strains[95]. In Australian first class level cricket in 1995/1996 to 2000/2001 hamstring strains was reported as the most common injury[96]. The most common injuries during the 1987/1988 professional soccer season was hamstring strains and ankle ligament sprains[95]. In a study, which investigated the injury patterns among runners, it was found that hamstring strains were the most common injury in sprinters[92]. In Australian football league the most commonly injured body part region was the thigh and the most common type of injury was a muscle strain. Hamstring had the highest recurrence rate of all injuries, 34% of the incidence of new hamstring strains in Australian football league[53]. Severe injuries of the proximal hamstrings have also been associated with water skiing[97].

Risk factors of sport injuries can be classified as intrinsic and extrinsic. Intrinsic risk factors relate to factors specific to the individual such as muscle strength, muscle flexibility, muscle fibre composition, age, anthropometric characteristics, physical fitness, psychological considerations and past injury history[13]. Extrinsic factors are external to the individual and include the nature of the sport, environmental conditions and use of protective devices[13]. The most common postulated risk factors of hamstring injuries are muscle weakness and muscle inflexibility[7;11;9]. Appropriate prevention strategies for hamstring injuries can only be instituted once the modifiable risk factors of hamstring injuries have been scientifically identified. The aim of this chapter is to review the evidence available regarding the etiology and risk factors associated with hamstring injuries. Specific intrinsic factors for hamstring strains that will be reviewed in this chapter are muscle strength, muscle flexibility, anthropometric characteristics, age, past injury history, muscle fibre composition, and physical fitness in relation to strength endurance, agility and aerobic fitness. Extrinsic factors will only be briefly examined and will include the nature of the sport, environmental conditions and the use of protective devices.

5.2. Methods

5.2.1. Search strategy and study identification

An electronic database search included a Pubmed Medline search to July 2004. All studies reporting on hamstring injury prevention and hamstring etiology were included across all sporting codes. The studies involving either sex, from adolescence to middle age were included. No language restrictions were applied. Animal studies were not included. Studies involving surgical intervention were excluded. The specific search terms included hamstring injuries, hamstring strains, hamstring function, intrinsic risk factors, extrinsic risk factors, muscle strains, soft tissue injuries, running injuries, and sport medicine.

5.2.2. Assessment of methodological quality

The selection of studies for inclusion involved a number of stages. The first stage involved assessment of the titles and abstracts to determine if the studies met the criteria. If there was doubt about the eligibility the full text was reviewed. The full text review was then obtained and reviewed to determine if the inclusion criteria were met. If the article was not excluded it was then formally abstracted. All identified studies were independently assessed and coded. The following criteria was used to assess the methodological quality of the studies:

- Was the diagnosis of hamstring injury clearly defined?
- Was the risk factor accurately measured prior to injury?
- Was the diagnosis appropriately applied?
- Was the number of subjects statistically sufficient?

All the relevant studies were then scored according to the system[98] recorded in Table 5.1.

Table 5.1 Scoring criteria of the studies

	Criteria	**Score**
		Yes
1.	There was a clearly stated research question	1
2.	The correct type of study was done to answer the research question	1
3.	The study was original	1
4.	The subject selection (cases and controls or the cohort of exposed subjects and controls) was free from selection bias	2
5.	The measures of outcome were clearly described and appropriate	1
6.	All the measures of outcome were valid and reliable	1
7.	Assessments were, as far as possible, "blind"	1
8.	Statistical analysis of data was appropriate and clear	1
9.	Was there recognition of the determinants of causation	1
	Total	**10**

5.3. Results

The initial search and examination identified 196 titles and abstracts as relevant. Of these 91 were excluded by their titles and 47 were excluded on the basis of their abstracts as irrelevant. The full texts of 40 articles were retrieved of which 27 were excluded as irrelevant and 13 studies met the criteria for inclusion. All these articles were English publications. Studies were excluded on the basis of not identifying risk factors of hamstring injuries, being a review article, not being a prospective or retrospective study and one study was excluded because no hamstring injuries occurred during the study. 17

full texts could not be located of which 8 were not considered relevant on the basis of publication in a non-scientific journal.

5.3.1. Characteristics of the studies

Thirteen studies totalling 3892 participants were included in the analysis. Eight of these studies were prospective cohort studies,[8;93;7;13;12;11;14;99] three were retrospective[9;4;100] and two were case control studies[6;10]. These studies examined the following risk factors of hamstring injuries: isokinetic muscle strength; muscle flexibility; anthropometric characteristics; age; past history; physical fitness; environmental factors and the use of thermal pants.

The total quality scores were calculated for each study based on the sum of the item scores (Table 5.1). The maximum score was 10 and the range of overall scores varied between 5 and 9. Tables 5.2 - 5.6 present the characteristics of each of the studies that were included in this review. Six of the studies involved Australian Rules Footballers,[8;93;7;13;12;9] two studies involved rugby players[14;10] and two involved runners of which one was conducted in marathon runners[100] and one in sprinters[4]. There were two studies that involved soccer players[11;99] and there was one study that involved soccer players and martial art athletes[6]. In only one study, female athletes were included and this was the study involving marathon runners[100]. There were 2 studies[7;9] that failed to report the sex of the subjects, but it could be assumed to be male as the sport was football.

All the studies that were reviewed had a similar definition of a hamstring injury. Hamstring injury was defined as a muscle strain that had to be severe enough to cause the athlete to miss a match and/ or training time[8;93;7;12;4;13;11;99;]. In a few studies, the clinical signs of a hamstring injury were described as a sudden onset of pain during sprinting or kicking; pain; localized tenderness and reduced range of motion of straight leg raise and reduced strength on resisted knee flexion in prone[8;93;7;13;]. Nine studies used a clinical diagnosis of the hamstring injuries[8;93;7;13;4;11;14] while one study used magnetic resonance imaging (MRI)[12] and two studies used soft tissue diagnostic ultrasound to confirm the diagnosis[12;8]. In one case control study the following definition for prolonged hamstring pain syndrome was used: persistent problems such as discomfort and inhibition during athletic activity and a unilateral hamstring injury confirmed by ultrasound[6]. The other case control study defined the test group as having sustained 2 or more grade 1 hamstring strains in the same leg in the past two years, which had been confirmed by a doctor or physiotherapist[10].

5.3.2. Reduced isokinetic muscle strength

Five of the thirteen studies included in this review, examined isokinetic weakness as a possible risk factor for hamstring injuries (Table 5.2). All of these studies used different study designs and the isokinetic testing was done at different angular velocities and therefore the results could not be pooled. The two prospective studies, which involved Australian Rules footballers aimed to establish isokinetic muscle weakness as a possible risk factor for hamstring injuries and had conflicting results[7;8]. The prospective study that confirmed the association between preseason isokinetic muscle weakness with hamstring injury involved 37 professional footballers from Australian Football League. The protocol of isokinetic testing used in this study was at angular velocities of 60, 180 and 300 degrees. Peak torque relative to body weight (in Newton-meters per kilogram), side- to- side comparisons and hamstring to quadriceps muscle isokinetic strength ratios were determined. Six players in this cohort sustained hamstring injuries. All the injuries were unilateral and the injured hamstring muscles were all weaker than their non-injured leg in absolute peak torque values and hamstring-to-quadriceps muscle ratios. The injured limbs had significantly lower hamstring-to-quadriceps at 60deg/sec ($p<0.001$), hamstring injured to non-injured hamstring muscle ratios at 60 deg/sec ($p=0.005$), and hamstring muscle peak torque at 60 deg/sec ($p= 0.011$)[7]. In the other prospective study of 102 male Australian Rules footballers these findings were not confirmed. All the players in this Australian Rules football study were tested for maximal voluntary isokinetic contraction at the start of the season at angular velocities of 60 and 180 degrees/second through a range of 5-95 degrees of knee flexion and extension. Twelve of the 102 players sustained one or more hamstring strains in this study. There was also no significant difference in hamstring peak torque between the dominant and non-dominant leg and between the injured and non-injured legs in the injured players. There was no significant difference between the injured and non-injured players in any of the relative hamstring and quadriceps concentric and eccentric muscle strength variables[8].

In two retrospective studies a possible association between hamstring injury and isokinetic weakness was reported. In the one retrospective study, the aim was to determine whether there are any differences in eccentric and concentric hamstring and quadriceps torques between sprinters who had suffered hamstring injuries compared to uninjured sprinters[4]. In this study 11 male sprinters that had sustained a hamstring injury during one of the two seasons before the season of the investigation were compared to a control group of 9 sprinters who had never sustained a hamstring strain. A Kincom muscle dynamometer was used to test the isokinetic muscle strength and subjects had to complete 72 maximum contractions. Concentric peak torque as tested at three different velocities 30, 180 and 270 deg/sec while eccentric peak torque as tested at 30, 180 and 230 deg/sec. The peak torque values of concentric and eccentric contractions of quadriceps and hamstrings muscles at the different angular velocities of the injured group were compared with the uninjured group values. The main finding of this study was that uninjured sprinters had significantly higher torques during 30 deg/sec concentric contractions of the hamstrings and during eccentric contractions of the hamstrings at 30 deg/sec ($p \leq 0.01$), 180 deg/sec ($p \leq 0.01$) and 230 deg/sec ($p \leq 0.001$) compared to injured sprinters ($p \leq 0.05$)[4]. The finding of this study supports the hypothesis that there is eccentric and concentric weakness of the hamstring muscle following a strain.

The second retrospective study was conducted over the period of 1973 to 1982 in 1098 intercollegiate football players that were divided into two groups[9]. The players in Group I (534 player-years) from 1973-1977 underwent a supervised training programme, which consisted of a supervised winter running programme and self-designed year-long stretching, running and weight lifting. Group II consist of 564 player-years from 1978-1982. These players received the supervised programme as group I but in addition had isokinetic deficits of the hamstrings and quadriceps corrected to a desired ratio of 0.60. It was found that Group 1 had 41 primary hamstring injuries with 13 recurrences and group II had 6 primary hamstring injuries with no recurrences[9]. These retrospective studies provide some evidence of a possible association between isokinetic strength variables and hamstring injury. It is important to note that the significant decrease in hamstring injuries in Group II may be as a result of a number of factors and not conclusively as a result of the isokinetic deficit correction.

A similar study was conducted on 26 athletes to determine if correction of isokinetic muscle strength levels and agonist and antagonist ratios could significantly reduce the incidence of injury when athletes return after their initial injury[6]. The athletes played soccer (n=14) or martial arts (n=7) at a national or international level. All these athletes had sought medical attention for prolonged hamstring pain syndrome such as discomfort and inhibition during athletic activity and difficulty reaching their previous standard of performance. All injuries were confirmed by soft tissue diagnostic ultrasound. The assessment protocol consisted of concentric contractions at angular speeds of 60 deg/sec and 240 deg/sec of both the hamstring and quadriceps muscles. Eccentric contractions of the hamstrings at angular velocities of 30 deg/sec and 120 deg/sec were conducted. The quadriceps-hamstring peak torque ratio was established and a combined ratio was determined in which the hamstrings was assessed eccentrically at 30 deg/sec and the quadriceps at 240 deg/sec concentrically. The subjects (n=18) were given an individualized rehabilitation programme based on the assessment deficits. Their programme included hamstring isokinetic strengthening with a standardized warm-up, a mode of eccentric or concentric contraction or both. The exercise programme was performed three times a week and included stretching exercises and analgesic electrical nerve stimulation. The subjects were observed for 12 months after the end of treatment, which coincided with the correction of the strength deficit of less than 5%. The subjects were reassessed in terms of pain and discomfort during training and competition, before rehabilitation, and on return to activity and at 6 and 12 months after treatment by using a visual analog scale. It was found that none of the subjects that completed the rehabilitation programme sustained a clinically diagnosed hamstring strain within the year after the rehabilitation and the pain rating scored were significantly reduced $(0.9 \pm 0.6)(p \leq 0.001)$[6].

Table 5.2. Characteristics of the studies examining isokinetic muscle weakness as a risk factor

	Bennell[8] 1998 (n=102)	*Jonhagen[4] 1994 (n=11)*	*Orchard[7] 1997 (n=37)*	*Crosier[6] 2002 (n=26)*	*Heiser[9] 1984(n=1098)*
Method. quality score	9	7	9	6	6
Study design	Pros.	Retro.	Pros.	Case control	Retro.
Sex	Male	Male	Unknown	Male	Unknown
Age (years)	Mean 22.2	22.0	Mean 22.0	25	Unknown
Population	Australian Rules footballers	Sprinters	Australian football league	Soccer (n=14) and martial arts (n= 5)	Football players
Isokinetic testing of ham. & quad.	Con. and Ecc. torque at 60° and 180°	Con. at 30°, 180° and 270° Ecc. at 30°, 180°, 230°	Con. and Ecc. torque at 60°, 180° and 300°	Ratios of Con. at 60° and 240° and Ecc. of 30° and 120°	Unknown
Injury definition	Clinical diagnosis; ultrasound	Clinical diagnosis	Clinical diagnosis	Clinical diagnosis ; ultrasound	Unknown
No. of ham. injuries	12	11	6	26	1098

Method, methodological; pros., prospective; retro, retrospective; ham, hamstring muscle; quad, quadriceps muscle; Con., concentric; Ecc, eccentric

5.3.3. Muscle inflexibility

The association between flexibility and hamstring strain was evaluated in six of the thirteen studies included in this review. Of these four were prospective and two were retrospective studies (Table 5.3). In the most recent prospective study of 306 football players the flexibility of the hamstring, adductor, rectus femoris and hip flexor muscles was measured using markers placed close to the movement axis and photographs were taken with a digital camera and analysed using the Kineview movement analysis system[99]. The passive knee extension test was used to measure flexibility of the hamstring muscle. The flexibility results of the passive knee extension test failed show any significance to hamstring injury in the univariate analysis and was not included in the multivariate analysis[99].

In another prospective study of 146 male professional soccer players the flexibility of the hamstring, quadriceps, adductors and calf muscles was measured goniometrically before the start of the season[11]. None of these players had a previous history of a lower extremity muscle injury in the preceding two years. The injuries of these players were monitored throughout the season and a clinical diagnosis was made of the muscle injuries. The players with hamstring injuries (n=13) were found to have significantly lower preseason flexibility in these muscles before their injury compared with the uninjured group ($p=0.02$). This study concludes that preseason hamstring muscle flexibility can be used to identify male soccer players at risk of developing their first hamstring muscle injury[11].

In an earlier prospective study of 37 professional Australian Rules footballers a protocol consisting of a number of tests were performed in the preseason. The flexibility of the lower back and hamstrings was assessed using the "sit and reach" test. Six players sustained a clinically diagnosed hamstring injury that resulted in them missing playing time. No significant association was found between the sit and reach results and hamstring injury[7].

In another prospective study that evaluated the association between hamstring and lower lumbar spine flexibility with hamstring injury, no significance was found[93]. This study consisted of 67 male Australian Rules footballers that were tested in the preseason. A computer analysis of videotape images of toe touching with knees extended from erect standing was used to measure the toe-touch distance and end range hip and lumbar spine flexion angles. Clinical diagnoses of hamstring injuries were made throughout the season. Eight of the 67 players sustained a hamstring injury during the season and six of these were confirmed on ultrasound. This study confirmed the results of the previous study that did not find any significant association between toe-touch flexibility and hamstring strain ($p \geq 0.05$)[93].

Many studies that examined flexibility as a risk factor for hamstring strain mentioned the possibility of neural flexibility as a possible risk factor. Neural flexibility can be described as the ability of the neural structures to move with the correct amount of tension between anatomical structures. One such study was included in this analysis. This study was a case control study that investigated the presence of adverse neural tension in currently asymptomatic rugby union players with a recent history of repetitive grade 1 hamstring strains and a matched control group with no hamstring injury history[10]. The test and control groups consisted of 14 male rugby union players with no history of spinal problems and no major lower limb pathology. The test group in addition had two or more grade 1 hamstring strains in the same leg in the past 2 years as diagnosed by a doctor or physiotherapist. The subjects had to be asymptomatic for hamstring strain for at least 4 weeks prior to testing. Active knee extension in lying and the "slump test" were used to test flexibility and neural tension respectively. No difference was found in muscular or neural flexibility between the groups. Eight of the 14 subjects in the test group (57%) had a positive slump test while none in the control group had a positive slump test. The results of this study provide evidence that players with a history of grade 1 hamstring strains may have adverse neural tension.

In a retrospective case control study, eleven sprinters with recent hamstring injuries were compared to nine uninjured runners in terms of flexibility and strength[4]. The flexibility was measured in supine lying with straight leg raise performed with the angle between the bench and the line connecting the greater trochanter and fibular head was measured. There was a significant decrease in hip joint range of motion in the injured compared with the uninjured sprinters ($p<0.01$)[4].

This demonstrates that there is conflicting evidence regarding muscle inflexibility as a risk factor for hamstring injuries.

Table 5.3 Characteristics of studies examining muscle flexibility as a risk factor

	Bennell[93] 1999 (n=67)	*Turl[10] 1998 (n=14)*	*Witvrouw[11] 2003 (n=146)*	*Jonhagen[4] 1994 (n=11)*	*Orchard[7] 1997 (n=37)*	*Arnason[99] 2004 (n=306)*
Method. quality score	9	8	8	7	9	9
Study Design	Pros.	Case-control	Pros.	Retro.	Pros.	Pros.
Sex	Male	Male	Male	Male	Unknown	Male
Age (years)	Mean 22.7	Mean 29.0	Unknown	Mean 22.0	Mean 22.0	Mean 24.0
Population	Australian Rules footballers	Rugby union players	Professional soccer players	Sprinters	Australian Football League	Football players
Measure.	Toe touch distance	Active knee extension and Slump test	Goniometric measure. of ham., quad., add., Calf	S.L.R	Sit and Reach	Passive knee extension test
Injury definition	Clinical diagnosis and ultrasound	Clinical diagnosis	Clinical diagnosis	Clinical diagnosis	Clinical diagnosis	Clinical diagnosis
No. of ham. Injuries	8	NA	31	11	6	31

Method, methodological; Pros. Prospective; Retro. Retrospective; Ham, Hamstring; Quad, quadriceps; add., adductors; S.L.R. , straight leg raise; measure, measurement

5.3.4. Anthropometric characteristics

Anthropometric characteristics as a possible risk factor in hamstring injuries was assessed in five of the thirteen studies examined (Table 5.4). Four of these studies were prospective and one study was retrospective. In the most recent prospective study of 306 football players height, weight and body composition measurements were analysed in a univariate analysis to determine their significance as predictors for hamstring injury[99]. Skinfold measurements were taken from six areas: triceps brachii, subscapular, pectoralis major, iliac crest, abdomen, and anterior thigh. There was a trend of a higher body fat percentage in the hamstring injured group compared to the non-injured group but no anthropometric measurements were identified as signicant predictors for hamstring injury[99].

In the prospective study, which involved 37 Australian Rules footballers the protocol consisted of a set of pre-season tests of which one test included height, weight and body composition measurements[7]. Body composition measurements were taken at 8 sites. There was no significant association found between height, weight or body composition and hamstring injury. It was reported that there was trend toward an association with higher thigh skin-fold thickness and hamstring injury but this was not statistically significant ($p= 0.143$)[7].

In the one prospective study, the height and weight of injured and non-injured Australian Rules footballers ($n=114$) was compared[12]. Of the 32 injured players in this cohort, 26 had a confirmed hamstring injury on MRI while the remaining six were diagnosed as referred pain of the posterior thigh. Height ($p=0.83$) and weight ($p=0.16$) were not significantly associated with hamstring injury in these 26 players. The athletes diagnosed with posterior thigh pain ($n=6$) were found to be taller (mean height 189.5cm) than those without injury (mean height 182cm) but it did not approach significance (Mann-Whitney, $p=0.07$)[12].

In the third prospective study that examined players' height, weight and BMI as potential risk factors for muscle strains, also involved Australian football league players[13]. This study found more hamstring injuries in players with higher body mass index ($p<0.001$) but body mass index correlated highly with player age and previous injury and therefore the authors attributed the association to these confounding variables[13].

The retrospective study that examined the relationship between anthropometric characteristics and hamstring strains involved 304 runners[100]. These runners registered for a marathon-training programme. This study involved a self-administered questionnaire in which subjects reported weight and height and injuries incurred in the previous 12 months. The anatomic measurements of the lower extremity that were done include arch height, heel valgus, knee tubercle-sulcus angle, knee varus, and leg-length difference. There were 184 injuries in 136 of the runners during the 12-month period. Thirteen of these were hamstring injuries. There was no significant relationship between hamstring injuries and height and weight. In the tercile comparisons left foot arch index had a significant p value for hamstring injuries with a 8.25% in the middle groups and 2.13% and 2.04% for the low and high groups respectively[100]. The stepwise regression analysis found belonging to the lowest left arch index group (Odds Ratio 0.064, p=0.023) as a predictor for hamstring injury[100].

Table 5.4. Characteristics of studies examining anthropometric measurements as a risk factor

	Verrall[12] 2001 (n=114)	***Orchard[13] 2001 (n=1607)***	***Orchard[7] 1997 (n=37)***	***Wen[100] 1997 (n=304)***	***Arnason[99] 2004 (n=306)***
Method. Quality score	9	9	9	5	9
Study design	Prospective	Prospective	Prospective	Retrospective	Prospective
Sex	Male	Unknown	Unknown	Male 133 Female 171	Male
Age (years)	Mean 22.21 (AFL) Mean 20.2 (SANFL)	Mean 23.53	Mean 22.0	Mean 41.1 Range 21-78	Mean 24.0 Range 16-38
Population	Australian Rules Football Clubs	Australian Football League	Australian Football League	Runners in a marathon programme	Highest division football players
Measurement	Height, weight, aboriginal	Height, weight, Body Mass Index, race	Height, weight, body composition	Arch height, knee tubercle sulcus angle, knee varus, leg length difference, weight, and height.	Skinfold measurements, Body Mass Index
Injury definition	Clinical diagnosis and MRI	Clinical diagnosis	Clinical diagnosis	Self-reported	Clinical diagnosis
No. of hamstring injuries	26	672	6	13	31

5.3.5. Age

Age as a possible risk factor for hamstring strains was examined in four studies[13;12;100;99] (Table 5.5). Three of these studies were prospective, and one study was retrospective. The most recent prospective study[99] found the older players (1>SD above the mean, 29 to 38 years) to have a greater risk of hamstring injury compared to the reference group in this cohort ($p=0.02$). In the multivariate analysis that included previous injury, age, weight and body fat, age was found to be as significant predictor for hamstring injury with an odds ratio of 1.4 times per year but previous injury was a confounding variable ($p<0.001$)[99].

In the other prospective study[13] that used logistic analysis to determine the risk factors for muscle strains an age greater than 23 years was found to be a significant risk factor for hamstring injury, independently of injury history (RR=1.24, 95% CI 1.14 -1.57)[7].

In third prospective study age was found~~-was also found to be~~ to be a significant risk factor even when confounding factors of previous posterior thigh pain are excluded. It was found that for every 1 year increase in age, the likelihood of a hamstring injury increased by 1.3 times, independently of past history of posterior thigh pain (OR 1.3 95% CI 1.1 – 1.5)[12].
In the one retrospective study, the relationship between age and hamstring strains was analyzed as a possible risk factor. Subjects with hamstring injuries were found to be older (mean age 47.7yr) than those without hamstring injuries. Hamstring injuries occurred more often in older subjects (9.57%) than in the younger (1.94%) and middle (1.98%) age groups[100].

Table 5.5. Characteristics of studies examining age as a risk factor

	Verrall[12] 2001 (n=114)	*Orchard[13] 2001 (n=1607)*	*Wen[100] 1997 (n=304)*	*Arnason[99] 2004 (n=306)*
Method. quality score	9	9	5	9
Study design	Prospective	Prospective	Retrospective	Prospective
Sex	Male	Unknown	Male 133 Female 171	Male
Age	Mean 22.21 (AFL) Mean 20.2 (SANFL)	Mean 23.53	Mean 41.1 Range 21-78	Mean 24.0 Range 16-38
Population	Australian Rules Football Clubs	Australian Football League	Runners in a marathon programme	Football players
Injury definition	Clinical diagnosis and MRI	Clinical diagnosis	Self-reported	Clinical diagnosis
No. of injuries	26	672	13	31

Method, methodology;AFL, Australian Rules Football;SANFL, South Australian National Football League

5.3.6. Past injury history

The relationship between a past hamstring injury and subsequent risk of a hamstring injury was investigated in four prospective studies. Three studies involved Australian Rules footballers[8;13;12] and one study involved football players of the two highest divisions in Iceland[99]. In all these studies, past injury history was a strong risk factor for hamstring injury[13;12;8;99;] (Table 5.6). All these studies had high methodological scores. These studies obtained high scores as they were prospective, had clearly defined outcome measures that were valid, assessments were "blind" and the statistical analysis was appropriate.

It was found that a hamstring injury within the previous 8 weeks (RR=6.33, 95% CI 5.21-7.70) and a hamstring injury more than 8 weeks ago (RR=2.42 95%CI 2.05-2.85) were strong predictors for hamstring injury[13]. The other prospective study found that a past history of posterior thigh pain increased the risk of sustaining a hamstring injury 4.9 times (OR=4.9; 95%CI 1.6 to 15.1)[12]. A past history of a knee injury was also found to be a predictor for hamstring strain (OR=5.6 95% CI 1.1 to 28.1)[12]. In the third study 35 players reported a past history of hamstring injury on one or both legs[8]. A significant percentage of these players who had a past history of a hamstring injury sustained a hamstring injury compared to those who had no past history of hamstring injuries (66% vs 31%; p=0.02)[8]. The odds ratio for sustaining a hamstring injury was 2.1 for players with a past history of hamstring injury[8].

The most recent prospective study that involved football players found that a previous hamstring injury placed the player at increased risk of a recurrent hamstring injury with an odds ratio of 11.6 (p<0.001) without age as a confounding variable[99].

Table 5.6. Characteristics of studies examining past injury history as a risk factor

	Verrall[12] 2001 (n=114)	***Orchard[13] 2001 (n=1607)***	***Bennell[8] 1998 (n=102)***	***Arnason[99] 2004 (n=306)***
Method. quality score	9	9	9	9
Study design	Prospective	Prospective	Prospective	Prospective
Sex	Male	Unknown	Male	Male
Age	Mean 22.21 (AFL) Mean 20.2 (SANFL)	Mean 23.53	Mean 22.2	Mean 24.0 Range 16-38
Population	Australian Rules Football	Australian Football	Australian Rules Football	Football players
Measurement	Severe knee injury, groin injury, severe back injury, posterior thigh pain within 2 player seasons	History of injury to hamstring, calf or quadriceps within the previous 8 or more than 8 weeks ago	History of injury to hamstring	Previous and recurrent injuries
Injury definition	Clinical diagnosis and MRI	Clinical diagnosis	Clinical diagnosis and ultrasound	Clinical diagnosis
No. of injuries	26	672	12	31

Method, methodology;AFL, Australian Rules Football;SANFL, South Australian National Football League

5.3.7. Physical fitness: strength endurance, agility, and aerobic endurance

Decreased physical fitness as a possible risk factor for hamstring injury was assessed in only two of the thirteen studies included in this review. In a prospective study, which involved 37 Australian Rules footballers, the protocol consisted of a routine of preseason tests, which assessed aerobic and anaerobic fitness, running speed, lower body strength and abdominal strength[7]. "Aerobic" fitness was assessed by determining the VO2max while running on the treadmill with the incline increasing 1% per minute. Anaerobic fitness was assessed on an air resistant cycle ergometer. Each subject did 5 maximal 6 second efforts for 30 seconds. Total work (in joules per kilogram), peak power (watts per kilogram), work and power decrements (percentages) and blood lactate (millimolar) 2 minutes after exercise were determined and recorded. Lower body explosive strength was assessed with a countermovement jump and three-step running jump using a Vertisonic sonar device to measure jump height. Acceleration and speed characteristics were evaluated from a standing start using timing lights 10, 20, 30 and 40 meters. Peak velocity was calculated as the average velocity between 30 and 40 meters. Abdominal strength was measured using a Seven-stage test[7]. The results of the study showed that abdominal strength, VO2max and the various measures of anaerobic fitness did not significantly influence the incidence of hamstring injuries. There was a trend towards an association between a higher score on countermovement jump ($p=0.177$), lower abdominal strength ($p=0.137$), higher peak velocity ($p=0.235$) and lower VO2max ($p=0.192$) and hamstring injury but there were not statistically significant[7].

The most recent prospective study[99] analysed the peak O2 uptake, power testing and jump tests to determine predictors for hamstring injury The peak O2 uptake was measured by an exercise session on the treadmill. The participant completed a period of 6 minutes warm-up, running on a level treadmill. The speed was gradually increased during the first three minutes until 70% to 80% of maximal heart rate was obtained and maintained for the final 3 minutes. Following a 3 minute break the participant was allowed to stretch while he was connected to a mouth/nose piece and O2 uptake and CO2 production was measured while he ran for about 2 minutes at the same speed as the final speed during the warm-up session. The speed was then increased by 0.5 meter per second every minute until 4 metres per second was reached and after the inclination of the treadmill was increased by 1.5 every minute until volitional exhaustion.

Maximal average power was measured in the extension phase of the squat. A Smith machine was used which is a slide machine with a guided horizontal barbell. A Musclelab unit was attached to the slide machine that measured vertical movement of the bar as a function of time. The jump tests were performed on a contact mat. The three jump tests were a standing jump, a countermovement jump and a one-leg counternmovement jump done on each leg. The results of these tests in the univariate analysis did not show any association with hamstring injury and were not included in the multivariate analysis. None of the remaining studies examined the relationship between parameters of physical fitness as a risk for hamstring injury.

5.3.8. Environmental conditions:

The role of environmental conditions as a possible risk factor for hamstring injury was examined in only one of the thirteen studies included in this review. In the prospective study that involved 1067 Australian Rules footballers intrinsic and extrinsic risk factors for muscles strains were determined[13]. Extrinsic variables that were included were the grade of the match, time of match (day or night), month, maximum and minimum temperatures on the day of the match, maximum wind speed on the day of the match, and rainfall and evaporation measures on the day of the month and in previous 7,14,28,90 and 365 days. The results were as follows: month of the year ($p=0.737$); rainfall on day of the game ($p=0.397$); rainfall in the previous 7 days ($p=0.305$); evaporation in previous 7 days ($p=0.953$); maximum temperature on day of the game ($p=0.263$). The analysis of this study therefore shows that there was no correlation between environmental factors and hamstring injury[13].

5.3.10. The use of protective devices

In one case control study the use of thermal pants to reduce the incidence of hamstring injury was reported[14]. This study involved 60 club rugby players who had reported to miss seven days or more of rugby due to a hamstring injury during either of the previous two playing seasons. Each player completed a questionnaire, which included all the personal details, injury history, the use of protective aides, and details of stretching and warm-up routines. The players were given the choice of wearing or not wearing a protective brace. During the course of the season the players had to report on a weekly basis about the participation in training and matches and the use of thermal pants during training and matches. Players completed questionnaires when a hamstring injury was sustained. Three subject groups were studied: Group 1(n=5) who wore thermal pants on the previously injured leg during training and matches for the entire duration of the season, Group 2(n=17) who never wore these pants and Group 3(n=22) who wore thermal pants some of the time and other times not. This study found that the hamstring injury rate among players in Group 3 was significantly lower ($p<0.05$) when they wore the thermal pants than when they did not[14]. There was however no difference between the players who wore thermal pants at all times and those or never who them.

5.4. Discussion

The high risk of hamstring injuries remains a significant clinical problem in a number of sporting codes that involve running and speed. Identification of the main risk factors for both the initial hamstring injury and recurrent injury would assist in the development of effective primary and secondary prevention programs. Effective prevention would ultimately reduce the incidence of injury. This review examined the evidence of a cause-effect relationship between risk factors in particular intrinsic risk factors and hamstring injury. Risks factors for hamstring injuries that were highlighted by these studies included: isokinetic muscle weakness; muscle and neural inflexibility, increasing age, past history of injury, environmental factors and the use of protective devices. Other postulated risk factors that were not included in this review, included muscle fibre composition[101], insufficient warm-up[n94;102;5;103] premature return to sport[94] nature of the sport and or player position;[104] training errors[104] and lumbo-pelvic stability[104]. These risk factors were either investigated in studies that did not meet the criteria of this review or have not been investigated.

5.4.1. Isokinetic muscle weakness

The studies that address isokinetic muscle weakness as a risk factor show controversy in this regard. The earliest study that reported the benefit of isokinetic strengthening in football players as a means of reducing recurrent hamstring injuries was retrospective[9]. The players who had received isokinetic strengthening as opposed to no isokinetic strengthening in rehabilitation after a hamstring injury had less recurrent injuries. This retrospective design made the study susceptible to recall bias and it was not representative of the incidence of hamstring injuries in intercollegiate football players. There were players that were in both experimental groups of this study and no statistically significant evidence was presented to clearly indicate a cause-effect relationship. The reduced hamstring injuries in the group who had received isokinetic strengthening could be due to of a number of other factors or due to chance. The group who had received isokinetic strengthening could have received more updated non-isokinetic exercises than the earlier group. The internal validity of the study was also limited due to history and maturation.

In the case control study that compared sprinters with previous hamstring injuries (n=11) to non-injured sprinters (n=9) there was significantly higher torques of concentric hamstring contractions at 30 deg/sec and significantly higher torques of eccentric hamstring contractions at 30, 180 and 230 deg/sec in the uninjured group of sprinters[4]. There was no difference found with the hamstring /quadriceps ratios. The validity of this study is weak due to recall and selection bias. The external validity is also reduced in terms of population validity as it involved a small sample of sprinters. The methodology of this study could also affect the results as an exceptionally high number of contractions (72 maximal contractions) were expected of the players.

In the two prospective studies there is conflicting evidence with regards to the role of pre-season isokinetic weakness as a predictor for hamstring injury. In the prospective study that found evidence of isokinetic weakness as a predictor of hamstring injury the external validity is reduced as it involved a small sample of 37 Australian Rules footballers [7]. The internal validity was reduced by maturation and history. There was also evidence of observation bias with regards to the subject testing and clinical diagnosis. This study reported that a hamstring and quadriceps ratio of ≤ 0.61 was a strong predictor for hamstring injury. This was however disputed by the other prospective study as 76% of the subjects in this subsequent study had ratios less than 0.6 and did not sustain a hamstring injury[8].

This second prospective study was also restricted to Australian Rules footballers but had a larger sample of subjects. The strength of this study is that the researcher was blinded to the preseason results and the clinical diagnosis was confirmed by ultrasound in 8 of the 14 injuries. This study did not confirm any relationship between isokinetic weakness and subsequent hamstring injury. This study limitation was that it did not conduct the isokinetic testing at high speeds of 200 or 300 degrees. However, previous studies that have confirmed isokinetic weakness as a risk factor for hamstring injury were conducted at angular velocities of 60 deg/sec. The limitation of this study was that there was no randomized selection as subjects volunteered to participate.

In a recent study included in this review involving isokinetic strength variables it was found that by correcting isokinetic muscle strength and correcting the hamstring and quadricep ratios could reduce the recurrence of a hamstring injury[6]. This study also had limitations in terms of internal and external validity. The study had poor generalisability as it involved a small sample of track and field and martial art athletes. The Hawthorne effect (knowledge of being part of an experiment) and Rosenthal effect (knowledge of being part of group treatment) were not controlled for by a double-blinded trial. The multiple treatment effect was also a factor that reduced external validity as subjects also had other treatment besides isokinetic strengthening. This study occurred over 12 months in which isokinetic testing parameters could change which means history and maturation could play a role. The new ratio (eccentric hamstring 30 deg/sec and quadriceps concentric at 240 deg/sec) that was included in this study has not been validated.

It is clear from this evidence that a conclusive cause-effect relationship between isokinetic muscle weakness and hamstring injury has not been established.

5.4.2. Muscle inflexibility

Muscle flexibility is probably the most common factor that is emphasized by medical professionals and coaches to reduce hamstring injury. In this review the evidence of muscle inflexibility as a risk factor in recurrent hamstring injuries was not documented. There is however evidence that muscle inflexibility could be associated with first time hamstring injury.

In both prospective studies that involved Australian Rules footballers no association was found between muscle flexibility and hamstring injury in[7;93]. In both studies small sample sizes were used, making generalization difficult. The lack of statistics power of the study could be a reason that a relationship between flexibility (measured by the toe-touch test) and hamstring injury could not be found as a small number of injuries were reported in this study[93]. The tests used to assess flexibility in these studies may also be inaccurate or lack sufficient specificity. The sit and reach test in the one study may not be specific to hamstring flexibility and could account for the lack of a relationship between injury and inflexibility[105]. The hamstring stiffness may only be a factor in the first third of the toe-touch test and not in relation to the final position[93]. Both the toe-touch and sit and reach are bilateral tests and are not sensitive to unilateral differences in muscle length[93]. In both prospective studies, a clinical diagnosis was made of the hamstring injury but in one study [93] 75% of the injuries were confirmed by ultrasound.

In the retrospective case control study, a significant difference was found in hip range of motion between injured and uninjured sprinters[4]. This study fails to report on the intra-tester reliability of their measurements of hip range of motion. The researcher was not blinded to the injury status of the subjects. This retrospective study design has the limitations of selection and recall bias.

In the case control study that compared muscle flexibility and adverse neural tension in rugby players with a past history of two or more grade1 hamstring injuries with uninjured players found normal flexibility but adverse neural tension in the rugby players with a past history of grade 1 hamstring injuries[10]. These findings lack external validity, as it was limited to rugby players with prior grade-1 hamstring injuries. The study design is also limited by selection and recall bias. The major limitation of this study is that it fails to report on the inter- and intra-test reliability of the slump test. It also fails to report on the accuracy of the slump test to assess neural tension as opposed to the tension of other muscular and ligamentous structures in the spine and lower limb. The validity of the slump test to assess adverse neural tension has not been confirmed. The strength of this study was that the researcher was blinded to the group allocation of each subject.

In a recent prospective study[11] it has been shown that muscle inflexibility is a risk factor for the initial or first hamstring injury[11]. The weakness of this study is that it fails to report on the researcher being blinded to the test results at the time of clinical diagnosis. Ultrasound or MRI was not used to confirm the clinical diagnoses of the hamstring injuries. The accuracy and reliability of goniometer testing to measure hamstring muscle length has not been consistently shown[106]. It has been reported that the measurement is confounded by the posterior rotation of the pelvis as the leg is raised[106]. As the pelvis rotated posterior during the hip flexion the ischial tuberosity and the origin of the hamstring muscles moves in the same direction as the muscle insertion thereby not affecting the muscle tension[106;93]. This study failed to limit or stabilize the pelvis during testing.

The most recent prospective study[99] did not find flexibility to be risk factor for hamstring injury. The flexibility test used in this study is different from the other studies in this review and it was reported to have an average coefficient of variance of 2.4% for intrarater reliability. None of the studies analysed in this review used the same method of assessing muscle flexibility, which makes comparison of these studies difficult. The association between muscle inflexibility and hamstring injury requires further investigations. There is one prospective study that found an association between muscle inflexibility and the first hamstring injury[11]. There is one study that found an association between the slump test and players with a past history of grade I hamstring strains[10]. Future studies are therefore needed to confirm these associations.

In conclusion, there is limited evidence to link muscle inflexibility and hamstring injury.

5.4.3. Anthropometric characteristics

Four of the five studies that examined anthropometric characteristics as possible risk factors for hamstring injury were prospective and attained high methodological scores (Table 4.4). The results of three of these studies could be pooled as they all involved Australian rules footballers. Three of the studies also used the same measurements (weight, height and body composition), while one study only assessed weight and height. It was postulated that mesomorphic body composition could predispose an athlete to hamstring injury. Possible confounding variables could be Type II muscle fibre composition, and possibly race. There was trend towards an association between increased thigh thickness and hamstring injury. All four prospective studies found that anthropometric measurements could not be used as predictors for hamstring injury[99;12;13;7]. The retrospective study found a significant relationship between a low left arch index and hamstring injury[100]. This study had several limitations in methodology due to its' retrospective design (selection bias, self-reporter and recall bias). The study was also limited in the reliability of the measurements with no true intra-observer reliability and inter-observer reliability. The study also failed to address the relationship between the arch index and hamstring injuries.

There is therefore no evidence to suggest that anthropometric measurements can be used as a predictor for hamstring injury.

5.4.4. Age

In three of the prospective studies it was confirmed that increased age was a significant risk factor for hamstring injury[12;13;99]. Regression analysis that excluded confounding variables such as past history of posterior thigh injury concluded that with an increase in age of one year an athlete is 1.3 times more susceptible to hamstring injury[12]. The other prospective study found that being older than 23 years of age increased the risk of sustaining a hamstring injury[13]. The weakness of these studies is that it was specific to Australian Rules footballers and the former study may have a sampling error as it lacked randomization. The most recent prospective study[104] found that an age increase per year placed a player 1.4 times greater risk of a hamstring injury but past injury was found to be a confounding variable. The weakness of the statistical analysis used in this study is that the cohort was divided into three groups where two groups (> 1SD above the mean and > 1 SD below the mean) were compared to a reference group, which was the intermediate group. Certain the predictor variables were selected from this univariate analysis for the multivariate analysis increasing the probability of significance.

The other study that found age to be a risk factor for hamstring injury was retrospective in nature and was limited by selection and recall bias[100]. The main weakness with this study is it's retrospective design, which makes it difficult to determine causation.

The theory that is used to explain increasing age as a risk factor, is that abnormalities of the lumbar spine are implicated in the development of muscle strains[13]. The lumbar roots supplying the hamstring namely L5 and S1 are commonly affected by age-related spinal degeneration. The other theory is that there is an age-related loss of muscle strength caused by degeneration of type II muscle fibres. The spinal degeneration leads to L5 and S1 nerve impingement leading to hamstring fibre degeneration and thus resulting in decreased muscle strength. These studies are consistent in confirming age as a risk factor for hamstring injury. However more studies are needed to confirm this.

In summary, there is some evidence to suggest that increased age increases the risk of sustaining a hamstring muscle injury.

5.4.5. Past injury history

The four prospective studies that have confirmed past history of hamstring injury or posterior thigh injury as a significant risk factor for hamstring strain have high validity[13;12;7;99]. In the one study, it was reported that athletes with a history of a posterior thigh injury were 4.9 times at increased risk of hamstring strain than those without[12]. It was found that after the exclusion of athletes with a past history of a posterior thigh pain, previous knee injury and previous groin injury are still significant risk factors for hamstring strains[12]. It can be postulated that after the groin or knee injury the biomechanical properties of the muscles are altered thereby making it susceptible to re-injury[12]. The other study reported that athletes with a recent injury of hamstring strain within 8 weeks and with a past history of hamstring injury more than 8 weeks ago have increased risk of hamstring injury[13]. The possible reasons for the past history of a hamstring injury being one of the strongest intrinsic risk factors can be attributed to confounding variables such as low hamstring muscle strength[13] or inadequate rehabilitation following injury[94;99]. The development of scar tissue at the site of the muscle damage may negatively affect the function of the muscle thereby making it susceptible to re-injury[12;99].

In conclusion, there is strong evidence to suggest that a past history of hamstring injury is a risk factor for a recurrent hamstring muscle injury.

5.4.6. Muscle fibre composition

None of the studies that were scored in this analysis examined muscle fibre composition as a possible risk factor. One study that examined intrinsic (player-related factors) that confirmed a past history of a calf muscle strain and recent hamstring injury as strong predictors for a hamstring injury alludes that a confounding variable that must be considered other than the obvious reason of biomechanical changes that occur in the running pattern placing increased strain on other muscle groups[13]. The possibility of genetic factors such as maximum player speed as a possible risk factor and that certain genetic types may be predisposed to muscle strains. This study also included race as one of the intrinsic factors that was examined in their study however fail to report on the any findings regarding race[13].

In the other prospective study that examined clinical factors as possibly associated with an increased risk of sustaining a hamstring muscle strain included race as a possible risk factor. Race was referred to as being aboriginal or non-aboriginal. Although there were only a small number of aboriginals in the cohort, it was found that being of aboriginal descent significantly increased the risk of sustaining a hamstring strain. This study attributes this to the aboriginal players being the fastest players with predominance of type II (fast twitch fibres) and thereby at increased risk of hamstring strain. However this is speculative, as it has not been shown that these were in fact the fastest players in the cohort[12].

Another study reported on the histochemical fibre type composition of the human hamstring muscles. Muscle specimens were obtained from the hamstring, quadriceps and adductor magnus. It was found that the hamstring muscles showed a relatively higher proportion of type II fibers. Type II fibers are more involved in exercise of high intensity and force production. Hamstring injuries frequently occur during sprinting or exercise at high speed. Type II fibers are increasingly recruited for neuromuscular activity as the exercise intensity increases. It has been reported that there is a considerable variability in the percentage of fiber types between individuals. It is however stated that faster muscles have more type II muscle fibers. The percentage of type II fibres has been reported to decrease with age. Age has been shown to be a significant risk factor. It can be speculated that the decrease in the percentage of type II fibers with increasing age can affect performance of the athlete in terms of the ability of the muscle to generate tension and force at speed[101].

5.4.7. Environmental factors

None of the twelve studies included in this analysis examined the effect of field conditions as an exclusive risk factor for hamstring injury. In a prospective study of 1169 Scottish club rugby players, the influence of weather and pitch conditions were examined in relation to rugby injuries[107]. This study was not included in this analysis because it did not analyse the effect of weather and field conditions to risk of hamstring injury specifically. This study found that the state of the pitch did not appear to influence the risk of injury in rugby union football, but weather conditions may play a role. There was a higher injury rate in autumn than in early winter, late winter or spring. The risk of lower limb fractures was higher on firm or hard pitches than on heavy slippery or yielding pitches with no mention of the effect on the rate of hamstring injuries.

5.4.8. The use of protective devices

The use of protective devices such as thermal pants by athletes is aimed at reducing the risk of hamstring injury. It is based on the theory that by maintaining a warm temperature of the muscle, injury can be prevented. There are animal studies (rabbit muscle) that have reported that warming the muscle increases the force and length of stretch of the muscle and thereby reducing the risk of a muscle tear[102;108]. The study in this analysis found some preliminary evidence that suggests that the use of thermal pants may assist in reducing the risk of hamstring injury in rugby.

5.4.9. Other factors

There are other factors that have been reported in the literature that were not addressed in the studies analyzed in this review. These factors include dys-synergic contraction of the agonist and antagonist muscles; insufficient warm-up; poor running style; premature return to sport; the nature of the sport; training errors; and lumbopelvic stability[94;113;114].

Dys-synergic contraction of the hamstrings and the quadriceps can be associated with muscle imbalances detected with isokinetic testing. A dys-synergic contraction refers to a contraction when the incorrect amount of force is generated at the incorrect time by the muscle. This dys-synergic action occurs particularly at the time of sudden change from eccentric to concentric contraction during the running cycle. It has been reported to be a factor that makes the hamstrings susceptible to tear[94;114;93].

Insufficient warm-up has been associated with the muscle tissue being cooler, more viscous and less flexible and therefore inadequately prepared for efficient contraction[94;102;5;103]. Neuromuscular co-ordination could also be affected by insufficient warm-up, which may result in inappropriate agonist and antagonist contraction[94].

It has been reported that if an athlete returns to his sport prematurely following an injury he is susceptible to re-injury. The theory is that the athlete would not have attained full strength, flexibility, endurance and co-ordination[94].

The nature of the sport or player position has also been discussed as factors that play a role in hamstring injury[104]. Sports that involve sprinting, quick changes in running direction, and kicking appear to be those associated with higher risk of hamstring injuries[94;93;11]. The sprinters in any sport have often been considered the most susceptible to hamstring injuries[92,104]. However, the forward players in rugby are also at risk due to the load placed on the hamstrings in the scrum and the short bursts of speed required of the flankers and props[104].

The errors that can occur in training can be related to inadequate preseason training, insufficient warm-up, or inappropriate transition from amateur to professional status in a sport[104]. The theory regarding the role of lumbo-pelvic stability is based on the attachment of the thoraco-lumbar fascia and the transference of force from it to the trunk and lower limbs. The transverse abdominus and internal oblique and sacrotuberous ligaments all attach to the thoraco-lumbar fascia[104]. If the athlete had a past history of lower limb injury, the pain associated with this injury could have inhibited these stabilizing muscles. Weakness of these muscles will in turn make running less efficient and increase strain on biarticular muscles such as the hamstring muscle group[104].

5.5. Summary

Intrinsic and extrinsic variables as possible predictors for hamstring injury were addressed in this review. Evidence relating isokinetic weakness and muscle inflexibility as significant intrinsic risk factors for hamstring injury is conflicting and sparse and further studies need to confirm any relationship. There is strong evidence to suggest that age and a past history of hamstring injury or posterior thigh pain are independent intrinsic risk factors for hamstring injury. This will however have to be confirmed with more studies to ensure that there are no confounding variables. There appears to be some relationship between the use of thermal pants and the reduction in the incidence of hamstring injury but more conclusive evidence is required. There is no evidence to suggest a significant relationship between anthropometric characteristics, physical fitness and environmental factors with the incidence of hamstring injury.

Chapter Six

Risk factors associated with hamstring injuries in club rugby players.

6.1. Introduction

The basic skills required in rugby are tackling, sprinting over short distances, and kicking. It is a sport characterised by speed and acceleration. Epidemiological studies of league and professional rugby report that musculo-tendinous strain as the most common injury affecting the lower limbs[55;21;15;1;40;17;52;53;41;22]. More specifically a hamstring strain is the most common muscle injury reported in league and professional rugby[52;53;15].

The main function of the hamstring muscle during running is rapid eccentric contraction to oppose the quadriceps action during the last third of the swing phase[94]. The hamstring muscle action changes from maximal eccentric to concentric action at ground contact. During kicking the muscle is lengthened across the hip and knee joint. The hamstring muscle contracts during open and closed chain activities, which makes it particularly vulnerable to injury[8].

The postulated risk factors for hamstring injuries are improper warm-up, muscle fatigue, previous injury, strength imbalance, poor flexibility, poor lumbar posture and lack of wearing thermal pants[109;2;94;110;111;5;112;7;]. However, there is minimal scientific evidence to show a cause-effect relationship for most of these postulated risk factors (Chapter 5). The association between risk factors and subsequent hamstring injury has only been examined in a few prospective studies in large athletic populations.

The most commonly postulated causative factors of hamstring injuries are muscle weakness and poor flexibility. Early studies identified a 10% bilateral deficit in isometric hamstring strength as a predictor for hamstring strains[113]. More recently there is the conflicting evidence about muscle strength imbalances as tested by isokinetic testing as being a predictor of hamstring injuries (Chapter 5). Retrospective studies have found no difference in hamstring injured and control athletes in terms of isokinetic concentric and eccentric torques[8]. A significant association between pre-season hamstring weakness and subsequent development of hamstring muscle strain injuries was found in a prospective study of 37 professional Australian footballers[7]. The dynamic ratio of concentric quadriceps and eccentric hamstrings is regarded as a good indicator of the capacity of the hamstring to provide dynamic stability in terminal knee extension[91]. A similar study of 100 Australian footballers found no significant difference for any isokinetic variables comparing injured and non-injured legs as well as injured and non-injured players[8].

A recent study that determined intrinsic and extrinsic factors associated with muscle strains reported that the strongest risk factor was a recent history of the same injury and the next strongest risk factor was a past history of the same injury. Increased age was also found to be a risk factor for hamstring injuries[13]. A prospective study identified the following clinical risk factors for hamstring strain: previous hamstring strain, increased age, and aboriginal descent, past history of knee injury or osteitis pubis[12].

Most studies that have reported on the preseason factors associated with hamstring injuries were limited because of small sample size[94;110;111;5;112;]. Furthermore, none of these studies have assessed abnormal neural length–tension function as a possible risk factor for hamstring strains. It was suggested that neural extensibility might play a role in the predisposition to hamstring injuries. The neural pathology may alter tension in the hamstring muscle, which in turn may influence the intensity of muscle contraction thus increasing the risk of injury[93]. It has been reported that a positive slump test in footballers is associated with hamstring injury[114;115]. The use of neural tissue mobilizations was advocated in the treatment of muscle strains, particularly the hamstring muscle, based on these studies[60;115;61].

A theoretical model proposed that a hamstring injury could occur as a result of a single factor's interaction with several other factors[103]. The factors they propose are: muscle strength imbalance, flexibility, inadequate warm-up and fatigue. This model will be referred to as the *muscle strength-flexibility-fatigue model.*

6.2. Aim of the study

The aim of this study was to test the muscle-strength- flexibility-fatigue model for hamstring injury risk by determining if any of the following variables tested in the pre-season are associated with hamstring injuries sustained by club rugby players: muscle weakness; altered range of motion; decreased aerobic fitness; decreased muscle endurance or decreased agility. It also aimed to determine if age, past history of a hamstring injury, anthropometric measurements and use of thigh sleeves could influence the risk of hamstring injury.

6.3. Methods

6.3.1. Study design

A prospective cohort design was used in this part of the study.

6.3.2. Subjects

The subjects described in the epidemiology study (Chapter 3) and in the prospective study (Chapter 4) participated in this study. A total of 102 male club rugby players were recruited from four rugby clubs in the Western Province (South Africa) Premier A and Super league division. Convenience sampling was used to select the clubs that participated in this study. Inclusion criteria for preseason testing were all rugby players aged between 18 and 35 years from these clubs who would start the season. Rugby players who reported a current injury and who would not be starting the season due to this injury were excluded from preseason testing. The age (mean ±SD) of the subjects was 23.9 ± 4.5 years, the mean height was 175.4 ± 6.2 cm and mean weight was 78.4 ±16.5 kg. The project was approved by the Research Ethics Committee of the University of Cape Town and all subjects provided written informed consent.

6.3.3. Preseason measurements

All subjects were tested prior to the commencement of the 2001 rugby season at the Sport Science Institute of South Africa, Cape Town, South Africa. Each subject completed a pre-season medical questionnaire (Appendix 2) to establish past injury history with particular relation to hamstring strains and a training history with particular relation to strength and flexibility training. The following physical tests were conducted. All subjects underwent the tests in the following order.

a) The slump test
b) Concentric and eccentric hamstring and quadriceps strength
c) The straight leg raise test
d) The sit and reach test
e) Body composition
f) Muscle endurance: 2-minute sit-up test
g) Agility testing: the Illinois agility test
h) Aerobic testing: the multistage shuttle run

The description of these tests has been detailed in chapter 4. As reported previously neither players nor their coaches were given the results of the tests and no specific rehabilitation programme was implemented on the basis of the deficits detected from the testing.

6.3.4 Diagnosis of hamstring strain

Players were monitored throughout the 2001 rugby season from April to October 2001. The physiotherapist was present at all the matches or practice sessions and made the diagnosis of all injuries. In addition all subjects were contacted by telephone during and immediately after the season to ensure no injuries were missed. A specific injury report form (Appendix 3) was used to standardize clinical examination and diagnosis of the hamstring injury. The diagnosis of a hamstring injury was made on the basis of clinical symptoms and signs. All the players with hamstring injury reported a history of sudden onset of hamstring muscle pain during sprinting or kicking. Clinical signs to confirm the diagnosis were local tenderness, decreased range of motion on a straight- leg- raise test on the affected side, and decreased strength and pain on resisted isometric contraction of the hamstring muscle in the prone position in inner, mid or outer range compared to the unaffected side. Finally, an injury was only recorded if it was severe enough to cause the player to miss a practice or match. Players who sustained a hamstring injury during the season formed the Injured group (I group) while players with no hamstring injuries formed the non-injured (NI) group.

The severity of a hamstring strain was classified as minor if less than 3 sessions were missed; intermediate if more than 3 and less than 10 sessions were missed; and severe if more than 10 sessions were missed. Any practice or match was classified as a session.

The players from the four rugby clubs were involved in 22 matches during the season excluding preseason games, which accounts for 1972 player hours of game time. Training hours were calculated at 2 sessions of 2 hours each week for two clubs and 2 sessions of 1.5 hours each week for the remaining clubs. Pre-season training hours were excluded. A total of 5021 player-training hours were studied. Injuries sustained during games were documented as injuries per 1000 player game hours, and injuries during training as injuries per 1000 player training hours. The sum of injuries sustained during games and training were documented as injuries per 1000 hours of total exposure.

6.3.5. Statistical analysis

The parameters of outcome from the isokinetic muscle strength testing were absolute and relative peak torque (peak torque per body weight), concentric and eccentric hamstring to quadriceps ratios, eccentric hamstring to concentric quadriceps ratios and hamstring to opposite hamstring ratios. The results of the slump test; the straight leg raise test; sit and reach test, skin fold assessment, agility Illinois test and multistage shuttle test were also analyzed. Paired t-tests were used to compare the injured and non-injured legs in injured players and the legs with and without a history of a hamstring strain. For all other comparisons of injured and non-injured players in terms of selected variables, univariate F-tests were used. Univariate F-tests were also used to compare the non-injured leg of injured players with the mean of the right and left leg of non-injured players with regard to the results of the isokinetic testing. A significance level of $p < 0.05$ was set for all the tests.

6.4. Results

6.4.1. Seasonal incidence of hamstring strains

In this cohort, 38.1% of all injuries were muscle strains and 32.4% of the muscle strains were hamstring strains. The incidence of hamstring strains was 2.3 injuries /1000 total rugby exposure hours. Nine of the 100 players (9%) sustained one or more clinically diagnosed hamstring strains during this season, which resulted in them missing playing time. Three players sustained more than one hamstring strain during the season. One of these players sustained a right and left hamstring injury during the season. Two players had two strains of the same hamstring during the season. Nine hamstring injuries occurred to the right leg and three to the left leg. This represented ten (83.3%) hamstring injuries to the dominant leg and two (16.6%) to the non-dominant leg. The amount of time missed from practices and games ranged between 3 to 10 sessions.

6.3.2. Physical characteristics of the players

There were no significant differences [mean ±SD] between the hamstring injured group (I) and non-injured group (NI) with respect to age (years) [I =26.0 ±4.0, NI = 23.6 ±4.0], years playing rugby [I =12.1 ±5.7, NI=10.8 ±6.8], weight (kilograms) [I=80.7 ±10.9, NI=77.8 ±16.3], and height (meters) [I=173.2 ±6.8, NI=175.4 ±6.2]

6.3.3. Use of thigh sleeves, anthropometric measurements and preseason training of the players

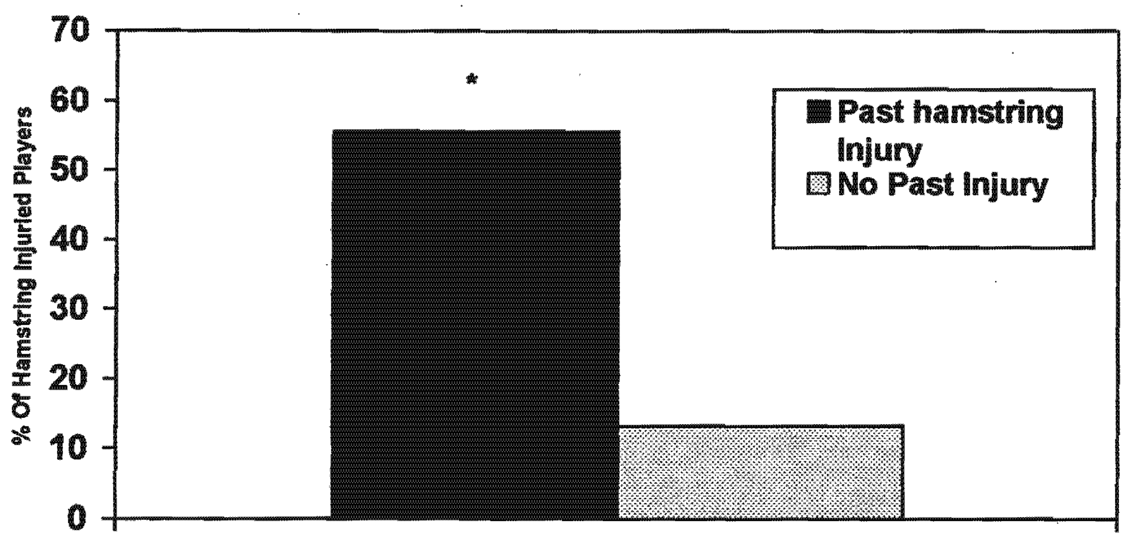
The use of thigh sleeves, anthropometric measurements and pre-season training of the injured and non-injured groups is depicted in Table 6.1.There were no significant differences between the two groups with respect to use of thigh sleeves, body composition, aerobic training; hamstring stretching or lower body strengthening as reported in the pre-season.

Table 6.1. Use of thigh sleeves; anthropometric measurements and preseason training of the players. Values are reported as frequency (%) or mean (SD)

Variable	*Injured Group (I) n=9*	*Non-Injured Group (NI) n=91*	*p value*
Use of thigh sleeves (Match) (% players)	1(11.1%)	7 (7.5%)	0.703
Use of thigh sleeves (Practice) (% players)	1 (11.1%)	4 (4.3%)	0.366
Sum of skin folds (mm)	95 (37)	84 (41)	0.438
Midthigh circumference (mm)	14.3 (5.3)	13.9(6.7)	0.881
Endurance Training			
Jogging (sessions/wk)	2.1 (0.7)	2.3 (1.0)	0.791
Jogging (min. /session)	40.0 (39.5)	38.7 (30.3)	0.921
Swim. (Sessions /wk)	1.0 (0.0)	1.9 (1.4)	0.188
Swim. (Min/session)	34.5 (24.3)	59.8 (52.6)	0.356
Hamstring stretching	8 (88.9%)	68 (74.7%)	
Sec. /stretch (sec)	17.3 (17.9)	28.0 (28.8)	0.307
No. stretches / session (no.)	3.4 (2.7)	2.9 (1.7)	0.493
Sessions/wk (no.)	3.4 (1.7)	4.0 (2.9)	0.529
Lower body strengthen.	4 (44.4%)	26 (27.9%)	
No. of sessions/wk (no.)	1.3 (0.5)	1.9 (0.9)	0.222
Reps /session (no.)	60.0 (42.4)	56.9 (39.9)	0.888
Sets /session (no.)	3.5 (1.3)	4.3 (4.4)	0.729

6.3.4. Past history of hamstring injury

A significantly greater percentage of players who sustained a hamstring injury during this study reported a history of hamstring injury compared with the non-injured group (55.6% vs. 13.2%; p= 0.001) [Pearson chi-square of 10.42, odds ratio of 8.23] Figure 6.1. Therefore, rugby players with a past history of a hamstring injury were 8.23 times more likely to sustain a hamstring injury than those without a past history.



* p=0.001

Figure 6.1 Injured players with a past history of a hamstring strain

6.3.5 Concentric and eccentric muscle strength and balance

The relative (peak torque per body weight) hamstring and quadriceps concentric and eccentric muscle strength variables for non-injured legs in injured players and the mean of right and left legs in non-injured players are depicted in Table 6.2. There were no significant differences between the injured and non-injured players with respect to concentric and eccentric quadriceps and hamstring strength.

The absolute (maximum torque) hamstring and quadriceps concentric and eccentric muscle strength variables for injured and non-injured legs in injured players are depicted in Table 6.3. There were no significant differences between the injured and non-injured legs of the injured players with respect to concentric and eccentric quadriceps and eccentric hamstring strength. However, concentric hamstring strength in the injured legs was greater compared with non-injured legs (p=0.04).

There were no significant differences in concentric hamstring to opposite hamstring ratio for the injured players 0.98±0.14 and non-injured players 0.94 ±0.16 and eccentric hamstring to opposite hamstring ratio for the injured players 1.03 ±0.19 and non-injured players 0.99 ±0.15. There were no significant differences between the two groups in terms of side-to-side hamstring muscle balance.

Table 6.2: Absolute and relative peak torque and ratios for injured leg of hamstring injured players and the mean of left and right legs in non-injured players

Variable	***Injured players (n=7) Mean (SD)***		***Non-injured players (n=75) Mean (SD)***		***p-value***
	Mean	SD	Mean	SD	
Concentric quad (N.m)	194	(41)	184	(35)	0.47
Eccentric quad (N.m)	277	(85)	265	(59)	0.61
Concentric ham (N.m)	130	(28)	122	(25)	0.47
Eccentric ham (N.m)	200	(53)	170	(37)	0.05
Concentric Quad (N.m/kgBW)	2.4	(0.21)	2.9	4.18	0.79
Eccentric Quad (N.m/kgBW)	3.5	(0.58)	3.98	4.62	0.77
Concentric Ham (N.m/kgBW)	1.6	(0.16)	1.89	2.61	0.80
Eccentric. Ham (N.m/kgBW)	2.5	(0.42)	2.53	2.83	0.99
Dynamic ratio	0.98	(0.13)	0.95	0.23	0.68

Quad, quadriceps muscle; Ham, Hamstring muscle; Con, concentric torque; Ecc, eccentric torque; BW, body weight

Table 6.3. Relative peak torque (expressed as peak torque per kg body weight) and ratios for non-injured leg of hamstring injured players and the mean of left and right legs in non-injured players

Variable	*Injured players (non-injured leg) (n=7)*	*Non-injured players (n=76)*	*P value*
Concentric Quad (N.m/kgBW)	2.32 (0.12)	2.80 (3.37)	0.71
Eccentric Quad (N.m/kgBW)	3.47 (0.74)	4.03 (4.63)	0.75
Concentric Ham (N.m/kgBW)	1.49 (0.26)	1.90 (2.55)	0.68
Eccentric. Ham (N.m/kgBW)	2.32 (0.40)	2.72 (4.22)	0.81
Con Ham/Quad ratio	0.67 (0.07)	0.67 (0.12)	0.89
Ecc. Ham / Quad ratio	0.72 (0.10)	0.66 (0.14)	0.27
Ecc. Ham/ Con Quad	1.02 (0.13)	0.95 (0.22)	0.48

Quad, quadriceps muscle; Ham, Hamstring muscle; Con, concentric torque; Ecc, eccentric torque; BW, body weight

Table 6.4. Absolute peak torque and ratios for injured and non-injured legs of players who sustained hamstring injuries

Variable	*Injured legs (n=7)*	*Non-injured legs (n=76)*	*P value**
Concentric Quad (N.m)	193.6 (40.6)	183.4 (28.9)	0.23
Eccentric Quad (N.m)	277.3 (84.5)	280.7 (100.4)	0.82
Concentric Ham (N.m)	129.6 (27.8)	119.4 (31.8)	***0.04**
Eccentric Ham (N.m)	198.3 (50.3)	186.1 (55.3)	0.22
Con Ham/Quad ratio	0.6 (0.1)	0.7 (0.1)	0.54
Ecc Ham/Quad ratio	1.5 (0.1)	1.4 (0.1)	0.26
Ecc Ham/ Con Quad	1.0 (0.2)	1.0 (0.1)	0.66

Quad, quadriceps muscle; Ham, Hamstring muscle; Con, concentric torque; Ecc, eccentric torque
***p< 0.05**

6.3.6. Flexibility

The flexibility tests included the slump test, the passive straight leg raise test (S.L.R test) and the sit and reach test. The results of the slump test of the injured and non-injured groups are depicted in Table 6.5. There were no significant differences between the two groups with respect to the pain response of the cervical extension component of the right leg, and cervical flexion and extension component of the left leg. However, the pain response of the cervical flexion component of the slump test for the right leg was significantly lower in the hamstring-injured group compared to the non-injured group (p=0.027).

The results of the passive SLR test of the hamstring injured and non-injured groups are depicted in Table 6.6. There were no significant differences with respect to range of motion of passive left SLR with ankle dorsiflexion. However, the passive straight leg raise test with ankle dorsiflexion and plantarflexion of the right leg was significantly more in the injured group than that of the non-injured group p=0.01and p= 0.04 respectively. The passive straight leg raise test with ankle plantarflexion of the left leg was significantly more in the injured group than the non-injured group (p=0.04). The hamstring-injured group was significantly more flexible than the non-injured group. The results of the sit and reach test of the hamstring injured group compared to the non-injured group is depicted in Table 6.6. There was no significant difference between injured players and non-injured players in terms of the sit and reach test.

Table 6.5. Pain response (V.A.S 0 -10) of the slump test for injured and non-injured players

Lower limb & cervical component	*Injured players Pain response (n=9)*	*Non-injured players Pain response (n=93)*	*P value*
R cervical flexion (VAS)	2.7 (3.0)	4.9 (2.8)	***0.027**
R cervical extension (VAS)	1.0 (1.2)	1.7 (1.8)	0.26
L cervical flexion (VAS)	2.9 (2.9)	6.1 (7.7)	0.22
L cervical extension (VAS)	1.1 (1.3)	1.6 (1.9)	0.47

***p<0.05**

Table 6.6. Range of motion of the SLR and Sit and Reach Test for injured and non-injured players

Variable	*Injured Players (n=9)*	*Non-injured Players (n=91)*	*P value*
R S.LR Dorsiflexion (°)	92.2 (22.2)	76.4 (15.3)	***0.01**
R S.L.R Plantarflexion (°)	95.2 (19.9)	83.3 (16.4)	***0.04**
L S.L.R Dorsiflexion (°)	88.4 (18.5)	78.3 (16.9)	0.09
L S.L.R Plantarflexion (°)	97.7 (19.1)	83.9 (19.4)	***0.04**
Sit and Reach (cm)	31.3 (9.1)	26.6 (8.9)	0.13

* <0.05

6.3.7 Muscle strength endurance; agility and endurance testing

The strength endurance, agility and endurance fitness of the hamstring injured and non-injured groups are depicted in Table 6.7. There were no significant differences between the injured and non-injured players in terms of the sit-ups, agility, and multistage shuttle run tests.

Table 6.7: Strength endurance; agility and aerobic fitness of injured and non-injured players

Variable	*Injured Players (n=9)*	*Non-Injured Players (n=93)*	*P value*
Sit ups (2min)	51.6 (12.1)	53.2 (17.9)	0.79
Agility (I test) (sec.)	16.6 (0.9)	16.7 (0.9)	0.86
Multistage Shuttle Run			
Level	7.6 (3.1)	8.7 (2.3)	0.16
No of shuttles	60.6 (30.9)	74.4 (24.1)	0.12

6.3.8. Positions injured, mechanism of injury and time of injury

Of the nine players who sustained a hamstring injury, six (66.67%) were backline players and three (33.3%) were forwards. Eight hamstring injuries occurred in matches of which 5 occurred with open running; 1 with kicking; 1 in the line-out and 1 in the ruck/maul. Of the 8 injuries that occurred during the matches, 3 occurred in the 3rd quarter of the game, 2 in the first and last quarter each, and 1 in the 2nd quarter of the game. The four hamstring strains that occurred during practices occurred during speed training. Most of the hamstring injuries occurred in the second half of the season soon after the midseason break that was in June. (Figure 6.2)

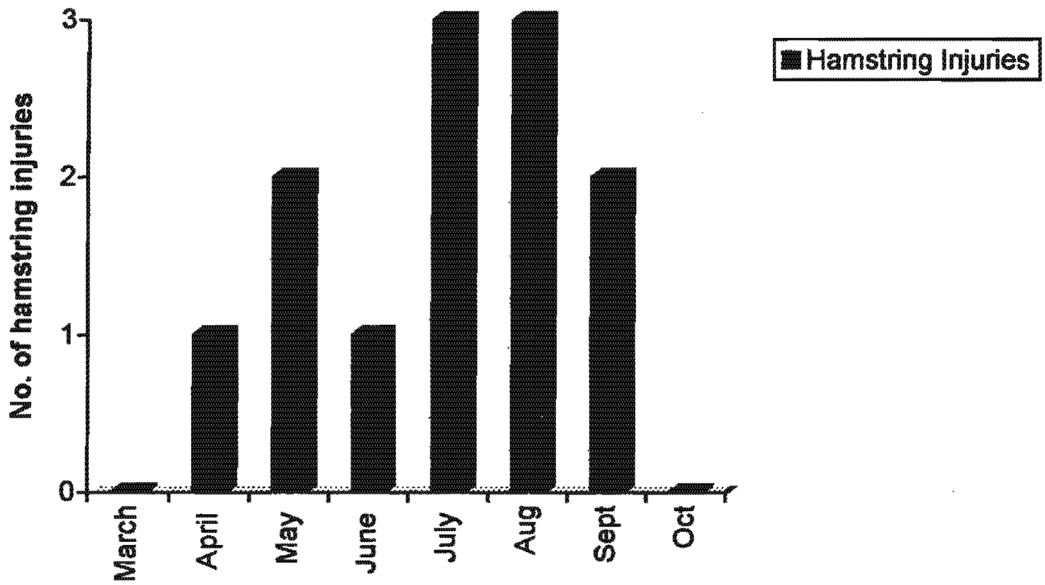


Figure 6.2. Hamstring injury occurrence (number) during the club rugby season

6.3.9. Weather and field conditions

Eight hamstring strains occurred during the day with 5 occurring in mild weather conditions, 2 in hot and 1 in cold weather conditions. Four hamstring injuries occurred at night and the weather conditions were classified as mild in 2 cases and hot in 1 and cold in another case. All hamstring injuries occurred during play on grass, which was classified as soft in six cases, dry in 5 cases and slippery in one case. Six of the nine players were wearing short studs, four players were wearing medium length studs and one player wore long studs at the time of injury.

6.4 Discussion

6.4.1 Seasonal incidence of hamstring strain

The seasonal incidence of hamstring injuries in this cohort of club rugby players was 9% (2.3 hamstring injuries /1000 total rugby exposure hours). This seasonal incidence is similar to the incidence reported in other prospective studies of this nature[7;8;13]. However, these studies were done on Australian Rules football players and not on rugby players. Previous epidemiological studies conducted in South African rugby players reported a seasonal incidence of 4.3% in school rugby players; 11% in club rugby players and 4% in professional rugby [2]. A comparison between studies is difficult as few studies relate incidence of hamstring injuries to exposure time to rugby.

6.4.2 Physical characteristics of the players

It has been reported that increasing age is a risk factor for muscle strains particularly hamstring strains[13;12;57]. It has also been reported that an increase in age of one year can increase the likelihood of hamstring injury by 1.3 times independent of a past history of posterior thigh pain[12]. Players older than 23 have also been reported to have an increase risk of a hamstring strain[13]. Although players in the hamstring-injured group in our study were older (26 ±4 years) compared to the non-injured group (24 ± 4 years) this was not statistically significant.

The number of years playing rugby has also been reported to increase the risk of injury but this was not specific to hamstring injuries[57]. In our study the hamstring-injured group reported more years of playing rugby than the non-injured group but this was not statistically significant. It has been reported that hamstring-injured players are taller but not heavier than the non-injured players[12]. In our study injured players were shorter than non-injured players but this was not statistically significant. We could therefore not confirm that increasing age or anthropometrics variables (height; weight) are risk factors for hamstring injuries in club rugby players.

6.4.3. Use of thigh sleeves and preseason training of the players

It has been reported that the use of thigh sleeves may reduce the incidence of hamstring strain by maintaining an increased temperature of the muscle during exercise[14]. In our study, we did not show any difference in the usage of thigh sleeves between hamstring injured and non-injured groups. However, the exposure to rugby and usage of the sleeves was not specifically measured in this study.

There were no significant differences between hamstring injured and non-injured players in terms of reported pre-season training. However, in the hamstring injured group there was a higher incidence of lower body strengthening and hamstring flexibility training in the preseason. This is probably related to the higher incidence of past hamstring injuries in this group and implies that players were engaging in more hamstring stretching to prevent recurrent injuries. The specific types of the strengthening programs of these players were not recorded.

This study cannot confirm the non-usage of thigh sleeves and the type of preseason training as risk factors for hamstring injury.

6.4.4. Past history of hamstring injury

This study confirms the results of other recently published studies that a previous hamstring injury is a significant risk factor for a recurring hamstring injury[13;12;8]. An odds ratio of 2.1 for hamstring injury in players with past history of hamstring injury has been reported[12]. In the present study an odds ratio of 8.23 for hamstring injury was shown, indicating that a player with a history of a previous hamstring injury is 8.23 times more likely to sustain another hamstring injury. It has been postulated that past hamstring injuries could be related to low hamstring muscle strength or poor hamstring flexibility.

6.4.5. Concentric and eccentric hamstring and quadriceps ratios

In this study we found no association between preseason concentric and eccentric isokinetic hamstring weaknesses and subsequent hamstring strains. It has previously been reported that there is an increased hamstring injury risk with a 10% muscle imbalance from side to side; isokinetic ratios of less than 60 % on either leg and less than 0.61 hamstring to quadriceps ratios measured at an angular velocity of 60°/sec[7]. The results of our study did not confirm this. There was no side-to-side hamstring muscle imbalance found in this study. None of the injured players in this cohort had a hamstring to quadriceps ratios of less than 0.61, (the mean ratio in this cohort was found to be1.00). These results indicate that players focus attention on increasing hamstring muscle strength and optimizing ratios but despite achieving this, hamstring injuries could not be prevented.

A limitation of our study is that hamstring and quadriceps ratios were not tested at higher speeds and that these higher speeds would more accurately simulate the sporting activity. However, studies that have documented an association between hamstring weakness and hamstring strains have these findings when testing was conducted at 60 degrees/second. A further limitation of our study, as with all other previous prospective studies is that isokinetic testing in the preseason may not have a predictive capacity of hamstring injuries during the season because the muscle ratios may change as the season progresses due to training, other injuries or fatigue.

The dynamometry isokinetic testing used in our study is an open chain activity while hamstring injuries mainly occur during running which is a closed chain activity. There may be value in testing the hamstring muscle control during a closed chain functional activity.

In our study, the injured leg of the players who sustained hamstring injuries demonstrated increased concentric hamstring strength compared to the non-injured leg. This could be as a result of selective strength training of previous injured hamstrings or pursuing leg dominance.

In summary, the results did not identify isokinetic muscle weakness as a risk factor for hamstring injury.

6.4.6. Flexibility

It has been reported that decreased flexibility is a risk factor for hamstring injuries. In most instances, studies that have reported the association between hamstring injury and reduced flexibility in the hamstring muscle have been of cross-sectional design, rather than prospective cohort studies[5;103;113]. In a recent prospective study of 146 Belgian male professional soccer players, reduced muscle flexibility was documented as a risk factor for hamstring injuries. However, this differed from our study and previous studies in that it specifically excluded subjects with previous hamstring injuries[11]. In addition, poor standardization and reliability of the methodology of flexibility measurements was the main limitation of the Belgian study. In other prospective cohort studies that have included reliable flexibility tests in the preseason, and that have not excluded subjects with previous hamstring injuries, flexibility was not a predictor for hamstring strain[7;93]. The results of our study confirmed this.

It has also been suggested that reduced neural flexibility, as tested by the slump test, could be a risk factor for hamstring injuries. In this study, players who sustained hamstring strains in the season demonstrated significantly greater flexibility as tested by the slump test on the right leg and by the right SLR dorsiflexion and plantarflexion and left SLR plantarflexion than non-injured players. This finding does not support the hypothesis that reduced neural flexibility increases the risk of hamstring injury. We suggest that players with a past hamstring injury engaged in flexibility training in order to prevent a recurrent hamstring injury, based on the commonly accepted hypothesis that increased flexibility reduces hamstring strains.

6.4.7. Muscle strength endurance, agility and endurance fitness

This study confirms the results of a previous study[7] that general strength endurance; agility testing or endurance fitness at the start of the season cannot be used to predict the risk of hamstring injury. It has been postulated that fatigue could be a risk factor for hamstring injury. Although agility testing has been shown to be a possible predictor for lower limb injury or any rugby injury it has not been found to be a predictor of hamstring injury. The preseason testing used in this study may not be specific enough to test hamstring muscle fatigue. Another limitation of our study is that these fitness variables may change over the season. It does however show that overall fitness of the player did not predispose the player to hamstring injury.

6.4.8. Positions injured, mechanism of injury, time of injury

To date, no studies have reported that certain positions played in rugby have an increased susceptibility to hamstring injuries. It has been postulated that it would occur in the players engaged in bursts of acceleration and deceleration and this would mainly be the backline players. In our study we show that 66.6% of the players who sustained hamstring injuries were backline players. The playing positions injured may relate to the mechanism of injury, which is mainly running. However, no cause-effect relationship can be drawn, as exposure time specific to each player position was not analyzed.

It has been reported that hamstring injuries occur either quite early or in the latter stage of practices or matches[107]. This has led to the conclusion that improper warm-up and development of muscle fatigue are risk factors for injury[102]. Poor conditioning may be a factor in the early stages while fatigue may be a factor in the latter stages. In our study there was no consistency of when hamstring injuries occurred in various phases of the matches and practices. However, the sample size of hamstring injuries in our study was too small to accurately determine if such a pattern existed.

6.4.9. Field and weather conditions

It has been postulated that hamstring injuries are more likely to occur in cold and wet conditions[102] but this was not shown in this study. None of the studies that have examined risk factors for hamstring injuries have reported on weather or field conditions at the time of injury. The present study could not determine any pattern with regard to weather or field conditions in relation to hamstring injuries due to the small number of injuries in this cohort.

6.5. Summary

The *muscle strength-flexibility-fatigue model* for the prediction of hamstring injury risk is not supported by the results of this study. Muscle strength, strength endurance, agility and endurance fitness tested in the preseason were not related to hamstring injuries. Rather, players with previous hamstring injuries were 8.23 times more likely to sustain a recurrent hamstring injury despite being as strong and flexible as non-injured players. We postulate that an alternative model be examined to explain why previous injuries increase the risk of hamstring injury, despite increased strength and flexibility.

We propose that the neuromuscular control of hamstring contraction, in particular the firing patterns of the hamstring muscle during running need to be analyzed. The periodic firing pattern of the nerve supplying the hamstring muscle group may be altered, thereby influencing the reactive ability of the muscle. A protective reflex hamstring contraction could result in an uncoordinated agonist-antagonist action. This new *neuromuscular control model* could be assessed by studying whether abnormal firing patterns of the hamstring muscle, exist in previously injured hamstring muscles. This would be the focus of future research to be conducted in our unit.

Chapter Seven

Summary and conclusions

Rugby is a contact sport associated with a high incidence of injury at school, club and professional levels. It is however difficult to make conclusive statements about the incidence of injury in rugby due to the differences in study design. Most studies reported injuries merely as frequency rather than documenting injuries as incidence per 1000 hours. There are still studies that fail to adhere to the IRB guidelines in terms of injury definition. There however appears to be a lower incidence of injuries among school rugby players compared to club and professional rugby players. In the comparison of injuries between school and professional rugby the incidence of concussion remains a problem particularly at school level. There is a lower incidence of concussion for professional rugby players that cannot be explained. The higher incidence of fractures of the upper limb at school level can also not be explained. The type of injuries, the anatomical distribution and the mechanism of injury for school and adult rugby players are similar. The sparse epidemiological data of South African rugby at all levels of play could be responsible for the lack of effective and accurate prevention programmes for rugby injury.

The first part of this thesis examined the seasonal incidence and nature of injuries of a 102 club rugby players. A high incidence of injury was reported for the 2001 rugby season for these players. The most common site of injury was the thigh of which hamstring strains were the most common. Ankle sprains were the next most common injury. The flanks, wings and centres were the positions of play most affected by injury and the most dangerous phase of play was the tackle. The highest incidence of injury was at the beginning of the season and most injuries occurred in the final half of the game. This data forms the basis on which the nature and risk factors for rugby injury could be examined.

The role of pre-season testing as possible predictors for rugby injury was examined. The possible risk factors that were analysed were age, years playing rugby, previous injury history, anthropometric factors, inflexibility, isokinetic muscle weakness, poor strength endurance, decreased agility, decreased endurance fitness and decreased height with the vertical jump. The physical tests that demonstrated an association with injury on the multivariate analysis were the two-minute sit-up test, one minute push up test, the agility test and the concentric quadriceps and eccentric hamstring strength. The players who completed between 46 and 60 repetitions on the two-minute sit-up test were at greater risk of a lower limb injury. Players who had performed less than 32 repetitions (p=0.03) or between 32 and 40 repetitions (p=0.01) on the one-minute push-up test were at increased risk of sustaining a rugby injury. Players who completed the agility test in less than 15.91seconds, between 15.91 and 16.39 seconds and between 16.4 and 16.89 seconds had increased risk of a rugby injury. The players who completed the agility test in more than 16.4 seconds had increased risk of a lower limb injury. Players with less than 150Nm torque eccentric hamstring strength and between 159.1-211.58 Nm torque concentric quadriceps strength were at greater risk of a lower limb injury.

This study failed to show any strong predictors for rugby injuries or lower limb rugby injuries. There is a possible association between poor strength endurance, poor concentric quadriceps and eccentric hamstring muscle strength and lower limb injury. The fastest and slowest players in the agility test are also at greater risk of injury. The accuracy and validity of the physical pre-season tests used for rugby players need to be investigated. The tests used in this study may fail to test the unique combination of skill, strength, speed and fitness required in rugby. Future research needs to investigate the findings with a larger sample size and more positional specific tests. However, there is preliminary evidence to suggest that there is an association with the players at either end of the spectrum (i.e fittest or least fit and fastest or slowest) that increase the risk of injury.

The second part of the thesis reviewed and investigated the risk factors of hamstring injury. The review examined intrinsic (person-related) and extrinsic (environment-related) risk factors for hamstring injury. There was conflicting evidence regarding isokinetic muscle weakness and muscle inflexibility as intrinsic risk factors for hamstring injuries. There was strong evidence to suggest that increased age and past history of a hamstring injury are independent intrinsic risk factors for hamstring injury. Future studies need to ensure that there are no confounding variables. There appears to be some relationship between the use of thermal pants and the reduction in the incidence of hamstring injury but more conclusive evidence is required. There is no evidence to suggest a significant relationship between anthropometric characteristics, physical fitness and environmental factors with the incidence of hamstring injury.

The *muscle strength-flexibility-fatigue model* and its prediction status of hamstring injury was not confirmed by this study. Muscle strength, muscle inflexibility, strength endurance, agility and endurance fitness as tested in the pre-season were not related to hamstring injuries. It was found that players with a past history of hamstring injury were 8.23 times more likely to sustain a recurrent hamstring injury. These players had no muscle weakness or muscle inflexibility at the start of the season.

An alternative model is needed to explain the phenomenon of recurrent hamstring injury in players despite normal isokinetic muscle strength and muscle flexibility. There has been a considerable amount of research identifying deficits in control in musculoskeletal pain[116]. Motor control rather than muscle strength has become the focus of rehabilitation of musculoskeletal pain. The control of movement refers to a sensory system that can detect the status of the system and external and internal factors that act on the body; a system that can interpret the sensory information and compare this with prior experience, predicted consequences, movement and stability demands; a central motor system that can act on the sensory inputs or motivation to move or plan appropriate strategies to meet the demands of the movement and/stability and a peripheral system that can act on the commands from the nervous system[116]. Exercise interventions have now incorporated these components to eliminate any deficits in motor control. The motor learning principles are applied to retrain the nervous system to use the muscles in a normal function.

A *neuromuscular control* model of hamstring injury needs to be analysed. The firing patterns of the hamstring muscle may be altered following the initial hamstring injury. The abnormal firing patterns can result in an altered reactive ability of the muscle. This could be the area of focus in future research.

Conclusions

- No conclusive statements can be made about the incidence of rugby injury due to differences in study design.
- The type of injuries, the anatomical distribution and the mechanism of injury for school and adult rugby players are similar.
- This study reported a high seasonal incidence of injury in club rugby players.
- The most common site of injury in club rugby players was the thigh of which hamstring strains were the most common.
- There is preliminary evidence to suggest that there is an association with the players at either end of the spectrum (i.e fittest or least fit and fastest or slowest) that increase the risk of injury.
- Muscle strength, muscle inflexibility, strength endurance, agility and endurance fitness as tested in the pre-season were not related to hamstring injuries.
- It was found that players with a past history of hamstring injury were 8.23 times more likely to sustain a recurrent hamstring injury.
- An alternative model is needed to explain the phenomenon of recurrent hamstring injury in players despite normal isokinetic muscle strength and muscle flexibility.

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Appendix 1

RESEARCH PROJECT 2001

INFORMED CONSENT FOR PHYSICAL TESTING

This research project involves pre-season testing of club level rugby players and monitoring and recording of injuries throughout the season. The aim is to identify the possible risk factors for lower limb injuries, which will assist in prevention of rugby injuries.

You will undergo the following tests:

1. Sit and Reach Test: To assess flexibility of your back and hamstring muscles
2. The Straight Leg Raise Test: To assess the flexibility of both legs.
3. Abdominal Sit Ups: To assess the number of sit-ups that can be completed in 2 minutes. There is risk of back pain or injury if done incorrectly, or with pre-existing back pain.
4. Agility Test: To assess your agility and speed. This test could aggravate an existing lower limb injury.
5. Multistage Shuttle Test: To assess your endurance.
6. Skin Fold Testing: To assess body fat composition
7. Isokinetic Testing: To assess strength of the hamstrings and quadriceps muscles and to compare their strength. There is minimal risk of a mild muscle strain if you have a muscle injury or fail to warm-up prior to the test.
8. Slump Test: To assess flexibility of the structures in your legs and back.

All necessary precautions will be taken to eliminate the minimal risks that do exist with these tests. You are free to withdraw at any stage of any of the tests. Your participation is voluntarily and you may withdraw at any time. There is a possibility that photographs or video material may be taken of you while tests are being conducted for research purposes.

I, ..., do hereby declare that to the best of my knowledge I am currently free from any existing medical condition or other complaint that would preclude me from undertaking any physical tests that have been described to me.

Signed at (place) .... on (date)................2001

Signature: .... Witness:...........................

Appendix 2

PRESEASON PLAYER MEDICAL PROFILE

Date:

A. PLAYER DETAILS

NAME:		
POSTAL ADDRESS:		
PHONE: CELL: WORK: HOME: FAX:		
AGE:	DATE OF BIRTH:	

PLAYING POSITION:		
YEARS OF PLAYING RUGBY		
NAME OF CLUB		
YEARS WITH PRESENT CLUB		
LEVEL OF PLAY IN THE CLUB		
LEVEL OF CLUB IN THE LEAGUE		
OTHER SPORT ACTIVITY:	LEVEL OF PLAY:	

NEXT OF KIN: PHONE (NEXT OF KIN):		

B: MEDICAL SCREENING:

1. CURRENT AND PREVIOUS INJURIES

Do you have, or have you ever had, any of the following conditions?

Nr.	INJURY	CURRENT (tick)	BEFORE (tick)	
1.	Concussion(s) Number:			
2.	Skull fracture(s) Number:			
3.	Neck injuries			
4.	Shoulder injuries			
5.	Arm/wrist/hand injuries			
6.	Ribcage/sternum injuries			
7.	Back injuries			
8.	Hip/groin injuries			
9.	Thigh injuries			
10.	Knee injuries			
11.	Lower leg injuries/shinsplints			
12.	Ankle injuries			
13.	Foot injuries			
14.	Muscle strains ("pulls")			
15.	Abdominal injuries			
16.	Any other injuries?			
17.	False teeth/bridge/crown?			

Details of injuries ticked off: (Please specify right or left where applicable)

Nr.	Injury no. 1: Diagnosis: Date: Treatment: Doctor/physio: Complete recovery Yes/No	
Nr.	Injury no. 2: Diagnosis: Date: Treatment: Doctor/physio: Complete recovery Yes/No	
Nr.	Injury no. 3: Diagnosis: Date: Treatment: Doctor/physio: Complete recovery Yes/No	
Nr.	Injury no. 4: Diagnosis: Date: Treatment: Doctor/physio: Complete recovery Yes/No	
Nr.	Injury no. 5: Diagnosis: Date: Treatment: Doctor/physio: Complete recovery Yes/No	

2. PAST ILLNESS OR MEDICAL PROBLEMS

Do you now have, or have you ever had, any of the following conditions?

Nr.	ILLNESS/CONDITION	CURRENT (tick)	BEFORE (tick)	
1.	Frequent headaches			
2.	Fainting spells/dizziness			
3.	Epilepsy or convulsions			
4.	Nosebleeds			
5.	Difficulty hearing			
6.	Frequent colds			
7.	Rheumatic fever			
8.	Heart murmur			
9.	High blood pressure			
10.	Diabetes			
11.	Skin disorders			
12.	Allergies: Food that should not be taken Skin allergies Medicines			
13.	Asthma			
14.	Hepatitis/jaundice			
15.	Indigestion/heartburn			
16.	Any other? Please state:			

Have you ever been hospitalized? **Yes/No**

Reason: ....

....

Do you have a family member that suffers from chronic disease (heart disease, blood pressure, seizures, asthma, diabetes, etc)? **Yes/No**

Please state details:	

Details of conditions ticked off:

Nr.	Condition no. 1: Diagnosis: Date: Treatment: Doctor/physio: Complete recovery Yes/No	
Nr.	Condition no. 2: Diagnosis: Date: Treatment: Doctor/physio: Complete recovery Yes/No	
Nr.	Condition no. 3: Diagnosis: Date: Treatment: Doctor/physio: Complete recovery Yes/No	
Nr.	Condition no. 4: Diagnosis: Date: Treatment: Doctor/physio: Complete recovery Yes/No	
Nr.	Condition no. 5: Diagnosis: Date: Treatment: Doctor/physio: Complete recovery Yes/No	

3. Immunisation

Have you ever been immunised against the following conditions?

IMMUNISATION	YES	NO	DATE	
Tetanus	Y	N		
Hepatitis A	Y	N		
Hepatitis B	Y	N		
Other in last year	Y	N		

3. MEDICATION/FOOD SUPPLEMENTS

Are you currently taking any medication (over the counter or prescription)?

Please state details:	

Are you currently taking any food supplements (vitamins, minerals, creatine, amino acids, etc)?

Please state details:	

4. PROTECTIVE EQUIPMENT

5.1. Do you use any of the following protective devices?

DEVICE	DURING MATCH		DURING PRACTICE		
Head shield	Y	N	Y	N	
Mouthguard	Y	N	Y	N	
Shoulder pads Left/right	Y	N	Y	N	
Thigh sleeve left/right	~~Y~~	N	Y	N	
Thermal pants					
Knee brace left/right	Y	N	Y	N	
Shin pads	Y	N	Y	N	
Ankle brace left/right	Y	N	Y	N	
Orthotics/inner soles	Y	N	Y	N	
Any other? Please state:	Y	N	Y	N	

5.2. Do you strap/tape any of the following?

ANATOMICAL PART	DURING MATCH		DURING PRACTICE		
Ears	Y	N	Y	N	
Shoulder: left/right	Y	N	Y	N	
Elbow: left/right	Y	N	Y	N	
Wrist: left/right	Y	N	Y	N	
Fingers	Y	N	Y	N	
Thigh	Y	N	Y	N	
Knee	Y	N	Y	N	
Ankle	Y	N	Y	N	
Any other? Please state:	Y	N	Y	N	

C. TRAINING PROFILE

Please complete the following table regarding your <u>stretching</u> habits for the past 3 months.

Muscle	How long do you hold your stretch?	How many stretches per session?	How many times per week?
Hamstrings			
Quadraceps			
Calf			
Groin			
Buttock			
Back			
Neck			
Biceps			
Triceps			
Deltoid			

If other please specify: ……………………………………………………………………………………

Please complete the following table regarding your <u>endurance</u> training for the past 3 months.

Type of training	How many sessions per week?	How much time per session?
Jogging		
Cycling		
Swimming		
Rowing		
Aerobic / Spinning Classes		

If other please specify ……………………………………………………………………………………

Please complete the following table regarding strength training for the past 3 months.

Type of training	How many sessions per week?	How much time per session?	How many sets?	How many repetitions per set?
Weight/gym training upper body				
Weight/gym training lower body				
Abdominals				

If other please specify ……………………………………………………………………………………

Please complete the table regarding other forms of training you may have done during the past 3 months.

Other training	How many sessions per week?	How much time per session?
Power training/plyometrics		
Skills training drills		

Please complete the table regarding other sport you may have done in the past 3 months.

Other sport	Level of play	How often
Cricket		
Touch rugby		
Beach Volleyball		
Golf		
Soccer		
Squash		

If any other please specify ……………………………………………………………………………………

Appendix 3

RESEARCH PROJECT 2001

INJURY REPORT

DATE: ______________

SECTION 1:

(To be completed by the player)

1. PLAYER INFORMATION

NAME:	
PLAYING POSITION:	
TEAM:	

PRE-SEASON MEDICAL PROFILE AND EXAMINATION DONE?	YES	NO	

2. ACTIVITY

DATE OF INJURY: ______________

MATCH OR PRACTICE	MATCH (tick)	PRACTICE (tick)	
	Hrs Played	Hrs Played	

Injury during match: (tick)

	vs.		

Injury during practice: (tick off)

Contact session		
Power training		
Speed Training		
Endurance training		
Skills training		

3. CONDITIONS

Please tick off:

WEATHER	HOT	COLD	MILD	RAINING		
	DRY	DAY	NIGHT			
SURFACE:						
Grass	WET	DRY	SOFT	FIRM	SLIPPERY	
Gravel & Grass	WET	DRY	SOFT	FIRM	SLIPPERY	
Gravel	WET	DRY	SOFT	FIRM	SLIPPERY	
STUDS	SHORT	MEDIUM	LONG			
TIME	1ST 20 MIN	2ND 20 MIN	3RD 20 MIN	4TH 20 MIN		

SECTION 2:

(To be completed by Physiotherapist/Doctor)

1. SITE OF INJURY

Head and neck: (tick off)

Face	Nose	Eye	Ear	
Neck	Head	Mouth	Jaw	

Upper limbs: (Please specify right or left)

Shoulder	Elbow	Wrist	Fingers	
Upper arm	Forearm	Hand	Collarbone	

Lower limbs: (Please specify right or left)

Pelvis	Hip	Knee	Foot	
Thigh (front)	Thigh (back)	Calf	Ankle	

Trunk:

Ribs	Sternum	Internal injury	Upper back	
Lower back	Groin	Buttock	Abdomen	

2. TYPE OF INJURY

Concussion	Muscle strain	Ligament sprain	Fractures	
Contusions	Internal organ	Chronic overuse	Lacerations	
If any other, please state:				

GRADING OF MUSCLE STRAIN:

GRADE 1	Mild pain with stretch /R.I.C.	Local tenderness
GRADE 2	Severe pain with stretch /R.I.C	Moderate tenderness
GRADE 3	Severe Pain/Painless	Palpable Defect

GRADING OF LIGAMENT SPRAIN:

GRADE 1	Mild pain with stretch /R.I.C.	Local tenderness
GRADE 2	Severe pain with stretch /R.I.C	Moderate tenderness
GRADE 3	Severe Pain/Painless	Palpable Defect

3. MECHANISM OF INJURY

Tackled	Tackling	Scrum	Line-out	
Open running	Ruck/maul	Foul play	Other	

If other, please describe: ………………………………………………………………………………

4. INJURY DETAILS:

SPECIFIC DIAGNOSIS:			
FIRST INJ/RECURRENT	First	Recurrent	
PROPHYLATIC BRACE/TAPING USED?	Please specify:		

5. **HAMSTRING INJURY** (complete if hamstring injury)

CLINICAL SIGNS: (tick)

Pain	Local tenderness	Decreased R.O.M of S.L.R.		
Pain with R.I.C Inner Range Middle Range Outer Range	Decreased strength on R.I.C.	Haematoma		

GRADING OF HAMSTRING STRAIN:

GRADE 1	Mild pain with stretch /R.I.C.	Local tenderness
GRADE 2	Severe pain with stretch /R.I.C	Moderate tenderness
GRADE 3	Severe Pain/Painless	Palpable Defect

6. **MANAGEMENT:**

Medical (tick)		Physiotherapy (tick)		Surgical	Rehabilitation	
Medication		Strapping				
Injection		Electrotherapy				
Sutures/Wound		Soft Tissue				
Investigations		Joint Treatment				
Other. Please specify:						

7. **RETURN TO MATCH FITNESS**: Date: ....

Number of sessions missed: (1session = 1 match or practice session. One week = 2 practice sessions and one game: 3 sessions)

3 or less	4 to 9	10 or more	Whole season	