TRAINING LOADS, INJURY PROFILES AND ILLNESS IN ELITE SOUTH AFRICAN RUGBY PLAYERS

A DISSERTATION BY CURT ARTHUR BARNES (BRNCUR001) IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE MASTER OF SCIENCE IN EXERCISE AND SPORTS PHYSIOTHERAPY FROM THE UNIVERSITY OF CAPE TOWN.

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DECLARATION

I, Curt Arthur Barnes (BRNCUR001), hereby declare that the work on which this dissertation is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

……Signed by candidate……

(Signature)

10/02/2019

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(Date)

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LIST OF ABBREVIATIONS

CEO- Chief Executive Officer

HREC- Human Research Ethics Committee

HRR- Heart Rate Recovery

EWMA- Exponentially Weighted Moving Averages

IRB- International Rugby Board

GPS- Global Positioning System

OR- Odds Ratio

RICG- Rugby Injury Consensus Group

RPE- Rate of Perceived Exertion

RWC- Rugby World Cup

sRPE- Session Rating of Perceived Exertion

TRIMP- Training Impulse

TRIPP- Translating Research into Injury Prevention Practice

UCT- University of Cape Town

URTI- Upper Respiratory Tract Infection

GLOSSARY OF RESEARCH TERMS

Acute training load: ***"****Acute training load is the number of exertional units calculated per one week of training and/or the total distance covered"* (Gabbett, 2016).

Chronic training load: *"Chronic training load represents a twenty-eight day (four week) rolling average of acute training load in exertional units and/or the total distance covered in metres"* (Hulin, Gabbett, Lawson, Caputi, & Sampson, 2016a).

Early competition: Early competition is defined by the outlined objectives for *"continual development of game-specific skills, maintaining aerobic endurance, anaerobic capacity, repeated effort ability, speed, agility and muscle power"* (Gabbett, 2010). In this study, early competition is ten weeks in total from the first official Super Rugby tournament game.

External training load: External training load is the physical 'work' completed by an athlete during training or a match and is calculated using a Global Positioning System (GPS) measuring the running metres covered (Gabbett, 2016).

Incidence: Incidence is the number of instances of illness or injury, during a given period of time in a specified population. Incidence can be measured as a frequency, a rate, or a proportion (Porta, 2014).

Injured Player Proportion: ***"****Injured player proportion is the proportion of participants that have sustained a time-loss injury over a specified period such as a tournament"* (Schwellnus et al., 2014).

Injury: Injury can be defined according to time-loss as *"any injury that prevents a player from taking full part in all training activities planned for that day and/or match play for more than one day following the day of injury"* (Fuller et al., 2007).

Internal training load: Internal training load is the physiological and perceptual response of an athlete to exercise training and will be calculated using the duration of each session multiplied by the scores of the modified rating of perceived exertion (RPE) scale which results in exertional units (Gabbett, 2016).

Late competition: Late competition is defined by the outlined objectives of *"maintaining game-specific skills, maintaining aerobic endurance, anaerobic capacity, repeated effort ability, speed, agility and muscle power"* (Gabbett, 2010). In this study, late competition is eleven weeks in total, from the end of early competition to the last game of the Super Rugby tournament.

Load: Load is described as *"the sport and non-sport burden (single or multiple physiological, psychological or physical stressors), as a stimulus that is applied to the human biological system over varying periods with varying magnitude"* (Schwellnus et al., 2016).

Medical Illness: A medical illness can be defined as *"any non-trauma related symptom and sign presenting in a player that required medical attention from the team physician on a specific day"* (Schwellnus et al., 2012).

Myopericarditis: Refers to an inflammatory process in the myocardium and the pericardium which is caused by enteroviruses and presents with influenza-like symptoms (Tseng, Hsieh, Hsu, Lin, & Chan, 2013).

Non-functional over-reaching: An accumulation of training and/or non-training stress which results in a plateau or decrease in an athletes performance with or without physiological and psychological signs and symptoms of maladaptation, lasting weeks to months until performance in restored (Meeusen et al., 2006).

Pre-season: Pre-season is defined by the outlined objectives of *"developing speed, agility and muscle power. Developing aerobic endurance, anaerobic capacity, repeated effort ability, speed, agility and muscle power"* (Gabbett, 2010). In addition, pre-season aims to develop game orientated skills for individuals and the team. In this study, pre-season was seven weeks preceding the first official Super Rugby tournament game.

Recurrent injury: A recurrent injury is defined as *"an injury of the same type and at the same site as the primary injury and which occurs after a player's return to full participation from the primary injury"* (Fuller et al., 2007).

Severity of time-loss: "*The number of days that have elapsed from the date of injury to the date of the player's return to full participation in team training and availability for match selection"* (Fuller et al., 2007). Severity is defined according to *"the number of days that a player is unable to train or play matches according to the classification: minimal (2-3 days), mild (4-7 days), moderate (8-28 days) and severe (≥28 days)"* (Schwellnus et al., 2014).

ABSTRACT

Background

Professional Rugby Union is a popular international team sport and is known to have one of the highest reported incidences of injury and illness across sporting codes. The Super Rugby tournament is played annually between professional Rugby Union teams and is one of the most competitive sports tournaments in the world. The demanding nature of the tournament has been associated with high rates of injury and illness, but the relationship between training loads on injury and illness profiles are unclear. As a result, the Super Rugby tournament is a platform to further investigate injury, illness and training load patterns within Rugby Union. Epidemiological data on training loads, injury profiles and illness patterns assist the development of preventative measures.

Aim

The aim of this study was to assess the relationships between training loads, injury profiles and illness rates in elite South African rugby players competing in the 2017 Super Rugby tournament.

Specific objectives

(a) To determine the incidence of training and match injuries during pre-season training, and early and late competition during the 2017 Super Rugby tournament; (b) To determine the incidence of illness during pre-season training, and early and late competition during the 2017 Super Rugby tournament; (c) To determine the anatomical site, type, mechanism and time-loss of injuries sustained during pre-season training, and early and late competition during the 2017 Super Rugby tournament; (d) To determine potential associations between internal and external training loads; and injury and illness, respectively.

Methods

A descriptive, observational, surveillance study design was conducted on the 2017 Super Rugby tournament. Thirty-nine adult participants were recruited from one South African team over a complete season, including preseason, early and late competition. Data were collected from the team medical personnel who routinely collected data on a daily basis. Training load data included squad size, training or match day, the duration of training or matches, and internal and external training load measures for training and matches.

Injury data included the participants age, the injury counts, the type of injury, the main and specific anatomical location, and the mechanism and severity of injury. Illness data included illness counts, the bodily system affected, symptoms and cause of illness, the specific diagnosis and time-loss.

Results

The overall incidence of injury was 12.8 per 1000 player hours. The majority (48.8%) of injuries occurred in the early competition phase. The incidence of match injuries (241.0 per 1000 player hours) was significantly higher than training injuries (3.3 per 1000 player hours). The lower limb (62.5%) sustained the greatest proportion of injuries. Muscle or tendon injuries accounted for 64.9% of all injuries. The tackle accounted for 28.8% of all injuries and 37.5% of all injuries were of a 'moderate' severity. The proportion of players that sustained a time-loss injury was 76.9% (n = 30) and 25.6% (n = 10) of players sustained a time-loss injury severe enough to prevent eight days or more of participation in training or matches.

The overall incidence of illness was 1.8 per 1000 player days. The proportion of players that acquired an illness was 28.3% (n = 11). Acute respiratory tract infections (28.6%) was the most common specific diagnosis. A large majority of illnesses (64.3%) did not result in time-loss.

A significant negative correlation between injury and internal training loads were detected in the preseason phase ($r = -0.34$, $p = 0.03$). There were no significant correlations between external training load and injury incidence. No significant correlations were observed between internal and external training loads and illness incidence. There were no significant odds ratios demonstrated between internal and external acute to chronic ratios, and injury and illness risk.

Conclusion

The incidence of match injuries in this study was significantly higher than previously reported incidence rates in the Super Rugby tournament. The profiles of match and training injuries, anatomical location, type, mechanism and severity of injuries are similar to previous studies. Illness rates were significantly lower than reported in previous studies. Internal training load and injury were significantly correlated in the preseason phase. Further studies are required to determine the relationship of training loads on injury and illness over consecutive seasons and in multiple teams.

CHAPTER 1: INTRODUCTION AND SCOPE OF THE THESIS

1.1. INTRODUCTION

Rugby Union is a physically demanding sport involving regular intervals of high intensity activity such as running, sprinting, rucking, mauling and tackling (Williams, Trewartha, Kemp & Stokes, 2013). During an 80-minute game, the object of the game is for two teams to contest, each with fifteen players on the field. According to the rules governed by the International Rugby Board (IRB), the aim is to score as many points as possible (Brooks & Kemp, 2008; Duthie, Pyne & Hooper, 2003).

The combination of high physical demands, together with repetitive collisions and contact, means the inherent risk of injury is substantial in Rugby Union (Williams et al., 2013). Across professional team sports, Rugby Union is known to have one of the highest reported incidences of injury and illness (Williams et al., 2013). Despite the inherent risk of injury due to the high physical demands, training load in Rugby Union is an independent and modifiable risk factor to injury (Thomson, 2014). As a result, the measurement of load and the monitoring of players has become a priority in Rugby Union (Quarrie et al., 2017). Load monitoring is used to determine whether a team and/or athlete is adapting to a prescribed training programme and to manage the risk of developing non-functional overreaching, illness, and/or injury (Halson, 2014). The adverse effects of training is therefore dose-related, with a rise in injury and illness rates in athletes when training loads are at their highest or lower than the minimum required for adaptation (Gabbett, 2016). This forms the basis of injury prediction.

The Super Rugby tournament is played annually between professional Rugby Union teams from Japan, South Africa, Argentina, New Zealand and Australia, and is considered to be one of the most competitive rugby competitions in the world (Kara, 2013; Schwellnus et al., 2014). Currently, eighteen teams participate weekly over a four-month period (Schwellnus et al., 2014). This duration is greater than other international tournaments (Schwellnus et al., 2014). A recent increase in the number of teams, weekly matches, bonus incentives and demanding travelling schedules in the Super Rugby tournament has been associated with insufficient recovery times to allow adequate adaptation to playing loads (Schwellnus et al., 2016). This has resulted in impaired performance and an elevated risk of injury and acute illness (Schwellnus et al., 2016). There is evidence that poor load management is a risk factor to both injury and illness (Soligard et al., 2016; Schwellnus et al., 2016). However, there is no evidence to substantiate these findings in the Super Rugby tournament. The demanding nature of the Super Rugby tournament provides an opportunity to further investigate the relationships between training load, injury and illness.

Research has been focused on developing the limited epidemiological data on injury profiles and illness rates in professional Rugby Union. As a result, research is scarce in determining the relationship of training loads on injury and illness over a complete season in competitions such as the Super Rugby tournament. Research is required to improve the understanding of how these variables co-exist and to facilitate the development of future injury and illness preventative measures.

1.2. AIMS AND OBJECTIVES

1.2.1. General aim

The aim of this study was to assess the relationships between training loads, injury profiles and illness rates in elite South African rugby players competing in the 2017 Super Rugby tournament.

1.2.2. Specific objectives

The specific objectives were:

- To determine the incidence of training and match injuries during pre-season training, and early and late competition during the 2017 Super Rugby tournament.
- To determine the incidence of illness during pre-season training, and early and late competition during the 2017 Super Rugby tournament.
- To determine the anatomical site, type, mechanism and time-loss of injuries sustained during pre-season training, and early and late competition during the 2017 Super Rugby tournament.
- To determine potential associations between internal and external training loads; and injury and illness, respectively.

1.3. SIGNIFICANCE OF THIS STUDY

Advances in injury prevention should be directed toward understanding the context within which the injuries occur (Finch, 2016). The significance of this study is to contribute to the limited epidemiological data on injury and illness incidence during a complete Super Rugby tournament in a South African Rugby Union, and to determine the relationships between training load, injury and illness. Epidemiological data can assist researchers to understand the current incidence of injuries and illness in the context of the Super Rugby tournament. This study will enable researchers to understand how a risk factor such as training load contributes to the burden of injury and illness in Rugby Union. In addition, the epidemiological data in this study will assist in determining the training loads in South African Rugby Union that predispose elite rugby players to injury and illness.

1.4. PLAN OF DEVELOPMENT

The development of the study includes a comprehensive analysis of injury, illness and training load patterns in general professional Rugby Union and across sporting codes followed by a review of these factors in elite rugby players participating in the Super Rugby tournament (Chapter 2). The literature review will provide the background for the research component of the dissertation and guide the methodology for investigating injury profiles, illness, and training loads in elite South African rugby players (Chapter 3). The results and discussion of the dissertation will be presented in Chapters 4 and 5. The limitations, recommendations, summary and conclusion will complete the dissertation (Chapter 6 and 7).

CHAPTER 2: LITERATURE REVIEW

2.1. INTRODUCTION

Professional Rugby Union is a popular team sport internationally, ranking second in participation to soccer (Bathgate, Best, Craig, & Jamieson, 2002). The beginning of professionalism in rugby in October 1995 coincided with an increase in injury incidence to both professional and amateur players (Garraway, Lee, Hutton, Russell, & Macleod, 2000). In Rugby Union a higher level of play has been linked to a higher incidence of injuries (Williams et al., 2013). The evolving nature of Rugby Union and the demanding schedules in competitions such as the Super Rugby tournament, has been associated with an increased risk of injury and illness in professional Rugby Union players (Quarrie et al., 2017; Schwellnus et al., 2012; Schwellnus et al, 2014; Williams et al., 2013). Training load has been identified as a modifiable risk factor for injury and illness, and the measurement of training loads and the monitoring of player responses to those training loads has been employed to promote player welfare (Quarrie et al., 2017). The precise relationship of training loads on injury and illness over a complete season in competitions such as the Super Rugby tournament is unclear.

In this review, the epidemiology of injuries and illness in professional Rugby Union with a focus on the Super Rugby tournament in elite adult rugby players will be presented. The aim of the epidemiological review of injuries and illness is to identify incidence patterns and the change in these patterns over time which may assist in targeting future research on injury and illness prevention (Steffen, Soligard, & Engebretsen, 2011). Training load and performance, and the relationship to injury and illness in Rugby Union using the injury prediction methods proposed by Gabbett (2010) will also be reviewed.

Science Direct, Google Scholar, Pubmed, Wiley and Ovid databases from 1995 through to February 2019 were searched using the keywords: '*epidemiology', 'elite', 'Rugby Union', 'injury', 'illness', 'consensus', 'catastrophic', 'training loads', 'prevention', 'Super Rugby tournament', 'load monitoring', 'risk factors', 'injury prevention', 'injury prediction', 'acute to chronic ratio', 'performance'* and *'time-loss'*. In this literature review, the term 'rugby' will be referred to as 'Rugby Union'.

2.2. INJURIES IN PROFESSIONAL RUGBY UNION

2.2.1. Level of play

The IRB classifies Rugby Unions into tiers according to playing strength and potential. Tier one teams participate in the Six Nations Championship or the Rugby Championship (International Rugby Board, 2012). For the purpose of this review, elite and/or professional teams will be included based on the 'level of play'. The classification of 'level one' teams are teams that participate in the top ranked leagues in tier one ranked nations (International Rugby Board, 2012). This review will include International and professional teams in tier one-ranked nations participating in 'level one' tournaments.

2.2.2. Injury definitions and classification

Injury definitions prior to 2007 ranged broadly from any injury or medical condition related to game or training absence, to an injury resulting in an emergency department visit (Brooks & Kemp, 2008). To improve inter-study comparisons and injury management, the IRB formed the Rugby Injury Consensus Group (RICG) in 2007 to standardize the definitions and methodologies in the recording and reporting of injuries (Fuller et al., 2007). The definitions and methodologies according to this consensus statement are noted below and were used in this review.

Definition of an injury

"*Any physical complaint, caused by a transfer of energy that exceeded the body's ability to maintain its structural and/or functional integrity, sustained by a player during a rugby match or training, irrespective of the need for medical attention or time-loss is defined as an injury*" (Fuller et al., 2007).

An injury resulting in a player receiving medical attention is referred to as a 'medical attention' injury. A 'time-loss' injury is an injury preventing a player from participating fully in all training activities planned for that day and/or match for more than one day following the day of injury (Fuller et al., 2007). Studies utilising the time-loss definition of an injury will be included in this review for inter-study comparisons.

Definition of a recurrent injury

"A recurrent injury is defined as an injury of the same type and at the same site as the primary injury and which occurs after a player's return to full participation from the primary injury" (Fuller et al., 2007).

Injury severity definition

"Injury severity is defined by the number of days that have elapsed from the date of injury to the date of the player's return to full participation in team training and availability for match selection" (Fuller et al., 2007).

The severity of time-loss injuries are categorised as follows: Minimal (2-3 days), mild (4-7 days), moderate (8-28 days) and severe (≥28 days) (Fuller et al., 2007).

Injury classification

Injuries are classified according to anatomical location, type and event such as training or a match (Fuller et al., 2007).

Mechanism of injury

Match and training injuries are divided into contact and non-contact (Fuller et al., 2007). The mechanism of injuries resulting from contact are divided into the following: kicking, collision, ruck, running, scrum, tackled, tackling and other (Fuller et al., 2007).

2.2.3. General epidemiology of injuries in professional Rugby Union

There is evidence of an increase in injury incidence following the onset of professionalism and the increase in Rugby Union participation (Garraway et al., 2000). Methodological limitations must also be considered. A two-fold rise in the incidence of injury, from 27% to 47%, in the Scottish Rugby Union was documented by Garraway et al. (2000) between 1993 and 1997. A small population of thirty professional players was reported in this sample and rule changes during this period potentially confounded the results (Williams et al., 2013). These findings were later mirrored with a two-fold increase in mean injury rates from the start of professionalism from 47 per 1000 player hours between 1994 and 1995 to 74 per 1000 player hours respectively from 1996 to 2000 in Australian Rugby Union (Bathgate et al., 2002).

It has been postulated that a rise in injury rates was associated with an increase in the speed of the game, time of ball in play, number of tackles and rucks, increasing size and fitness of players, and harder tackling (Bathgate et al., 2002; Brooks & Kemp, 2008). Professional players had to cope with the increase in physical and psychological demands of being full time athletes (Bathgate et al., 2002).

Studies on the Rugby World Cup (RWC), International and Club Rugby Union have consistently demonstrated one of the highest rates of injury incidence in matches in comparison to other team sports (Brooks & Kemp, 2008).

However, injury rates in Rugby Union are comparable with various collision sports including Rugby League, Ice Hockey, Australian Rules Football, and American Football as cited by Williams et al. (2013) (Lorentzon, Wedren, & Pietilä, 1988; Phillips, Standen, & Batt, 1998; Orchard & Seward, 2002; Meyers & Barnhill, 2004). In ten studies in professional Rugby Union from 1995 to 2012, the overall incidence of 81 per 1000 player hours (95% CI: 63-105) for matches and three per 1000 player hours (95% CI: 2-4) for training were documented (Williams et al., 2013). The main finding in this study was that a higher level of play was associated with a higher incidence of injuries (Williams et al., 2013).

2.2.4. Epidemiology of injuries in the Super Rugby tournament

There is limited literature reporting injury epidemiology in the Super Rugby tournament. Five studies have reported the epidemiology of injuries in the Super Rugby tournament (Fuller, Raftery, Readhead, Targett, & Molly, 2009; Holtzhausen, Schwellnus, Jakoet, & Pretorius, 2009; Schwellnus et al., 2014; Targett, 1998; Whitehouse, Orr, Fitzgerald, Harries, & McLellan, 2016). The definition of injury varied in two studies prior to the 2007 Consensus Statement and therefore this review will focus on the three studies that have applied guidelines from the 2007 Consensus Statement.

In a study by Schwellnus et al. (2014), the overall injury incidence was 9.2 per 1000 player hours (95% CI: 7.9-10.8). Fifty five percent of all players sustained a time-loss injury and 25% of all players sustained more than one injury across five South African Rugby teams over sixteen weeks in the 2012 Super Rugby tournament (Schwellnus et al., 2014). The overall incidence was higher than reported in the 2014 Super Rugby tournament across five Australian teams as shown in Table 1 (Whitehouse et al., 2016).

2.2.5. Match injuries and training injuries

A number of studies in professional Rugby Union confirm that match-related injury incidence was significantly higher than training injury incidence (Brooks, Fuller, Kemp, & Reddin, 2005a; Fuller, Laborde, Leath, & Molloy, 2008). Williams et al. (2016) postulated that an increase in 'ball in play' time by 30% from the 1995 to the 2003 RWC resulted in longer exposures, and an increased risk of injury. In addition, another potential reason for the higher match-related injuries was the use of wider definitions for injury in comparison to previous studies (Brooks, Fuller, Kemp, & Reddin, 2005c).

In a meta-analysis of ten studies in senior men's professional Rugby Union, the match-related injury incidence was 27 times higher than in training, which was similar to the 2014 Super Rugby tournament. This is significantly lower than reported in the 2012 Super Rugby tournament where the incidence of match injuries were 40 times higher than training as shown in Table 1 (Schwellnus et al., 2014; Whitehouse et al., 2016; Williams et al., 2013).

The match-related injury incidence reported by Williams et al. (2013) and Schwellnus et al. (2014) were similar and higher than reported in the 2014 Super Rugby tournament, but significantly lower than the 2008 Super Rugby tournament (Table 1) (Fuller et al., 2009; Whitehouse et al., 2016).

Table 1: The incidence of overall, match and training injuries in the Super Rugby tournament and in one meta-analysis.

Reference	**Incidence of injury (95% CI)**		
	Overall	**Match**	**Training**
Fuller et al. (2009)	96.30 (86.90-106.70)	96.30 (86.90-106.70)	Not reported
Schwellnus et al. (2014)	9.20 (7.90-10.80)	83.30 (69.40-99.20)	2.10 (1.50-3.00)
Whitehouse et al. (2016)	6.96 (5.89-8.04)	66.07 (53.78-78.36)	2.33 (1.69-2.98)
Williams et al. (2013)	Not reported	81.00 (63.0-105.0)	3.00 (2.00-4.00)

Incidence is expressed as injuries per 1000 hours of exposure.

The explanation for the disproportionate decrease in the incidence of match injuries reported by Williams et al. (2013) and Schwellnus et al. (2014) in contrast to the earlier study by Fuller et al. (2009) is not clear. The change and implementation in game rules over time, the number of teams, the format of the Super Rugby tournament, and injury prevention programmes used by individual teams during the five to six year period could have potentially contributed to the decline in injury incidence (Schwellnus et al., 2014).

2.2.6. Injured player proportion

The use of injured player proportion in tournaments of varying duration has been recommended for inter-study comparisons (Schwellnus et al., 2014). Injured player proportion is calculated as the percentage of players who sustain an injury during the period of a tournament (Schwellnus et al., 2014). Recurrent injuries or more than one injury per player are not considered in the calculation as these are considered new injuries which potentially results in an overestimation (Schwellnus et al., 2014). The authors maintain that despite the overestimation, the proportion of players who are likely to sustain an injury in the Super Rugby tournament are two times greater compared to the players in the RWC as shown in Table 2 (Schwellnus et al., 2014).

Table 2: The injured player proportion across studies.

Tournament	Reference	Sample (n)	Duration (weeks)	Percentage (%)
1999 Super Rugby Tournament	Targett (1998)	75	14	64
2008 Super Rugby tournament	Fuller et al. (2009)	441	16	82
2012 Super Rugby tournament	Schwellnus et al. (2014)	83	16	55
2003, 2007 & 2011 Rugby World Cup	Best, McIntosh, & Savage (2005); Fuller et al. (2008); Fuller et al. (2013)	615	7	26-34

Injured player proportion is expressed as a percentage (%).

2.2.7. Types of musculoskeletal injuries

A common trend in studies reporting on the Super Rugby tournament and a meta-analysis of seven studies was that majority of the injuries affected the lower limb as shown in Table 3 (Fuller et al., 2009; Schwellnus et al., 2014; Whitehouse et al., 2016; Williams et al., 2013). Muscle or tendon and joint or ligament injuries also accounted for a significant proportion of the injuries (Table 3) (Fuller et al., 2009; Schwellnus et al., 2014; Whitehouse et al., 2016; Williams et al., 2013).

Several authors have agreed that to significantly reduce the overall injury burden in professional Rugby Union, injury prevention strategies should focus on components of the game causing the most time-loss from participation in training and matches (Brooks & Kemp, 2008; Schwellnus et al., 2014; Williams et al., 2013). An example is injury prevention strategies that target lower limb injuries and increase safe methods in contact situations (Williams et al., 2013). At an elite level the balance between performance and safety provides a challenge with the implementation of interventions (Williams et al., 2013).

Table 3: Anatomical location and injury types in Super Rugby tournament studies and in one meta-analysis.

Reference	**Anatomical location (%)**			**Injury type (%)**		
	All injuries	**Match injuries**	**Training injuries**	**All injuries**	**Match injuries**	**Training injuries**
Fuller et al. (2009)	Lower-limb 48.7	Lower-limb 48.7	Not reported	Muscle or tendon 27.8	Muscle or tendon 27.8	Not reported
	Head or neck 21.2	Head or neck 21.2	Not reported	Joint or ligament 18.8	Joint or ligament 18.8	Not reported
Schwellnus et al. (2014)	Lower-limb 48.1	Lower limb 41.3	Lower-limb 73.0	Muscle or tendon 50.0	Muscle or tendon 46.2	Muscle or tendon 64.5
	Upper limb 25.6	Upper limb 30.2	Trunk 11.8	Joint or ligament 32.7	Joint or ligament 33.6	Joint or ligament 29.0
Whitehouse et al. (2016)	Lower-limb 57.1	Lower-limb 52.3	Lower-limb 68.0	Joint or ligament (%) Not reported	Joint Ligament (%) Not reported	Not reported
	Head or neck 20.5	Head or neck 22.5	Head or neck 16.0	Muscle or tendon (%) Not reported	Muscle tendon (%) Not reported	Not reported
Williams et al. (2013)	Not reported	Lower-limb (%) Not reported	Not reported	Not reported	Muscle tendon (%) Not reported	Not reported
	Not reported	Upper limb (%) Not reported	Not reported	Not reported	Joint Ligament (%) Not reported	Not reported

2.2.8. Catastrophic injuries in the Super Rugby tournament

A low rate of head and/or neck injuries (13.1%) including concussions has been reported in general professional Rugby Union and in the 2012 Super Rugby tournament (Schwellnus et al., 2014; Williams et al., 2013). From the overall head and neck injuries reported by Schwellnus et al. (2014), 43% were classified as minimal severity and 4.8% were classified as 'severe', which were similar to findings by Whitehouse et al. (2016). Despite the relatively low rates of head and/or neck injuries, the intervention of catastrophic injury-preventing behaviours remains a priority due to the negative impact catastrophic injuries impose on player-welfare (Brown, Gardner-Lubbe, Lambert, Mechelen, & Verhagen, 2015).

Since the amended scrummage Law in 2007 and the 'zero tolerance' sanctions by the IRB for dangerous tackles in 2009 and 2011, a reduction in head and neck injuries have been reported (Murray, Murray, & Robson, 2014). This could be a result of the strict regulations to remove players for the duration of a game if a concussion is suspected. However, the lack of consistent concussion definitions across studies at an elite level could have also resulted in the low incidence of concussion reported in the literature (Gardner, Iversion, Williams, Baker, & Stanwell, 2014). The IRB has also sanctioned rule modifications in 2012 that reduce head trauma in Rugby Union and implemented awareness programs such as 'Recognize and Remove' and guidelines for player returning to participation following a concussion (Gardner et al., 2014; McKee et al., 2013; McCrory et al., 2013). There is evidence to support a decline in concussion, head and/or neck, and spinal injuries through injury prevention programmes such as BokSmart and RugbySmart (Gardner et al., 2014; Gianotti, Quarrie, & Hume, 2009; Viljoen & Patricios, 2012). The introduction of behavioural alterations and technical training in players to prevent catastrophic injuries were considered to be successful (Brown et al., 2015; Gianotti et al., 2009; Quarrie, Gianotti, Hopkins, & Hume, 2007).

2.2.9. Mechanisms of injury in the Super Rugby tournament

The majority of injuries in Rugby Union result from the contact event, with the main causes of injury being the tackle, ruck, maul, collision and scrum (Bathgate et al., 2002; Brooks et al., 2005c, Fuller, Brooks, Cancea, Hall, & Kemp, 2007). Across five studies in general professional Rugby Union, being tackled by another player resulted in the highest match-related injury incidence of 29 per 1000 player hours (95% CI: 19-46) (Williams et al., 2013).

In the 2008, 2012 and 2014 Super Rugby tournament, the tackle was the most common cause of injury (Fuller et al., 2009; Schwellnus et al., 2014; Whitehouse et al., 2016). In the 2008 Super Rugby tournament, being tackled resulted in the highest proportion of match injuries (41.4%) followed by tackling (26.7%) for all match injuries (Fuller et al., 2009). In the 2012 Super Rugby tournament, tackling accounted for 23.1% of all injuries similar to 20.7% reported in the 2014 Super Rugby tournament (Schwellnus et al., 2014; Whitehouse et al., 2016). Being tackled accounted for 20% and 22.5% of all injuries in the 2012 and 2014 Super Rugby tournaments respectively compared to 41.4% in the 2008 Super Rugby tournament (Fullet et al., 2009; Schwellnus et al., 2014; Whitehouse et al., 2016).

The tackle in Rugby Union has the highest risk of injury for both the ball carrier and the tackler (Hendricks & Lambert, 2010). Injury prevention strategies such as defensive drills and techniques to develop tackling technique before and when fatigued have been recommended for coaches in order to reduce the risk of injury (Gabbett, 2008). Players with an increased level of physical conditioning and better tackle technique have a decreased risk of injury for any number of tackles and the amount of impact per tackle (Hendricks & Lambert, 2014).

2.2.10. Severity of injuries in the Super Rugby tournament

In general professional Rugby Union using a graded time-loss injury definition from training and matches, the most common severity of injury was 'moderate' with 28 per 1000 player hours (95% CI: 25-31) followed by 'mild' with 23 per 1000 player hours (95% CI: 20-26) (Williams et al., 2013).

In the 2008 Super Rugby tournament, the severity of injury was presented as a function of group severity for two competitions preventing direct comparisons with the 2012 Super Rugby tournament (Fuller et al., 2009). In the 2012 Super Rugby tournament, the most common severity of injury was lower than previously reported with a 'minimal' severity accounting for 2.8 per 1000 player hours (95%c CI: 2.1-3.7) followed by 'moderate' with 2.4 per 1000 player hours (95% CI: 1.7-3.2) (Schwellnus et al., 2014). The severity of match and training injuries are presented in Table 4. In addition, according to the injured player proportion in this study, 20.4% of players sustained a 'moderate' injury (8-28 days) and 14.5% sustained a 'severe' injury (≥28 days) (Schwellnus et al., 2014). Overall, 34.9% of players sustained an injury during the tournament that resulted in a time-loss of eight days or more (Schwellnus et al., 2014). To determine the injury severity in the Super Rugby tournament, more data are required to make inter-study comparisons within the Super Rugby tournament and across general professional Rugby Union.

Table 4: Severity of injuries according to the time-loss classification in the 2012 Super Rugby tournament study (Schwellnus et al. 2014).

	Minimal (2-3 days)	**Mild (4-7 days)**	**Moderate (8-28 days)**	**Severe (≥28 days)**
All injuries	32.9	24.9	27.5	14.8
Match injuries	35.2	26.2	24.6	13.9
Training injuries	22.2	18.5	40.7	18.5

Severity of injury according to minimal, mild, moderate and severe is expressed as a percentage (%).

2.2.11. The impact of time-loss injuries

Injuries pose a substantial impact on the well-being of an athlete by the induced psychological, emotional, financial and physical stress through both pain and on-going rehabilitation (Hurley, 2014). Time-loss injuries from training or matches influence a team's success through availability of the best players for a given match (Williams et al., 2016). The absence from training may disrupt tactical preparation and cause a negative psychological effect on the team and/or individual (Raysmith & Drew, 2016; Williams et al., 2016).

In addition, amongst 1462 players within fifteen teams in the English Premiership, an increase in injury incidence and injury days per team was associated with a decrease in team success (William et al., 2016). A reduction in injury incidence was related to a positive change in league points (Williams et al., 2016).

2.3. SUMMARY: INJURIES IN PROFESSIONAL RUGBY UNION AND THE SUPER RUGBY TOURNAMENT

Injury incidence in Rugby Union remains comparable to other collision sports (Williams et al., 2013). A higher level of play has been associated with a higher incidence of injury (Williams et al., 2013). There are a limited number of epidemiological studies on the Super Rugby tournament. Studies aligned with the 2007 Consensus Statement reported a lower incidence of injury in the 2012 and 2014 Super Rugby tournament compared to the 2008 Super Rugby tournament (Fuller et al., 2009; Schwellnus et al., 2014; Whitehouse et al., 2016). The injury incidence in the Super Rugby tournament studies is higher compared to the general professional Rugby Union (Schwellnus et al., 2014). The precise reason behind the wide variation of injury incidence is not clear.

The incidence of match-related injuries is significantly higher than training injuries in professional Rugby Union and in two Super Rugby tournament studies (Williams et al., 2013; Schwellnus et al., 2014; Whitehouse et al., 2016). The most commonly reported anatomical location of injury in is the lower-limb with the muscle or tendon and joint or ligament accounting for the majority of the injury types (Fuller et al., 2009; Schwellnus et al., 2014; Whitehouse et al., 2016; Williams et al., 2013). Being tackled and tackling are the most frequent causes of injury (Fuller et al., 2009; Hendricks & Lambert, 2010; Schwellnus et al., 2014; Whitehouse et al., 2016). In the literature, the most common time-loss severity of injuries documented in Rugby Union was 'moderate' (Williams et al., 2013). However, the literature on the Super Rugby tournament reported majority of the injuries as 'minimal' (Schwellnus et al., 2014).

Injuries pose a substantial impact on a rugby player's well-being and time-loss from training and matches negatively influences team success (Hurley, 2014). A low rate of catastrophic injuries with a 'minimal' severity has been reported in the Super Rugby tournament (Schwellnus et al., 2014). A substantial decline in catastrophic injuries has been attributed to the effectiveness of injury prevention programmes such as BokSmart and RugbySmart (Gardner et al., 2014; Gianotti, Quarrie, & Hume, 2009; Viljoen & Patricios, 2012).

2.4. ILLNESS IN PROFESSIONAL RUGBY UNION

2.4.1. Introduction

A medical illness can be defined *"as any non-trauma related symptom and sign presenting in a player that requires medical attention from the team physician on a specific day"* (Schwellnus et al., 2012). Acute illness poses a significant health burden to elite athletes during ongoing competitions lasting days or weeks (Raysmith & Drew, 2016).

The intensive training schedules of elite rugby players may put this population at an increased risk to upper respiratory tract infection (URTI) through suppressed immune function and an increase in the exposure to pathogens (Gleeson, Nieman, & Pedersen, 2004).

2.4.2. Epidemiology of illness in professional Rugby Union and in the Super Rugby tournament

One of the first studies to report illness incidence per 1000 player days of exposure in comparison to the previous methodology of per 1000 registered athletes during a tournament was a prospective cohort study of the 2010 Super Rugby tournament (Schwellnus et al., 2012). In this study, 469 illnesses were recorded in 187 of 259 players representing a prevalence of 72.2% over 16 weeks (Schwellnus et al., 2012). From the total number of illnesses, 87.6% were new illnesses and 12.4% were repeated illnesses (Schwellnus et al., 2012).

The respiratory system (30.9%) and the digestive system (27.5%) were the most frequently affected bodily systems (Schwellnus et al., 2012). The most frequent diagnosis was gastroenteritis (19.8%), followed by acute URTI (15.9%) (Schwellnus et al., 2012). Furthermore, the most suspected causes of illness was infection (58.7%) followed by environmental causes (17.7%) (Schwellnus et al., 2012).

The overall illness incidence of 20.7 per 1000 player days (95% CI: 18.5-23.1) reported by Schwellnus et al. (2012), was higher than the incidence reported during the 2010 Confederations Cup Football tournament as depicted in Table 5 (Dvorak et al., 2011). Similar results reporting the most affected bodily system (respiratory system) and suspected cause of illness (infection) have been mirrored across numerous sporting codes including aquatic sports, Winter Olympic Games, track and field athletes, and football (Table 5) (Alonso et al., 2010; Dvorak et al., 2011; Engebretsen et al., 2010; Mountjoy et al., 2010).

In a prospective longitudinal study over 48 weeks during the European Cup of 31 professional Rugby Union players, the majority of reported illnesses affected the respiratory system (Cunniffe et al., 2010). From the total squad, 92% of the players experienced at least one respiratory tract illness with a total of 123 reported cases (Cunniffe et al., 2010). The term upper respiratory illness was used because the diagnosis of an infection could not be determined (Cunniffe et al., 2010). This limits comparisons across studies as the illness definition and methodologies vary from the study published by Schwellnus et al. (2012).

Table 5: Studies reporting illness across various sporting codes.

Reference	Sporting Code	Sample size (n)	Acute illness n (%)	Illness incidence per 1000 registered athletes	Illness incidence per 1000 player days	Most common bodily system n (%)	Most common specific diagnosis n (%)	Most suspected cause of illness n (%)
Mountjoy et al. (2010)	Aquatic Sports	2592	184 (7.1%)	71.0	Not stated	Respiratory system 91 (50.3%)	Upper respiratory tract infection 49 (26.6%)	Infection 89 (49.2%)
Engebretsen et al. (2010)	Winter Olympic Games	2567	185 (7.2%)	72.1	Not stated	Respiratory system 113 (62.8%)	Upper respiratory tract infection 61 (54.0%)	Infection 111 (63.3%)
Alonso et al. (2010)	Track and Field Athletics	1486	135 (9.1%)	68.2	Not stated	Respiratory system 48 (35.6%)	Upper respiratory tract 41 (30.4%)	Infection 44 (32.1%)
Dvorak et al. (2011)	Football	736	99 (12.1%)	135.0	7.7	Respiratory system 40 (40.0%)	Upper respiratory tract infection 31 (31.3%)	Infection 60 (60.6%)

The reason for the high illness incidence reported in the 2010 Super Rugby tournament is not clear. Authors relate the high illness incidence to a number of factors such as long duration of the tournament (sixteen weeks), the environment, weekly training sessions and matches at a high intensity, travelling over numerous time-zones and the varying climatic conditions between the International teams participating in the tournament (Schwellnus et al., 2012). The prolonged duration of the 2010 Super Rugby tournament and traveling to multiple destinations in one season are two factors that vary from previously mentioned tournaments. There is a paucity in the literature on illness incidence within Rugby Union using consistent definitions and methodologies.

2.4.3. Time-loss from illness in the Super Rugby tournament

In the study by Schwellnus et al. (2012), 83.3% of illnesses resulted in no time-loss during the 2010 Super Rugby tournament. A time-loss of one day was found in 9.6% of the reported illnesses, time-loss of more than one day was 6.5% of the illnesses, and time-loss for the remaining illnesses were not reported (Schwellnus et al., 2012). In other sporting codes such as such as aquatic sports, Winter Olympic Games, track and field athletes, and football, illness did not result in extensive time-loss from participation (Alonso et al., 2010; Dvorak et al., 2011; Engebretsen et al., 2010; Mountjoy et al., 2010).

2.4.4. The impact of acute illness on exercise performance

Acute infective illness can reduce exercise performance through its impact on different organ systems resulting in a reduction in muscle strength, motor co-ordination, muscle mass, maximal oxygen uptake and endurance capacity (Friman & Wesslén, 2000; Schwellnus et al., 2016; Weidner & Sevier, 1996). Fever reduces temperature regulation capacity resulting in greater fluid losses decreasing stroke volume and cardiac output, causing a decline in maximal oxygen consumption (Schwellnus et al., 2016). Aerobic capacity determined by heart rate response during sub-maximal exercise is subsequently decreased (Friman & Wesslén, 2000). A reduction in exercise performance can last two to four days after full clinical recovery from upper respiratory illness (Schwellnus, Jeans, Motaung, & Swart, 2008). In addition, the combination of acute illness and strenuous exercise can increase the risk of serious medical complications such as myopericarditis (Schwellnus et al., 2008; Tseng et al., 2013).

2.4.5. Training load and the risk of illness

High training load and excessive psychological stress in combination with international travel during demanding competitions such as the Super Rugby tournament are risk factors for illness in elite athletes (Schwellnus et al., 2016). Prolonged training and competition load are linked to increasing the risk of sub-clinical immunological changes that may increase the risk of illness (Schwellnus et al., 2016). A single bout of strenuous endurance exercise is known to cause a temporary functional immune-depression for three to 72 hours called the 'open window' phenomenon (Friman & Wesslén, 2000). The severity and duration of the immune-depression is linked to the effort exerted during exercise which potentially increases the sensitivity to URTI and other infections (Friman & Wesslén, 2000). Insufficient rest periods can result in a cumulative decline in immune function resulting in acute infective illness (Friman & Wesslén, 2000; Weidner & Sevier, 1996). This immune dysfunction is primarily related to the suppressive effect of cortisol and adrenaline hormones (Gleeson et al., 2004). Cunniffe et al. (2010) suggests that illness may be prevalent in elite level sport where multiple stressors (physiological, psychological, environmental and behavioural) could exist in tournaments like the Super Rugby tournament.

Changes to internal and external training loads are associated with an elevated risk of illness (Schwellnus et al., 2016). The relationship between fluctuations in training load (intensity, frequency, type and duration) and the risk of acquiring an acute illness is documented in a limited number of studies (Schwellnus et al., 2016). Cunniffe et al. (2010), observed that periods of elevated training intensity and a decline in game participation were followed by high rates of upper respiratory illness. There was no indication whether the incidence of upper respiratory illness directly resulted in reduced participation for the periods of elevated training intensity. This has been the only study in elite Rugby Union to extensively investigate the impact of training load on mucosal immunity and the incidence of illness. In a study conducted by Heath et al. (1991), recreational runners were studied prospectively over twelve months, an increased risk of illness was preceded by phases of elevated training volumes.

The relationship between absolute training load and the risk of illness has been previously modelled as a J-shaped curve with very low or no training being associated with a higher risk of illness than moderate training load in recreational and sub-elite athletes (Shephard, Shek, & Dinubile, 1999). In this model, there is good evidence to support that very high training loads in contrast to moderate training loads are associated with an increased risk to illness in recreational and sub-elite populations across sporting codes (Fahlman & Engels, 2005; Gleeson, Bishop, & Tauler, 2013; Heath et al., 1991; Novas, Rowbottom,& Jenkins, 2003; Schwellnus et al., 2016).

In elite athletes participating on the highest level, current evidence reports that the J-shaped model does not apply where high absolute training loads are not linked to an elevated risk to illness but reveal a S-shaped curve as illustrated in Figure 1 (Hellard, Avalos, Guimaraes, & Toussaint, 2015; Malm, 2006). The precise reason behind this is not clear and whether this model can be applied to the Super Rugby tournament has not been established (Malm, 2006). Currently, quantifying the absolute changes in training load associated with illness risk in a specified sport has not been studied extensively (Schwellnus et al., 2016).

Literature reporting the prevention of illness in professional Rugby Union is limited. One study that investigated the prevention of infections using supplementation was conducted by Haywood et al. (2014). This study reported a positive effect of daily probiotic supplementation on the incidence rate of URTI with fourteen incidents in the placebo group versus six incidents in treatment group in elite Rugby Union players (Haywood, 2014). A significant reduction in the duration of symptoms of URTI was noted, however, the self-reported severity of illness remained unaffected (Haywood, 2014). This study presented numerous methodological limitations including a small sample size of thirty players, the consumption of alternative medication, unconfirmed compliance to consuming the supplement over bye-periods, and the sensitivity of the severity data due to players training whilst ill (Haywood, 2014).

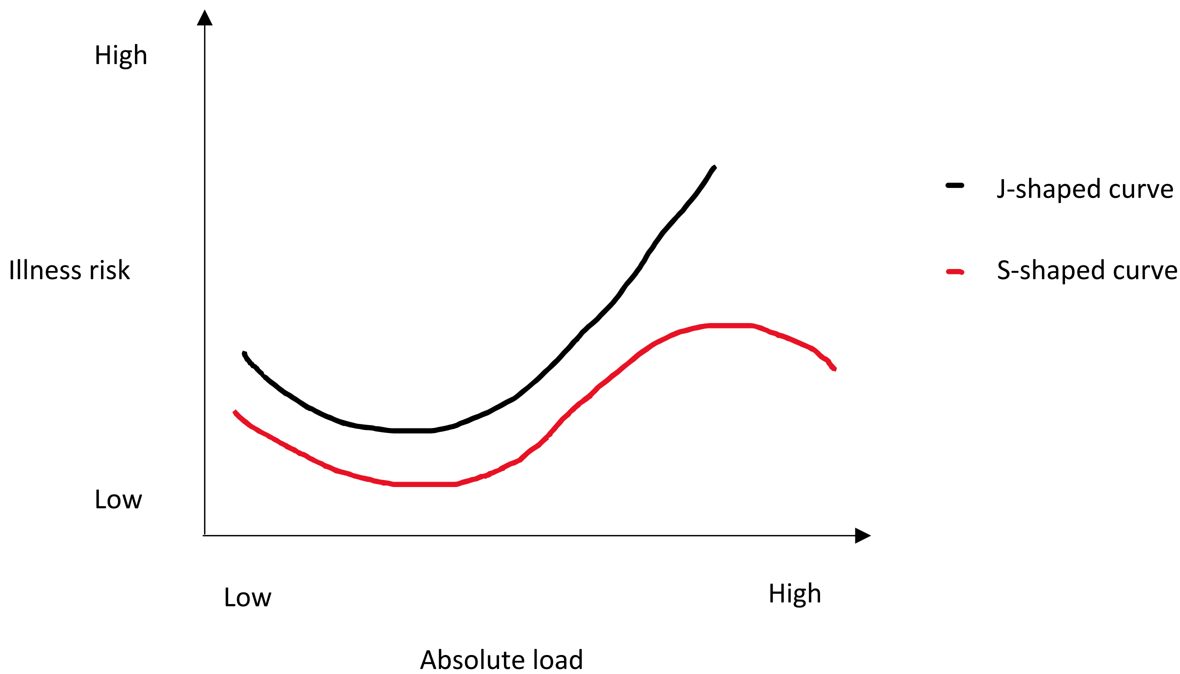

Figure 1: The relationship between load and illness risk in recreational and sub-elite athletes (J-shaped curve) and elite athletes (S-shaped curve) as adapted from Shephard, Shek, & Dinubile (1999), Malm (2006) and Schwellnus et al. (2016).

2.5. SUMMARY: ILLNESS IN PROFESSIONAL RUGBY UNION

Despite the paucity in the literature on illness in Rugby Union, the existing literature reports a high incidence of illness in the Super Rugby tournament compared to other sporting codes (Alonso et al., 2010; Dvorak et al., 2011; Engebretsen et al., 2010; Schwellnus et al., 2012; Mountjoy et al., 2010).

Most of the reported illnesses in Rugby Union impacted the respiratory system and URTI was the most common diagnosis (Schwellnus et al., 2012). Infection was the most frequent cause for illness, and time-loss from training and/or matches were not extensive in majority of the illnesses across numerous sports (Schwellnus et al., 2012).

A decrease in performance has been observed in acute illness and can last two to four days post full clinical recovery (Friman & Wesslén, 2000; Schwellnus et al., 2016; Weidner & Sevier, 1996). Exercise training with acute illness has been associated with serious medical complications in strenuous activity (Schwellnus et al., 2008; Tseng et al., 2013).

Prolonged competition load and insufficient rest periods results in an elevated risk of illness illness (Schwellnus et al., 2016). An S-shaped curve has been suggested for elite athletes with a decrease in illness risk at high absolute training loads (Hellard, Avalos, Guimaraes, & Toussaint, 2015; Malm, 2006). The precise reason behind this phenomenon is not clear. Given the current data, quantifying the amount of training load as it relates to an increased risk of illness in a specified sport has not been studied extensively. Literature is limited in reporting the prevention of illness in professional Rugby Union.

2.6. TRAINING LOAD, PERFORMANCE AND INJURY

2.6.1. Introduction

Load is described as the sport and non-sport burden (single or multiple physiological, psychological or mechanical stressors) as a stimulus that is applied to the human biological system over varying periods with varying magnitude (intensity, duration, type, frequency) (Schwellnus et al., 2016). The primary aim of training within professional sport is to enhance exercise performance through progressive sport specific skills and physical conditioning to build 'fitness' (Cross, Williams, Trewartha, Kemp, & Stokes, 2016). To achieve this aim, training loads are altered during various periods in a training cycle to induce or reduce fatigue depending on the training phase (Halson, 2014). As a result, the increase in a players durability enables the player to adapt to the demands of their sport without sustaining an injury, and therefore remaining available for selection (Williams et al., 2016).

2.6.2. The relationship between training load and performance

Professional Rugby Union players concurrently participate in various training modes within each training phase such as power, strength, speed, aerobic and anaerobic conditioning, along with specific rugby training such as team plays, skills, and technical sessions (Argus, Gill, Keogh, McGuigan, & Hopkins, 2012). The performance of an athlete in response to training can be established from the difference between positive function ('fitness') and negative function ('fatigue'), with the optimal training stimulus enhancing performance whilst limiting the negative consequences of training (Calvert, Banister, Savage, & Bach, 1975).

The inappropriate balance between training load and recovery can lead to maladaptation to training resulting in an elevated risk of injury, illness, and non-functional over-reaching, which is fatigue lasting weeks to months (Cummins, Orr, & O'Connor, 2013; Gabbett, 2016; Halson, 2014).

Injuries related to load are commonly perceived as preventable (Gabbett, 2016). The aetiology of non-traumatic injury includes intrinsic and extrinsic risk factors, with load management being a major risk factor (Cross et al., 2016). Inappropriately managed training load can increase the risk of injury through various mechanisms on a tissue level and/or whole-athlete level (Soligard et al., 2016). On a tissue level, excessive micro-damage and injury can occur if the magnitude (intensity, frequency, type and/or duration) of loading is greater than the tissue's load-bearing capacity or if recovery time between loading cycles is insufficient (Anderson, Triplett-McBride, Foster, Doberstein, & Brice, 2003; Dye, 2005). At an athlete level, inappropriately managed loading increases the risk of injury through a decline in decision-making, co-ordination and motor control (Soligard et al., 2016).

The fatigue from excessive loads leads to a decline in muscular force development and contraction velocity which increases the forces on passive tissues, kinematic and neural feedback, and reduces joint stability (Cortes et al., 2014; Cortes, Greska, Kollock, Ambegaonkar, & Onate, 2013; Gandevia, 2001; Hooper et al., 2014; Rozzi, Lephart, Gear, & Fu, 1999; Wojtys, Wylie, & Huston, 1996).

Low absolute loads have been associated with an increased risk of injury through insufficient adaptation to cope with higher loads (Gabbett & Domrow, 2007; Orchard et al., 2015). Similarly, elevated loads are known to increase the risk of injury in team sports (Gabbett, 2004a). Characteristics such as elevated aerobic capacity, high intensity running ability, and a greater body mass index, can be improved with a progressive increase in loads and a reduced injury risk (Bartolomei, Hoffman, Merni, & Stout, 2014; Gabbett, 2004a). Recent studies indicate that a sudden increase in load beyond what an athlete is able to tolerate is a risk factor to injury in comparison to consistently high loads (Cross et al., 2016; Gabbett & Domrow, 2007; Hulin et al., 2016a).

Large changes in prescribed load from week to week through increases in frequency, intensity or duration have been shown to significantly increase the risk of injury (Cross et al., 2016; Gabbett, 2016). In a study of 183 Rugby League players over two competitive seasons, acute increases in training load early in the competition decreased the performance of agility (Gabbett & Domrow, 2007). Through gradual and controlled loading, high cumulative loads decrease the risk of injury through adaptation and the development of physical attributes (Hulin, Gabbett, Caputi, Lawson, & Sampson, 2016b; Soligard et al., 2016). Monitoring athletes is therefore pertinent in managing the relationship between load and injury risk (Soligard et al, 2016).

2.6.3. Current load monitoring practices

Monitoring training load is useful in estimating the adaptive response of an athlete to a prescribed training load and to reduce the associated risk of developing non-functional overreaching, injury and illness (Halson, 2014). The benefits of monitoring an athlete include recording changes in performance, determining the level of fatigue, establishing an understanding of training responses and the requirements for recovery (Foster, 1998; Halson, 2014; Impellizzeri & Rampinini, 2005). A study by Taylor, Chapman, Cronin, Newton, & Gill (2012) found that the most common reasons for monitoring were injury prevention (29%), effectiveness of training (27%), performance maintenance (22%) and preventing overtraining (22%).

The method of load monitoring differs between individualised and team based sports (Halson, 2014). In team-based sports, useful load monitoring measures include sport specific physiological measures, movement based patterns and skills. Team based sports are perceived to be more challenging in load monitoring due to factors like specific tactics and the diverse number of training activities (Halson, 2014). There are numerous load monitoring measures available, however, a limited number of measures are supported with sufficient evidence for their use (Borresen & Lambert, 2009; Halson, 2014). In load monitoring, the quantification of load can be divided into internal and external load (Halson, 2014).

Internal training load represents an individual's internal physiological or perceptual response to a given load (Gabbett, 2016). The rating of perceived exertion (RPE) is used to measure internal training load based on the athlete monitoring their own physiological stress during exercise and retrospectively with their perceived effort within 30 minutes after the completion of exercise (Borresen & Lambert, 2009). This method is the session rating of perceived exertion (sRPE) which quantifies training load by multiplying the duration in minutes by the athletes RPE on a scale of zero to ten for a training session (Borresen & Lambert, 2009; Day, Foster, 1998).

Heart rate (HR) monitoring is a method commonly used to assess internal training load based on a linear relationship between HR and the rate of oxygen consumption during steady state exercise (Hopkins, 1991). However, daily variation in submaximal heart exists and variables such as hydration, environment and medication may impact the variation of daily heart rate (Bagger, Peterson, & Pederson, 2003). The combination of HR and RPE as a ratio may assist in determining the level of fatigue of an athlete (Martin & Anderson, 2000). Training Impulse (TRIMP) is a unit of physical effort that is calculated using training duration and maximal, resting, and average HR during the exercise session and is useful in assessing the level to which exercise raises heart rate between resting and maximal levels (Borresen & Lambert, 2009; Halson, 2014). Lactate concentrations are sensitive to changes in exercise intensity and duration.

Practical limitations do exist in regular monitoring such as the time and site of sampling, inter- and intra-individual differences in lactate concentrations based on ambient temperature, hydration, diet, glycogen, previous exercise and muscle mass used during exercise training (Borresen & Lambert, 2009; Beneke, Leithäuser, & Ochentel, 2011). Heart rate recovery (HRR) measures autonomic function and training status in athletes through measuring the rate at which HR declines once exercise is completed (Halson, 2014). Heart rate recovery is useful in assessing changes in training status but factors that affect the variation of daily heart rate such as hydration, environment, and medication require more studies and better standardisation methods for its use (Daanen, Lamberts, Kallen, Jin, & Meeteren, 2012).

External training load is the physical 'work' performed by an athlete during training or matches (Gabbett, 2016). Measuring external training load uses the hours of training, distance of the training activity, and the number and intensity of sprints among others (Gabbett, 2016; Soligard et al., 2016). External load has become pertinent in determining the capacity of an athlete by the amount of physical 'work' completed in training and/or competitions (Gabbett, 2016).

In team-based sports, global positioning system (GPS) and movement pattern analysis are commonly used to quantify external training load (Halson, 2014). In addition, the jump test, isokinetic, iso-inertial dynamometry and sprint performance are used to measure neuromuscular function in team-based settings (Twist & Highton, 2013).

Whether in team-based or individual sports, the adaptation to training and the magnitude of training load could vary between individual athletes (Borresen & Lambert, 2009; Halson, 2014). Individualised monitoring in alignment with sport-specific thresholds are important to identify an athlete's training response in order to determine the training outcome (Halson, 2014).

2.6.4. Internal and external training load and injury

Internal training load is recorded as exertional units by using the sRPE method which multiplies the duration of each session by the score of the modified RPE scale (Gabbett, 2016). Using subjective monitoring in athletes' is known to be sensitive in calculating the changes in response to internal loads (Booth & Thomason, 1991).

In a study by Cross et al. (2016), a higher one-week (1245 exertional units or more), high week to week changes (1069 exertional units) and four-week cumulative loads (8651 exertional units or more) were the limits associated with a higher injury risk in 173 senior professional Rugby Union players.

External training load calculation using GPS is reliable and valid in establishing the total distance completed by an athlete in metres (Hulin et al., 2016a; Rampinini et al., 2014). In elite Rugby League, a similar sport to Rugby Union, distances greater than nine meters of high speed running (> $7m.s^{-1}$) per session through a single bout or accumulated were 2.7 times more likely to sustain a non-contact, soft-tissue injury than players who performed less high speed running per session (Gabbett & Ullah, 2012; Hendricks & Lambert, 2010). The individual characteristics of an athlete in combination with the internal and external training loads provide the outcome and response of training (Impellizzeri & Rampinini, 2005).

2.6.5. Acute and chronic training load: Acute to chronic ratio

Load should be considered as an acute and cumulative ratio when determining athletic performance, overall well-being and injury risk (Quarrie et al., 2017). According to Gabbett (2016), a measure for athlete's preparedness and injury risk can be determined as a ratio by comparing an athletes' acute training load with the chronic training load completed. An athlete is considered well prepared if the athlete has performed a low acute training load (one week) resulting in minimal 'fatigue' with a high rolling average of chronic load (three to six weeks rolling average) which represents 'fitness' (Gabbett, 2016). In contrast, an athlete will be in a state of 'fatigue' if the athlete has performed a low chronic training load coupled with a high acute load resulting in an acute to chronic ratio greater than one (Gabbett, 2016).

In athletes returning to training following injury and/or illness, preventing high weekly changes in load is also recommended (Blanch, & Gabbett, 2016; Cross et al., 2016; Herring, Kibler, & Putukian, 2012). Variables such as internal and external training measures should be modelled in a manner that is specific to the individual athlete, the type of sport and the initial injury mechanism (Blanch & Gabbett, 2016). There is a paucity in research in prescribing acute and chronic loads in athletes returning to participation following a time-loss injury and/or illness in Rugby Union.

2.6.6. The injury prediction model

The production of the first injury risk prediction model for non-contact injuries in elite Rugby League players was presented by Gabbett (2010). This model has become a well-established injury-prediction method which predicts an increase in injury risk if the current training loads exceed the planned training loads (Gabbett, 2010). In addition, the model reports a specificity of 98%, sensitivity of 87%, a positive predictive value of 62%, and therefore provides a platform for managing training load and injury risk (Gabbett, 2010). The similarities between Rugby League and Rugby Union has resulted in the need for further research into the application of the injury prediction model in Rugby Union (Kara, 2013).

Through calculating the acute to chronic ratio, the training ideal has been reported within the range of 0.8-1.3 but a ratio equal to or greater than 1.5 represents an increased injury risk (Gabbett, 2016; Hulin et al., 2013). The range of 0.8-1.3 has been suggested in order to minimise the risk of injury (Gabbett, 2016; Hulin et al., 2016b). Figure 2 represents a guide for interpreting the acute to chronic workload ratio based on data from three team sports (Blanch & Gabbett, 2016; Gabbett, 2016). Different sports vary in training-load relationships and could therefore differ in the training ideal range for a specific population (Gabbett, 2016). A study by Hulin et al. (2013), documented that acute load similar to, or lower than the chronic load with an acute to chronic ratio of equal to or less than 0.99 resulted in the likelihood of injury of four percent for elite fast bowlers in cricket over the following seven days. If the ratio was greater or equal to 1.5, the risk of sustaining an injury was two to four times greater over the following days (Hulin et al., 2013; Malone et al., 2017). Gabbett (2010) reported that a consistent progression of five to ten percent in training load more than the previous week is effective in increasing performance but 15% or greater than the previous week, increases the risk of injury between 21% and 49% (Gabbett, 2010).

It has been hypothesized that the balance between acute and chronic training loads are important in determining injury risk (Gabbet, 2016; Hulin et al., 2013). Since the introduction of the acute to chronic training load concept, several studies have reported on the independent role of chronic training load on injury risk in elite Rugby League and Football (Hulin et al., 2016a; Murray, Gabbett, Townshend, Hulin & McLellan, 2016). Findings have demonstrated that high chronic training loads are associated with a decreased risk of injury and lower chronic loads are associated with an increased risk of injury (Hulin et al., 2016a; Malone, Roe, Doran, Gabbett & Collins, 2017; Murray et al., 2016). With gradual and controlled loading, high cumulative loads provide resilience against sustaining an injury through the adaptation and development of physical attributes (Hulin et al., 2016b; Soligard et al., 2016). In a study by Hulin et al. (2016a) , from 44 match injuries, no match injuries were recorded in players (n= 17) with very-high chronic training load (≥ 22.1km) during short between match recovery times. In addition, a high chronic training load (18.9 – 22.1km) was associated with a match injury risk of 73% lower than moderate-low chronic training load (Hulin et al., 2016a).

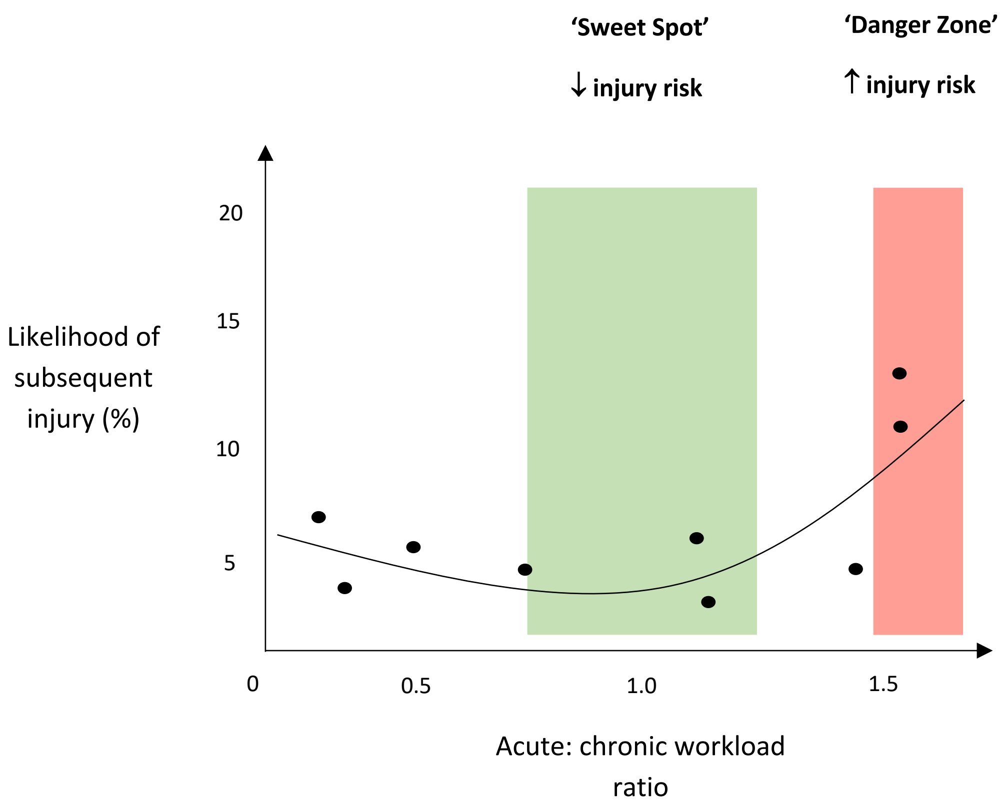

Figure 2: A proposed guide to interpreting and applying the acute:chronic workload ratio. The green are represents low injury risk. The red area represents high injury risk. Adapted from Blanch and Gabbett (2016) and Gabbett (2016).

Further research is needed to report the effectiveness of this hypothesis in Rugby Union. A study by Cross et al. (2016) in the English Premiership Rugby competition supports the hypothesis of the injury prediction model where an increased injury risk was recorded for elevated acute training loads or large changes in week to week acute training loads. In addition, a 'U-shape' curve was reported for four-week cumulative loads with a substantial increase in injury risk when loads were at their highest (Cross et al., 2016).

Literature has recently focused on the mediating and moderating factors of the workload-injury relationship (Windt, Zumbo, Sporer, MacDonald & Gabbett, 2017). Mediators are viewed as the mediating factors which result in an increased risk of injury such as neuromuscular fatigue as a result of sudden changes in acute training load (Windt et al., 2017). Moderators are known as factors which modify the interaction between training load and injury (Windt et al., 2017). For example, a sudden change in acute training load may increase neuromuscular fatigue however, factors relating to an athlete's aerobic fitness and physical condition may moderate the relationship between training load and injury (Windt et al., 2017).

It has been shown that high chronic training loads (> 4750 AU) may enable athletes to tolerate greater exposure to maximal velocity running (Malone et al., 2017). Numerous studies have reported that athletes with a greater aerobic capacity and prolonged high intensity running ability have a decreased risk of injury as higher chronic training loads offer a protective effect against injury (Gabbett & Domrow, 2007; Gabbett & Ullah, 2012; Windt et al., 2017). Further studies are warranted to investigate moderating factors that improve an athlete's resilience to injury (Windt et al., 2017).

In recent studies, methodological elements of the acute to chronic training load concept have been critiqued. It has been reported that the use of rolling averages for the calculation of the acute to chronic ratio is limited in determining the training outcome (Hawley, 2002; Williams, West, Cross & Stokes, 2017). The accuracy of the ratio in detecting the variations in cumulative loads such as the decaying nature of fitness and the impact of fatigue over time has been questioned (Hawley, 2002; Williams et al., 2017). The use of exponentially weighted moving averages (EWMA) has been proposed as it includes a decreasing weighting for each older training load value (Williams et al., 2017). More weighting is applied to higher loads at 28 days (when estimating fatigue) and higher acute to chronic ratios are noted at day 28 (Williams et al., 2017). As a result, the rolling average approach and the EWMA differ in the resultant ratio as to whether an athlete is considered to be in the 'sweet spot' range of 0.8 to 1.3 (Gabbett, 2016). Further research is warranted in the use of the EWMA.

The calculation of the acute to chronic ratio includes the correlation between the numerator and the denominator (Lolli et al., 2017). However, the acute training load forms a large part of the chronic training load forming 'mathematical coupling' (Blanch & Gabbett, 2016; Lolli et al., 2017). Authors have reported that this method could undermine the accuracy of the correlations and compromise the inferences drawn from the resulting values (Lolli et al., 2017; Pearson, 1896). Authors recommended the exclusion of the acute training load measure in the calculation of chronic training load (Lolli et al., 2017).

In addition, modelling the relationship between cumulative training load or the acute to chronic ratio (continuous risk factors) into distinct categories (injury or no injury) is known as discretization (Carey et al., 2018). According to Carey et al. (2018), discretization has not been critically examined in the context of training loads and injury .This method assumes that each individual within a given category has equal risk resulting in a loss of information and excluding variation within a category (Bennette & Vickers, 2012; Carey et al., 2018). As a result, the statistical power of the study and the detection of relationships between variables is compromised (Altman & Royston, 2006; Bennette & Vickers, 2012; Carey et al., 2018; Kahan, Rushton, Morris & Daniel, 2016). Modelling workload-injury relationships with continuous methods such as spline regression or fractional polynomials have been recommended (Carey et al., 2018). In addition, probabilistic scoring methods have been suggested when assessing injury models (Carey et al., 2018).

Data are limited in South African Rugby Union in monitoring and accessing internal and external training loads, injury profiles and illness at an elite level. There is a lack of established data investigating the relationships of training loads on injury and illness rates using validated ranges from the injury prediction model in elite South African Rugby Union players.

2.7. SUMMARY: TRAINING LOAD, PERFORMANCE AND INJURY

The ideal training load prescription optimizes performance whilst limiting the negative consequences of training by determining an athlete's response to training (Calvert, Banister, Savage, & Bach, 1975). Internal and external training loads are typically monitored with the combination resulting in training outcome (Impellizzeri & Rampinini, 2005). Monitoring athletes is needed to contribute to the existing pool of data on load and injury and/or illness risk within elite South African Rugby Union players. While a number of potential markers for measuring internal and external training load are available, few have evidence-based support for their use (Borresen & Lambert, 2009; Halson, 2014). Through individual monitoring, the training outcome can reveal fatigue based on the changes between internal and external training loads (Impellizzeri & Rampinini, 2005).

Sudden increases in acute training load beyond what an athlete is adapted and prepared for is a risk factor to injury in contrast to consistently high training loads (Cross et al., 2016). Through gradual and controlled loading, high cumulative loads of training provide a protective effect against injuries through the development and adaptation of various physical attributes (Hulin et al., 2016b; Soligard et al., 2016).

The acute to chronic ratio provides a measure of an athletes preparedness and injury risk by emphasizing both positive ('fitness') and negative ('fatigue') consequences of training (Gabbett, 2016). The injury-prediction method predicts injury risk based on current and planned acute and chronic training loads (Gabbett, 2010). Various sports may represent different training-load relationships as well as acute to chronic ratios (Gabbett, 2016).

2.8. SUMMARY OF THE LITERATURE

A higher level of play within Rugby Union has been associated with an increased incidence of injury (Williams et al., 2013). Overall, the incidence of injury in the Super Rugby tournament is one of highest among general professional Rugby Union (Fuller et al., 2009; Schwellnus et al., 2014; Whitehouse et al., 2016; Williams et al., 2013). The reason for the wide variation of injury incidence is unclear. Match injuries are significantly higher compared to training injuries in Rugby Union and in two Super Rugby tournament study (Williams et al., 2013; Schwellnus et al., 2014; Whitehouse et al., 2016). The most frequent causes of injury is the contact event with being tackled and tackling (Bathgate et al., 2002; Fuller et al., 2007; Fuller et al., 2009; Hendricks & Lambert, 2010; Schwellnus et al., 2014; Whitehouse et al., 2016; Williams et al., 2013).

Literature on the Super Rugby tournaments reported the majority of the injuries as 'minimal' severity (Fuller et al., 2009; Schwellnus et al., 2014; Whitehouse et al., 2016). Injuries pose a substantial impact on a rugby players well-being and time-loss from training and matches negatively impacts team success (Hurley, 2014).

There are a limited number of epidemiological studies on the Super Rugby tournament reporting the incidence of training and match injuries. The anatomical site, type, mechanism and time-loss of injuries has been well documented in general professional Rugby Union. However, following the 2007 Consensus Statement on Rugby Union injury epidemiology research, there is a paucity in injury epidemiology and profiles in general professional Rugby Union and the Super Rugby tournament.

A high incidence of illness has been reported in the 2010 Super Rugby tournament in comparison to other sporting codes (Alonso et al., 2010; Dvorak et al., 2011; Engebretsen et al., 2010; Schwellnus et al., 2012; Mountjoy et al., 2010). The majority of the reported illnesses occurred in the respiratory system (Schwellnus et al., 2012). Infection was the most frequent diagnosis and most of the illnesses did not cause extensive time-loss from training and/or matches (Schwellnus et al., 2012). A decrease in exercise performance is documented in acute illness (Friman & Wesslén, 2000; Schwellnus et al., 2016; Weidner & Sevier, 1996). Changes to internal and external training loads are associated with an elevated illness risk (Schwellnus et al., 2016). However, more data are required on the Super Rugby tournament to determine illness epidemiology over a complete Super Rugby tournament and to quantify the association between training loads and illness.

Prolonged load from training and competitions with insufficient recovery time has been linked to a decrease in performance, elevated risk of injury and acute illness (Schwellnus et al., 2016). Despite the increasing demands, successful sporting teams report a high availability of players and lower injury rates than unsuccessful teams (Williams et al., 2016). The adverse effects of training load are dose-related (Gabbett, 2016). Training load prescription is typically measured through internal and external training load, with the combination resulting in training outcome (Impellizzeri & Rampinini, 2005). There are limited training load measures with evidence to support their use. High cumulative loads of training offer protection from sustaining an injury due to the development of physical characteristics (Hulin et al., 2016b; Soligard et al., 2016). Monitoring internal and external training loads may aid in revealing fatigue in athletes (Impellizzeri & Rampinini, 2005). Load monitoring is needed to contribute to the existing pool of data on load, illness and injury risk within elite South African Rugby Union.

A ratio which compares acute and chronic training load provides a measure of an athlete's preparedness and injury risk (Gabbett, 2016). Training-load relationship varies in different sports and as a result, the ideal training range for a specific population could differ (Gabbett, 2016).

Preventing high weekly changes in load through load monitoring and management is also suggested to prevent new and/or subsequent injury in the re-integration of athletes back into training (Blanch, & Gabbett, 2016; Cross et al., 2016; Herring, Kibler, & Putukian, 2012). The existing data on the Super Rugby tournament has demonstrated elevated injury and illness rates (Schwellnus et al., 2012; Schwellnus et al, 2014; Whitehouse et al., 2016).

However, the precise relationship between training load and the high rates of injury and illness profiles in the Super Rugby tournament is unclear. Internal and external training load data in the Super Rugby tournament over a complete season can assist researchers to understand how a risk factor such as training load contributes to the burden of injury and illness in Rugby Union.

CHAPTER 3: METHODOLOGY

3.1. INTRODUCTION

The Translating Research into Injury Prevention Practice (TRIPP) framework recognizes that to develop a sufficient evidence base for injury prevention, the first step is to determine the incidence and severity burden within the context of implementation (Finch, 2006). The second step is to establish the aetiology and mechanisms of injury through epidemiological studies (Finch, 2006). Internationally, Rugby Union is known to have one of the highest reported incidences of injury and illness (Williams et al., 2013) (Section 2.1). In addition, a higher level of play has been associated with a higher incidence of injury (Williams et al., 2013) (Section 2.2.3). The demanding nature of the Super Rugby tournament has resulted in high rates of injury and illness reported in a limited number of studies (Fuller et al., 2009; Schwellnus et al., 2012; Schwellnus et al., 2014; Whitehouse et al., 2016) (Sections 2.1, 2.2.4 and 2.4.3). There is evidence that load management is a major risk factor to both injury and illness but these findings have not been reproduced within the Super Rugby tournament (Schwellnus et al., 2016; Soligard et al., 2016). Despite the potential adverse effects of training load, there is a lack of systematic recording of training and match loads associated with the Super Rugby tournament (Gabbett, 2016) (Section 2.6).

The aim of this study was to assess the relationships between training loads, injury profiles and illness rates in elite South African rugby players competing in the 2017 Super Rugby tournament. The specific objectives of this study are described in Chapter 1 (Section 1.2.2).

3.2. RESEARCH DESIGN AND RECRUITMENT

This study had a descriptive, observational, surveillance design. Adult male professional Rugby Union players were recruited from one South African Rugby Union participating in the 2017 Super Rugby tournament. The Rugby Union selected was based on data availability from consistent, ongoing recordings of internal and external training and match loads, injuries and illness over a 28-week period. Following ethical approval (HREC REF: 124/2018), the e-mail addresses for each participant and a weekly training schedule was requested from the Head Coach via e-mail (Appendix I). All participants contracted to the selected Union were approached via e-mail. Participants were invited to meet in the Team Meeting room at Growth Point Stadium, Durban for a verbal information session. The information session was arranged at a suitable time based on the participants weekly training schedule prior to signing the consent forms for the use of their data.

Data on training and match loads, injuries and illness are routinely collected by training and medical staff throughout the season. These data were used by coaching and support staff for information purposes and the monitoring of the participants. Although the participants were aware of, and participate in the ongoing monitoring, express informed consent was obtained from the participants to use their data in this study (Appendix II). These data were collected from the 11th January 2017 until the 22nd July 2017, and were included in this study for analysis purposes following permission by the individual players to use it for such purpose.

3.3. PARTICIPANTS

3.3.1. Inclusion Criteria

Participants who provided informed consent to participate in the study were included. Participants who were contracted to the selected Rugby Union for the full period of the 2017 Super Rugby tournament were eligible. Participants with complete data-sets of training-loads, injury and illness records over the complete 2017 Super Rugby tournament were included.

3.3.2. Exclusion Criteria

Participants who were released from their contract during the monitoring period or had not been contracted for the full 2017 Super Rugby tournament were excluded. Participants on loan to an alternate Rugby Union were also excluded. Contracted participants in alternative squads that served as a back-up player to the 2017 Super Rugby squad were excluded. Participants with incomplete training-loads, injuries and illness records were excluded. Participants who did not consent to participate or who withdrew from the study were not included. Participants could withdraw from the study by communicating directly with the researcher or supervisors verbally, telephonically or via e-mail.

3.3.3. Sample Size determination

Purposive sampling was used to recruit 45 elite South African rugby players to participate in the study. Based on the recruited population of 45 participants, with an expected injury incidence of 50%, and an acceptable margin of error of 5%, a sample size of 36, 39 and 41 was required for 80%, 90% and 95% statistical power for injury incidence respectively (Schwellnus et al., 2014). This calculation was performed on StatCalc by Epi Info.

3.4. MEASUREMENT INSTRUMENTS:

Instrumentation used for collecting data on injury, illness, training and match loads included self-designed data collection forms. These forms were based on the available data routinely collected by the Team Management.

3.4.1. Injury data collection

The training and match-related injuries were routinely collected by the Team Physician and the Head Physiotherapist. The injury data was collected from the Team Physician and the Head Physiotherapist. These data were collected and recorded on the injury data collection form and Boksmart Serious Injury Report Form (Appendix III and IV). Demographical data in the form of age was collected as part of the collected injury data (Appendix IV). The inclusion of injuries was based on the time-loss definition of an injury according to the 2007 Consensus Statement (Fuller et al., 2007). The Orchard Sports Injury Classification System 10.1 was used to code injury diagnosis (Rae & Orchard, 2007). Injury classifications such as location, anatomical site, type, mechanism and time-loss were defined according to the 2007 Consensus Statement on injury definitions and data collection procedures (Fuller et al., 2007; Schwellnus et al., 2014). The severity of time-loss injuries was classified as mild (2-3 days), moderate (8-28 days) and severe (≥28 days) (Fuller et al., 2007; Schwellnus et al., 2014).

3.4.2. Illness data collection

Illness events were routinely recorded daily by the Team Physician. These data were collected and documented on the illness data collection form (Appendix V). Illness data included the presenting symptoms, diagnosis, suspected cause of illness and time-loss from training and/or matches (Schwellnus et al., 2012) (Appendix V).

3.4.3. Training and match load data collection

3.4.3.1. Internal training loads

Internal and external training loads were recorded by the Head Strength and Conditioning Coach. Internal training loads were documented on the internal load data collection form (Appendix VI). The internal training load forms provided information on daily squad size, the type of training day, team and individual training minutes (Appendix VI). The RPE was completed by each player thirty minutes after every training session (field and gym) in order to calculate the internal training load using the modified RPE scale (Appendix VII). For both training and match loads, the reported RPE by each player was completed using the 2017 electronic application system Kitman Labs Ltd.

Subjective monitoring is more sensitive than objective measures in calculating acute and chronic changes in an athletes response to load (Booth & Thomason, 1991). Rating of perceived exertion is a physiologically valid and reliable method for estimating exercise training intensity thirty minutes after a training session (Day, McGuigan, Brice, & Foster, 2004; Dunbar et al., 1992; Herman, Foster, Maher, Mikat, & Porcari, 2006).

3.4.3.2. External training loads

External training loads were collected from the Head Strength and Conditioning Coach and documented on the external training load data collection form (Appendix VIII). The total distance a participant completed in metres for both training and matches were obtained. External training load was determined using the GPS in metres which has been found valid and reliable in determining the total distance completed in metres in athletes participating in field-based team sports (Hulin et al., 2016a; Rampinini et al., 2014).

3.4.3.3. Acute and chronic training load

Acute and chronic training loads were determined based on the internal and external training load data recorded on the internal and external training load data collection forms (Appendix V and VIII). For internal and external training load, acute training load was considered as the number of exertional units and the total distance covered over one week or seven days (Gabbett, 2016; Hulin et al., 2013) (Appendix V and VIII). Chronic training load represented a four week rolling average of acute training load in exertional units and the total distance covered in metres (Hulin et al., 2016b; Hulin et al., 2013) (Appendix V and VIII). The balance between acute and chronic training loads are important in determining injury risk (Gabbett, 2016; Hulin et al, 2013). Comparing acute to chronic training load as a ratio provides a measure of an athletes preparedness and injury risk (Gabbett, 2016; Hulin et al., 2013; Hulin et al., 2016b).

3.5. PROCEDURE

Ethical approval was granted by Human Research Ethics Committee (HREC) at the Faculty of Health Sciences, University of Cape Town (UCT) (HREC REF: 124/2018) (Appendix I). A letter of permission to conduct the study was signed by the Chief Executive Officer (CEO) of the Sharks Rugby Union (Appendix IX). Participants were then invited to a verbal information meeting that provided an explanation of the study and the informed consent forms. Informed consent forms were e-mailed and returned once completed from each participant who agreed to enrol in the study. Data for training and match loads, injuries and illness were then collected from the respective Team Management staff.

Once data were collected, participants were included based on the inclusion and exclusion criteria and statistical analysis was then completed.

3.5.1. Informed consent

All participants were required to complete an informed consent form prior to their inclusion in the study (Appendix II). The study procedures were explained to the participants as a group at the verbal information meeting. At this meeting, participants were requested to write their contact details on a paper slip and place it in a box at the back of the meeting venue if they were interested in participating. Once contact was made and if the participant was still willing to participate, the informed consent forms were e-mailed to them. Participants were given one week to revert back with questions to allow sufficient time to read the consent form prior to signing. The participants were reminded by a cellular text message to return the forms or ask further questions. All information regarding the study and the use of information were included in the consent form. The risks and benefits were clearly outlined and the participants right to refuse participation at any point of the study was explained.

3.5.2. Data Management

A randomised number was assigned to each participant once injury, illness and training load data were recorded to ensure confidentiality. All paper data were locked away in a storage cupboard and electronic data on a password secured lap-top in a locked office. Access to the data was restricted to the researcher. All identifiable data were coded, and any identifiable data will be destroyed at the end of the study by the researcher. Coded data will be stored for six years on completion of the study.

3.6. DATA AND STATISTICAL ANALYSIS

Statistical analysis was completed using STATISTICA (version 13.2). Demographical data of the squad in the form of age was presented in mean values.

3.6.1. Injury incidence and player hours

Descriptive statistics were reported in the form of counts for the number of injuries. Injuries were further divided into match and training related injuries. All data in the form of counts were modelled using a linear (Poisson) regression. The incidence of injury was calculated per 1000 player hours of exposure for pre-season, early and late competition phases (Gabbett & Domrow, 2007; Thomson, 2014).

For training, exposure was calculated by multiplying the number of players on a training day that have completed the training session by the sessions duration in minutes (Schwellnus et al., 2014).

Match player hours were calculated individually by adding the number of minutes an individual participant has participated for in each match (Schwellnus et al., 2014).

Match player hours for the squad were calculated by 1.33 hours (80 mins) of play multiplied by fifteen players (20 match-player hours) (Schwellnus et al., 2014). Total match player hours included 20 hours per match played and extra-time was included when appropriate (Schwellnus et al., 2014).

3.6.2. Illness incidence and player-days

Descriptive statistics were reported in the form of counts for the number of illnesses. All data in the form of counts were modelled using a linear (Poisson) regression. Illness incidence was calculated per 1000 player days for each season phase and time-loss was classified as illness resulting in one or more lost training and/or match days (Schwellnus et al., 2012). The total player days were calculated by the total team tournament days multiplied by the daily squad size (Schwellnus et al., 2012) (Appendix V). Total player days included training and match related days from the first day of pre-season training until the last match day of the season.

3.6.3. Training and match loads

Internal training load for training and matches was calculated by the intensity of each session using the modified RPE scale and the duration of the session in minutes (Foster, 1998; Gabbett, 2016; Kelly & Coutts, 2007). Training load was quantified by multiplying the RPE by the duration of the training session resulting in exertional units (Foster, 1998; Gabbett & Domrow, 2007). Match load was calculated by multiplying the RPE after each match by the number of minutes each participant played during the match (Foster, 1998; Gabbett, 2004a). External training load for training and matches was presented in meters completed by a participant.

The acute to chronic ratio was calculated by dividing the acute training load by the chronic training load for internal and external training loads (Gabbett, 2016) (Appendix V and VIII). The first acute to chronic ratio began on the first day of the fourth week of pre-season and the last ratio was recorded on the last match of the season.

Shapiro-Wilks tests were used to test the normality of the distributed data prior to analysis. Data were found to be not normally distributed and were assessed using non-parametric tests.

Descriptive statistics for internal and external training load were presented as median values along with minimum and maximum values. Chi-squared tests were performed through Friedman's ANOVA to assess for associations between internal and external training loads, internal and external acute to chronic ratios for all participants and by groups of injury and illness.

Mann-Whitney U tests were conducted to further determine associations between groups injury and non-injury, illness and non-illness on variables of internal and external training loads, and internal and external acute to chronic ratios. In addition, effect sizes were calculated to measure the magnitude of difference between significant mean differences reported from the Mann-Whitney U testing.

Spearman's rank correlation coefficients were used to determine the strength of the relationship between the changes in both internal and external training loads and training and match injuries using the acute to chronic index ratio. Spearman's rank correlation coefficients were used to determine the strength of the relationship between changes in internal and external training loads and illness using the acute to chronic index ratio.

Odds ratios were used to determine the likelihood of injury and illness for internal and external acute to chronic ratios per season phase. The incidence of injury and illness on return to play following four-week time-loss as a result of injury or illness were determined based on counts. Statistical significance was accepted at $p < 0.05$.

3.7. ETHICAL CONSIDERATIONS

Ethical considerations in this study were guided by the Declaration of Helsinki (Fortaleza, Brazil, 2013). A statement of disclosure was received by the HREC to address any potential conflict of interest (Appendix X).

3.7.1. Autonomy

All participants were given a choice to participate in the study. Although the researcher was employed by the selected Union, the employee has not been involved in the data collection during the season. The employee does not work directly with the Super Rugby Squad (Appendix X). This information was explained verbally in the information session and documented in the informed consent form to the participants. Participants were informed that they could freely withdraw from the study at any point without penalty or discrimination (Appendix II).

3.7.2. Risk to participants

Participants were informed about the risks of participating in the study prior to signing the informed consent form (Appendix II). There were no physical risks involved, beyond those inherent risks in participating in rugby as a professional sport, as there was no physical testing in this study.

Confidentiality was maintained by assigning random numbers to each participant once data were collected.

The researcher acknowledged the risk of injury and illness information affecting the players' availability for national squads and international clubs if not kept confidential. Data were protected in password protected documents, and hardcopies were secured in locked cabinets to eliminate this. In the event of a severe injury, it is possible that the participant may be unofficially identified by the public through speculated association, due to media coverage and public interest in the Super Rugby tournament. Every effort to maintain confidentiality was therefore made, and will be made during the publication of the study.

3.7.3. Benefits to Participants and Team Management

3.7.3.1. Participants

There was no remuneration or direct benefits to the participants. There were no costs incurred by the participants. All participants benefitted through an infographic presentation on the results at the end of the study (Appendix XI). Participants benefitted individually with confidential reports on their training and match loads, injuries and illness (Appendix XII). Data that identified participants as potentially having trends that may predispose them to prospective injury or illness were encouraged by the researcher to engage with their management personnel regarding potential risks.

3.7.3.2. Team Management

A statistical report was given to the Team Management involved in the collection of data. Results did not disclose details about individual players as this may impact on their careers. Data trends that represented an alternative ideal training range for this population were presented which could aid in future preparation for the following competition.

CHAPTER 4: RESULTS

4.1. PARTICIPANTS

Forty-five participants were recruited for this study. Thirty-nine participants were eligible for inclusion in the study and six participants were excluded. The study sample is summarized in Figure 3.

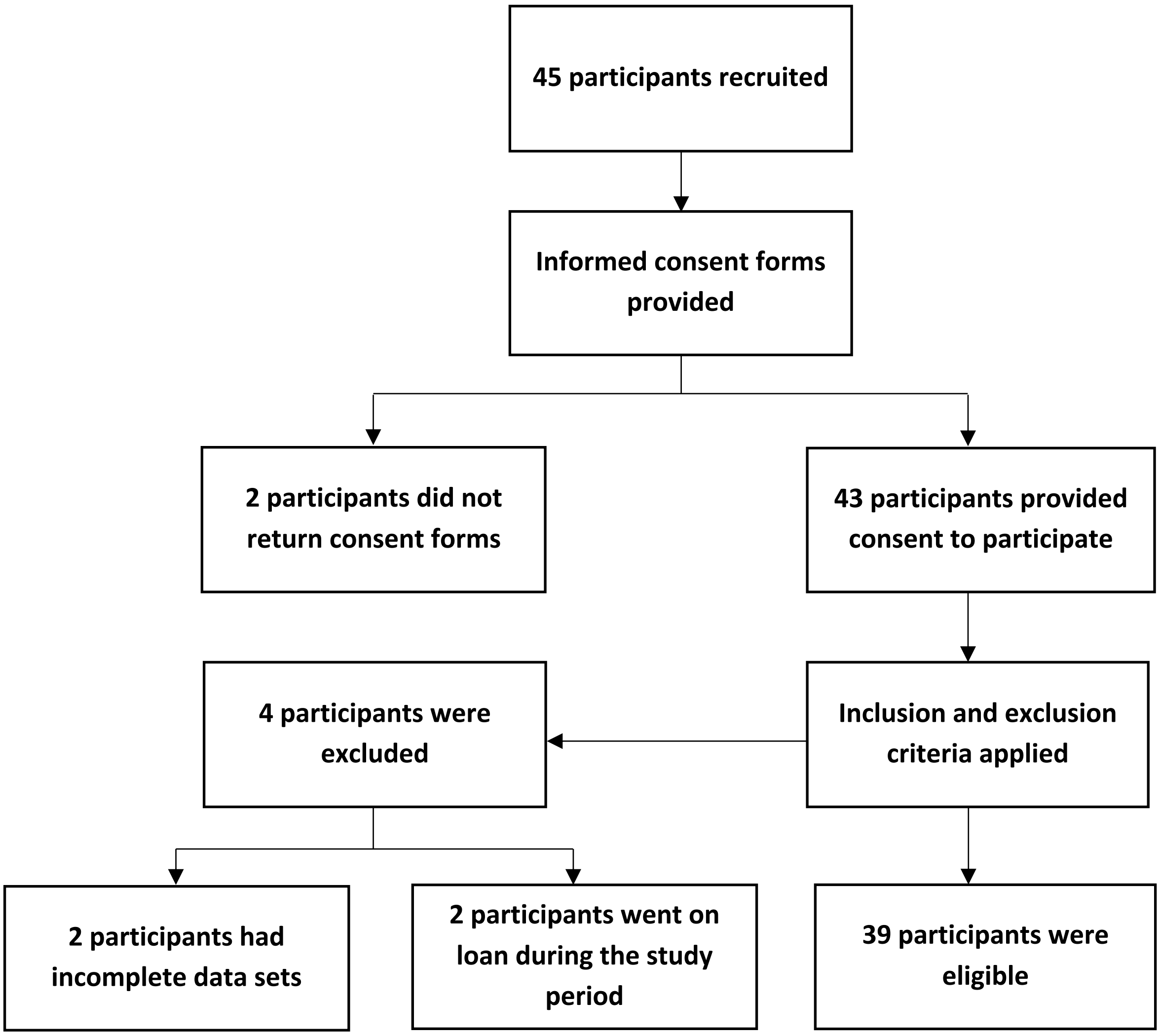

Figure 3: Summary of study sample

4.2. DESCRIPTIVE ANALYSIS OF TRAINING AND MATCH EXPOSURE

4.2.1. Demographic data

Demographic data analysis was limited to age and player position data only, to protect privacy and confidentiality of individual players given the small and highly identifiable study cohort. The mean age of the overall squad was 25.3 ± 4.0.

4.2.2. Overall, training and match player hours of exposure

A total of 6277 player hours of exposure were recorded over the 2017 Super Rugby tournament with a mean all player hours of 160.9. Of the total player hours, 249 were match player hours, and 6028 were training player hours. The mean match and training player hours per player was 6.4 and 154.6 respectively.

4.2.3. Overall, training and match player hours per season phase

According to season phases, the highest overall player hours were demonstrated in the late competition phase and lowest during the preseason phase. Training player hours were highest in late competition and match player hours were highest in early competition as shown in Table 6. Additional training and match exposure per main player position is shown in Appendix XIII.

Table 6: Overall, training and match exposure in player hours per season phase.

Season Phase (weeks)	All players (n= 39)			
	Overall player hours	**Training player hours**	**Match player hours**	**Mean player hours**
Preseason: (1-7)	1926	1926	0	275 ± 94
Early competition: (8-17)	2065	1930	135	120 ± 39
Late competition: (18-28)	2286	2172	114	113 ± 60

Mean player hours are expressed as mean ± standard deviation.
Red colour represents the highest values; Green colour represents the lowest values

4.2.4. Weekly training and match player hours

Figure 4 shows weekly match and training player hours. The training player hours were higher than the match player hours over the 28 weeks. The highest exposure point in training player hours was in week two and the lowest in week 21.

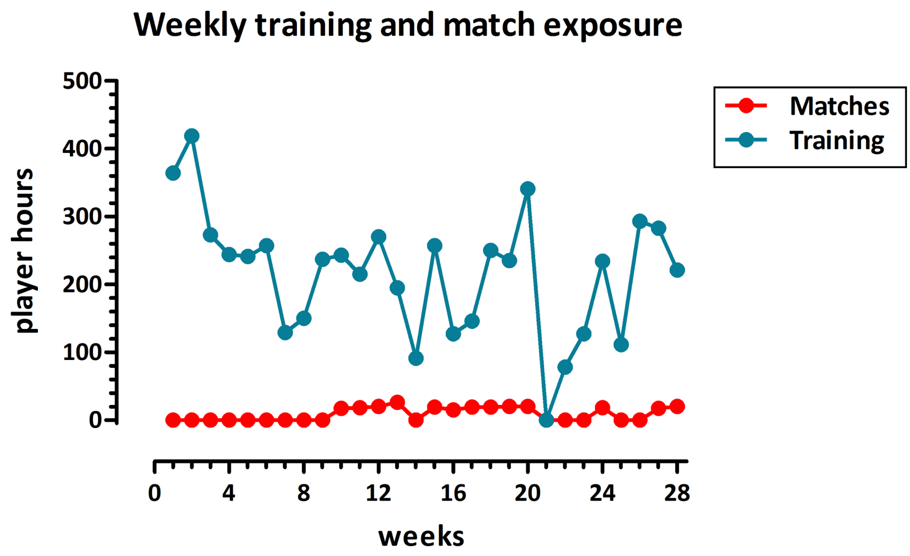

Figure 4: Weekly match and training exposure over 28 weeks.

4.3. INJURY PROFILE

4.3.1. Incidence of injury per season phase

A total of 80 injuries were recorded over the 28-week period. Thirty-eight injuries were excluded from the analysis as twenty-eight did not result in time-loss, three did not fall within the study period and seven occurred in non-rugby related incidents. The highest percentage of injuries were reported in the early competition phase (48.8%). Table 7 illustrates the number of injuries and the incidence of injury per season phase.

Table 7: Injury incidence for overall, training and matches per season phase.

Season Phase (weeks)	Overall		Training		Matches	
	Injury (n)	Incidence 95% (CI)	Injury (n)	Incidence 95% (CI)	Injury (n)	Incidence 95% (CI)
Preseason (1-7)	7	3.6 (1.6-7.2)	7	3.6 (1.6-7.2)	0	0
Early (8-17)	39	18.0 (13.7-25.7)	7	3.6 (1.6-7.2)	32	237.0 (165-331)
Late (18-28)	34	14.9 (10.5-20.1)	6	2.8 (1.1-5.7)	28	245.0 (166-350)

Incidence is expressed as injuries per 1000 hours of exposure.
Red colour represents the highest proportion; Green colour represents the lowest proportion.

4.3.2. Incidence of match and training injuries

The overall incidence of injury was 12.8 per 1000 player hours (95% CI: 10.0-15.8) as shown in Table 8. Match injuries accounted for 241.0 per 1000 player hours (95% CI: 186.0-308.0) in comparison to training with 3.3 per 1000 player hours (95% CI: 2.1-5.0). Matches incurred the greatest number of injuries in comparison to training despite having a significantly lower exposure in player hours with 249 player hours in comparison to 6028 player hours. Injury incidence per season phase according to main playing position is depicted in Appendix XIII.

Table 8: Player hours and the incidence of time-loss injuries for all participants.

	All players (n= 39)		
	Number of time-loss injuries	**Player hours**	**Incidence of injury (95% CI)**
All injuries:	80	6277	12.8 (10.0-15.8)
Match injuries:	60	249	241.0 (186.0-308.0)
Training injuries:	20	6028	3.3 (2.1-5.0)

Incidence is expressed as injuries per 1000 hours of exposure.
Red colour represents the highest proportion; Green colour represents the lowest proportion

4.3.3. The proportion of injured participants

From the total squad, 76.9% (n= 30) sustained a time-loss injury. According to the severity of injury, minimal (2-3 days) severity represented the highest time-loss in the proportion of injured players with 28.2% (n = 11). This was followed by mild (4-7 days) 23.1% (n = 9), moderate (8-28 days) 23.1% (n = 9), and severe (≥28 days) 2.5% (n = 1). Therefore, 25.6% (n= 10) of the total squad (n = 39) sustained an injury severe enough to prevent eight days or more of participation in training and/or matches.

4.3.4. Main anatomical location

The percentage and incidence of injury according to anatomical location are shown in Table 9. The majority of all injuries occurred in the lower limb with 62.5%, followed by the head or neck region with 15%. The main and specific anatomical location of injuries per main playing position are presented in Appendix XIII.

Table 9: The percentage and incidence of injury for all participants according to main anatomical location.

Main Anatomical Region	Injury (n)	Percentage (%)	Player hours	Incidence (95% CI)
All players:	80	100	6277	12.7 (10.0-15.8)
Head/neck	12	15.0	6277	1.9 (1.0-3.3)
Upper limb	10	12.5	6277	1.6 (0.8-2.8)
Trunk	8	10.0	6277	1.3 (0.6-2.4)
Lower limb	50	62.5	6277	8.0 (6.0-10.4)

Incidence is expressed as injuries per 1000 hours of exposure.
Red colour represents the higher incidence; Green colour represents the lower incidence.

The lower limb had the highest proportion of match (60%) and training (70%) related injuries. The frequency and incidence of match and training related injuries by main anatomical location are shown in Table 10.

Table 10: The percentage and incidence of all training and match related injuries for all participants by main anatomical location.

Main Anatomical Region	Match injuries				Training injuries			
	Injury (n)	Percentage (%)	Player hours	Incidence (95%CI)	Injury (n)	Percentage (%)	Player hours	Incidence (95%CI)
All players:	60	100	249	241.0 (185.5-308.0)	20	100	6028	3.3 (2.1-5.0)
Head/neck	10	16.7	249	40.1 (20.4-71.6)	2	10	6028	0.3 (0.06-0.10)
Upper limb	10	16.7	249	40.1 (20.4-71.6)	0	0	6028	0
Trunk	4	6.6	249	16.1 (5.1-38.8)	4	20	6028	0.6 (0.2-1.6)
Lower limb	36	60	249	145.0 (103.0-198.0)	14	70	6028	2.3 (1.3-3.8)

Incidence is expressed as injuries per 1000 hours of exposure.
Red colour represents the higher incidence; Green colour represents the lower incidence.

4.3.5. Specific anatomical location of injuries

According to specific anatomical location, the thigh region had the highest frequency of injuries with 20%, followed by the knee with 12.5% as depicted in Table 11.

Table 11: The incidence of injuries according to specific anatomical location for all participants.

Specific Anatomical Region	**Injury (n)**	**Incidence (95% CI)**
All injuries:	80	12.7 (10.2-15.8)
Head	6	1.0 (0.4-2.0)
Neck	6	1.0 (0.4-2.0)
Thoracic Spine	3	0.4 (0.1-1.3)
Chest	2	0.3 (0.1-1.0)
Shoulder	6	1.0 (0.4-2.0)
Upper arm	1	0.2 (0-0.8)
Wrist	3	0.4 (0.1-1.3)
Lumbar spine	3	0.5 (0.1-1.3)
Gluteal	3	0.4 (0.1-1.3)
Groin	3	0.4 (0.1-1.3)
Hip	1	0.2 (0-0.8)
Thigh	16	2.5 (1.5-4.0)
Knee	10	1.6 (0.8-2.8)
Lower leg	7	1.1 (0.5-2.2)
Ankle	7	1.1 (0.5-2.2)
Foot	3	0.4 (0.1-1.3)

Incidence is expressed as injuries per 1000 hours of exposure.
Red colour represents the higher incidence; Green colour represents the lower incidence.

4.3.6. Type of injuries

Soft-tissue injuries (muscle, tendon, ligament, brain and skin) accounted for 96% of all injuries. Of the soft-tissue injuries, the majority occurred in muscles or tendons (64.9%), followed by joints or ligaments (25.0%).

For matches, the incidence of muscle or tendon injuries was 148 per 1000 player hours (95% CI: 106-203) and ligament or joint injuries was 60 per 1000 player hours (95% CI: 35-97). For training, the incidence of muscle or tendon injuries was 2.2 per 1000 player hours (95% CI: 1.2-3.6) and joint or ligament was 0.8 per 1000 player hours (95% CI: 0.3-1.8) as shown in Table 12. Additional incidence and percentage of injury types according to main playing position is illustrated in Appendix XIII.

Table 12: The incidence and percentage of injury types for all injuries including match and training injuries.

Anatomical type	Injury (n)	Incidence	(95% CI)
All injuries:	80	12.0	(10.0-15.8)
Muscle/tendon	50	8.0	(6.0-10.4)
Joint/ligament	20	3.2	(2.0-4.8)
Skin	2	0.3	(0.1-1.1)
Bone	3	0.5	(0.1-1.3)
Brain	4	0.6	(0.2-1.5)
Unspecified	1	0	0
Match injuries:	60	241.0	(186.0-308.0)
Muscle/tendon	37	148.0	(106.0-203.0)
Joint/ligament	15	60.0	(35.0-97.0)
Skin	1	4.0	(0.2-20.0)
Bone	3	12.0	(3.0-32.0)
Brain	4	16.0	(5.1-3.9)
Unspecified	0	0	0
Training injuries:	20	3.3	(2.1-5.0)
Muscle/tendon	13	2.2	(1.2-3.6)
Joint/ligament	5	0.8	(0.3-1.8)
Skin	1	0.1	(0-0.8)
Bone	0	0	0
Brain	0	0	0
Unspecified	1	0.1	(0-0.8)

Incidence is expressed as injuries per 1000 hours of exposure.
Red colour represents the higher incidence; Green colour represents the lower incidence.

4.3.7. Injury mechanisms

The most common mechanism for all injuries was 'other' (32.5%) followed by the tackle (28.8%). Being tackled contributed overall to 21.3% of all injuries. The mechanism and frequency of injury for all participants is shown in Table 13. Additional mechanism and percentage of injuries according to main playing position is depicted in Appendix XIII.

Table 13: The mechanism and percentage of all injuries.

Mechanism	Injury (n)	Percentage (%)
All injuries:	80	100
Conditioning	1	1.2
Tackling front on	5	6.3
Tackling side on	1	1.2
Tackled front on	5	6.3
Tackled side on	10	12.5
Tackled from behind	2	2.5
Twisted	5	6.3
Landing	1	1.2
Side step	3	3.8
Acceleration	6	7.5
Deceleration	3	3.8
Weight training	1	1.2
Slipped	1	1.2
Other	26	32.5
Collision	7	8.8
Kicked	2	2.5
Kneed	1	1.2

Red colour represents the higher percentage; Green colour represents the lower percentage.

From the overall number of match injuries, the mechanism of being tackled accounted for 32% as shown in Table 14. The most common mechanism for training injuries were 'other' as depicted in Table 14.

Table 14: The mechanism and frequency of all match and training injuries.

Mechanism	Match injuries		Training injuries	
	Injury (n)	Percentage (%)	Injury (n)	Percentage (%)
All injuries:	60	100	20	100
Conditioning	0	0	1	5.0
Tackling front on	5	8.3	0	0
Tackling side on	1	1.7	0	0
Tackled front on	8	13.3	1	5.0
Tackled side on	6	10.0	0	0
Tackled from behind	2	3.3	0	0
Twisted	5	8.3	0	0
Landing	1	1.7	0	0
Side step	3	5.0	0	0
Acceleration	4	6.7	2	10.0
Deceleration	0	0	0	0
Weight training	0	0	1	5.0
Slipped	1	1.7	1	5.0
Other	14	23.3	12	60.0
Collision	6	10.0	1	5.0
Kicked	1	1.7	1	5.0
Kneed	1	1.7	0	0

Red colour represents the higher percentage; Green colour represents the lower percentage.

Overall, contact related injuries (37.5%) were greater than non-contact injuries (30%) with 'other' accounting for 32.5% of all injuries. From all match injuries (n = 60), contact injuries (46.6%) were greater than non-contact (30.0%) injuries. From all training injuries (n = 20), non-contact injuries (30%) were greater than contact related injuries (10%).

4.3.8. Injury Severity

The incidence and percentage of all, match and training injuries according to time-loss severity are displayed in Table 15. A total of 736 days of time-loss occurred due to injury over the 28-week period. A 'moderate' severity was the most frequent severity and resulted in a time-loss of 414 days followed by 'mild' severity resulting in a time-loss of 134 days. Severity of injury according to main playing position is shown in Appendix XIII.

Table 15: The incidence and percentage for all, match and training injuries according to time-loss severity.

Injury severity	Injury (n)	Percent (%)	Time-loss (days)	Incidence (95% CI)
All injuries:	80	100	736	12.7 (10.2-15.8)
Minimal (2-3 days)	24	30	44	3.8 (2.5-5.6)
Mild (4-7 days)	24	30	134	3.8 (2.5-5.6)
Moderate (8-28 days)	30	37.5	414	4.8 (3.3-6.7)
Severe (≥28 days)	2	2.5	144	0.3 (0.1-1.0)
Match injuries:	60	100	557	241.0 (18.5-308.0)
Minimal (2-3 days)	18	30	35	72.3 (44.0-112.0)
Mild (4-7 days)	17	28	95	68.3 (41.0-107.0)
Moderate (8-28 days)	24	40	336	96.4 (63.0-141.0)
Severe (≥28 days)	1	2	91	4.0 (0.2-19.8)
Training injuries:	20	100	179	3.3 (1.1-5.0)
Minimal (2-3 days)	6	30	9	0.9 (0.4-2.0)
Mild (4-7 days)	7	35	39	1.1 (0.5-2.3)
Moderate (8-28 days)	6	30	78	0.9 (0.4-2.0)
Severe (≥28 days)	1	5	53	0.2 (0-0.8)

Incidence is expressed as injuries per 1000 hours of exposure.
Red colour represents the higher time-loss and incidence; Green colour represents the lower time-loss and incidence.

Match injuries contributed to 75% of all time-loss with 557 days of time-loss, compared to training injuries resulting in 179 days. A large proportion of match-related injuries were 'moderate' (40%) with a time-loss of 336 days. The most frequent severity recorded for training injuries was 'moderate' severity resulting in 78 days of time-loss.

4.4. ILLNESS

4.4.1. Incidence of illness

Over the 28-week period, 7644 player-days were recorded. The overall incidence of illness was 1.8 per 1000 player days (95% CI: 1.0-3.0). The number of illnesses in each phase of the season are depicted in Table 16. A similar incidence of illness occurred in the early and late competition phases.

Table 16: Total exposure, illness and incidence per season phase.

Season Phase (Weeks)	Overall		
	Total Exposure	**Illness (n)**	**Incidence (95%CI)**
Preseason (1-7)	1911	0	0
Early Competition (8-17)	2730	7	2.6 (1.1-5.0)
Late Competition (18-28)	3003	7	2.3 (1.0-4.6)

Incidence is expressed as illness per 1000 player days.
Exposure is expressed as player days.
Red colour represents the higher proportion; Green colour represents the lower proportion.

4.4.2. Illness player proportion of time-loss illness in all players

The proportion of players that acquired an illness in the study was 28.2% (n = 11). From the total number of illnesses (n = 14), new illnesses accounted for 93% (n = 13) and recurrent illnesses accounted for 7% (n = 1).

4.4.3. Bodily systems affected by illness

The respiratory system was the most commonly affected bodily system followed by the digestive system. An incidence of 0.9 per 1000 player days (95% CI: 0.4-1.8) and 0.7 per 1000 player days (95% CI: 0.3-1.6) were demonstrated for the respiratory and digestive system, respectively as illustrated in Table 17.

4.4.4. Symptoms of illness

Diarrhoea (28.7%) was the most commonly presented symptom followed by symptoms listed as 'other' (21.4%), sore throat (14.3%) and fatigue (14.3%). The duration of symptoms prior to reporting were not included in the collection of data.

4.4.5. Specific diagnosis and suspected cause of illness

From the overall number of illnesses reported, acute URTI was the most common specific diagnosis (28.6%) followed by non-infective gastroenteritis (21.4%). Infection and causes listed as 'other' were the most common suspected cause of illness (35.6%) respectively followed by environmental (21.5%).

4.4.6. Time-loss of illnesses

Of the illnesses, 64.3% resulted in no time-loss, 21.4% in one day of time-loss and 14.3% more than one day of time-loss. The majority of time-loss as a result of illness was due to acute URTI with four days, followed by non-infective gastroenteritis with three days, as depicted in Table 17.

Table 17: The overall number, percentage, incidence and time-loss of illness per bodily system.

Bodily System	Illnesses (n)	Percentage (%)	Incidence (95% CI)	No time-loss	One day time-loss	> One day time-loss
All systems:	Illnesses (n = 14)	100	1.8 (1.0-3.0)	9	3	2
Respiratory:	All respiratory system illnesses (n = 7)	50.0	0.9 (0.4-1.8)	4	2	1
	Acute upper respiratory tract infection (n = 4)	28.6	0.5 (0.2-1.3)	1	2	1
	Allergic rhinitis (n = 2)	14.3	0.3 (0-0.9)	2	0	0
	Allergic sinusitis (n = 1)	7.1	0.1 (0-0.6)	1	0	0
Digestive:	All digestive system illnesses (n = 6)	43.0	0.7 (0.3-1.6)	4	1	1
	Non-infective gastroenteritis (n = 3)	2.1	0.4 (0.1-1.0)	3	0	1
	Other (n = 3)	2.1	0.4 (0.1-1.0)	3	1	0
Other:	Eye and adnexa (n = 1)	7.1	0.1 (0-0.6)	1	0	0

Incidence is expressed as illness per 1000 player days.
Red colour represents the higher proportion; Green colour represents the lower proportion.

4.5. INTERNAL AND EXTERNAL TRAINING LOADS AND INJURY

4.5.1. Internal training loads and injury

4.5.1.1. Descriptive analysis of the internal training loads

The weekly internal training loads of participants over the 28-week tournament are represented in Figure 5. Week 21 represents a bye week, with complete rest. Weeks 14 and 18 were also bye weeks however, participants continued to train with off-feet conditioning. Weekly internal training load per main player position is presented in Appendix XIII.

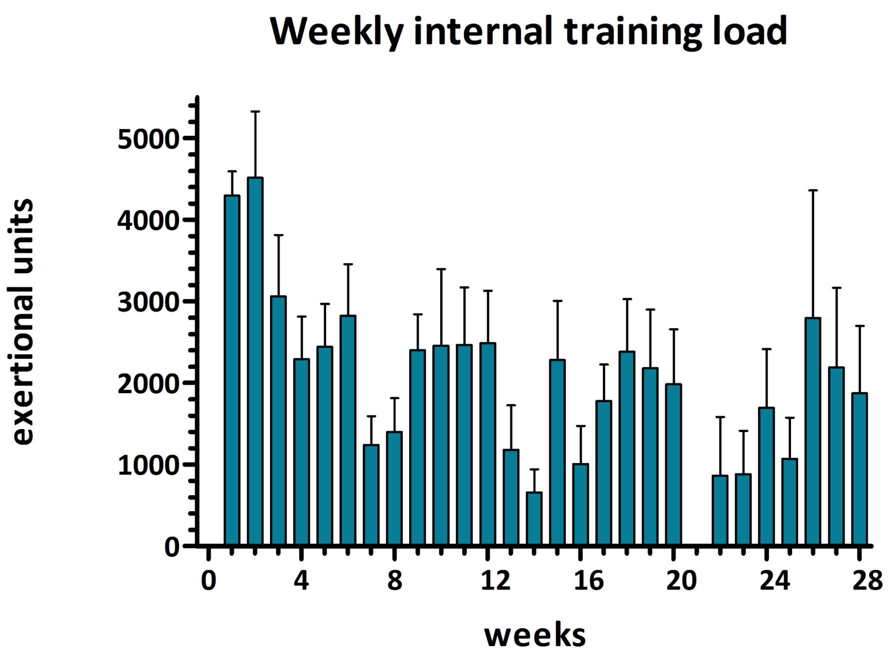

Figure 5: Bar graph illustrating internal training loads over 28 weeks for all participants.

Per season phase, preseason had the highest median value of internal training load followed by the early competition phase as shown in Table 18. In addition, the range of internal training loads in the preseason phase were the highest with 3273 followed by the range of the late competition phase with 2797.

Table 18: Descriptive data of the total internal training load over 28 weeks in exertional units. Data are expressed as median and range (minimum to maximum).

Internal training load (exertional units)	**Median (range)**
Total internal training load (n = 39):	1285 (0-4514)
Preseason load (n = 39)	2824 (1241-4514)
Early competition load (n = 39)	2030 (656-2487)
Late competition load (n = 39)	1875 (0-2797)

4.5.1.3. Internal training loads and injury incidence

There was a significant main effect of time in weekly internal training loads ($F_{1,26} = 704.5$, $p < 0.00001$) for all participants. The median value of internal training load in the injured group (n = 30) was 2191 (0-4439) which was higher than the non-injured group (n = 9) with 2020 (0-4766). There was also a significant main effect of time in weekly internal training loads for the injured ($F_{1,27} = 546.1$, $p < 0.00001$) and non-injured ($F_{1,27} = 202.2$, $p < 0.00001$) groups. The significant effects detected in individual weekly internal training loads for injured and non-injured participants are shown in Appendix XIII.

4.5.1.5. Correlation measure of internal training loads and injury incidence

Per season phases, a significant negative correlation (r = -0.34, n = 39, p = 0.03) was detected between internal training loads in the preseason and injury incidence. As training loads decreased, the incidence of injury increased. Significant weekly correlation measures of internal training loads and injury incidence are shown in Appendix XIII.

4.5.2. External training loads and injury

4.5.2.1. Descriptive analysis of the external training loads

The weekly external training loads for each participant over the 28-week tournament are represented in Figure 6. Bye weeks are evident in weeks 14 and 21 represent zero. In addition, week 18 also represented a bye week but included one field based running session in the training week. Weekly external training load according to main player position is presented in Appendix XIII.

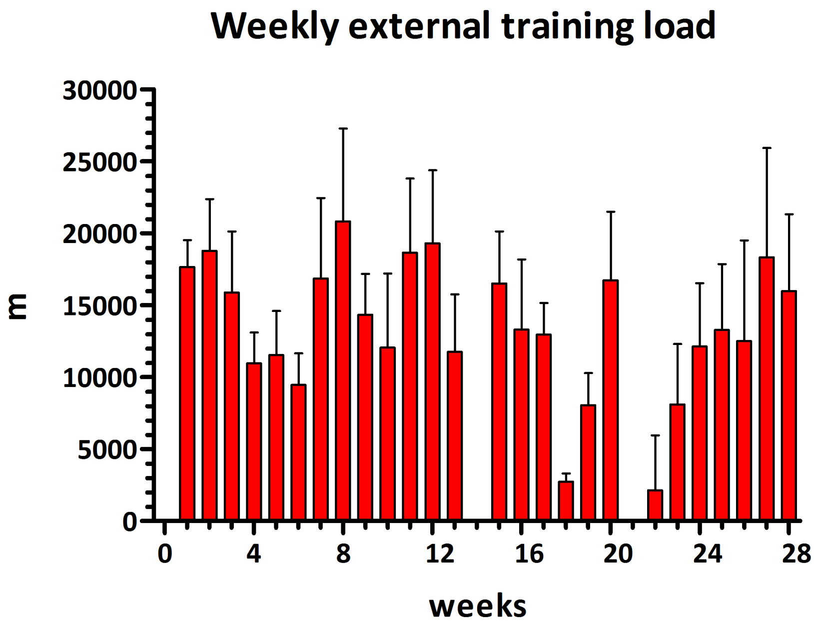

Figure 6: Bar graph illustrating external training loads for all participants.

Per season phase, preseason had the highest median value of external training load followed by the early competition phase as shown in Table 19.

Table 19: Descriptive data of the total external training load over 28 weeks for all participants in meters. Data are expressed as median and range (minimum to maximum).

External training load (meters)	**Median (range)**
Total external load (n = 39)	13118 (0-20834)
Preseason load (n = 39)	14760 (8817-17295)
Early competition load (n = 39)	13994 (9371-16970)
Late competition load (n = 39)	10928 (233-12831)

4.5.2.3. External training loads and injury incidence

There was a significant main effect of time in weekly external training loads for all participants ($F_{1,27}$ = 710.8, $p < 0.00001$). The median value of external training load in the injured group (n = 30) was 12780 (0-20258) which was lower than the non-injured group (n = 9) with 14841 (0-22753). A significant main effect of time was also detected in weekly external training loads in the injured ($F_{1,27}$ = 207.8, $p < 0.00001$) and non-injured ($F_{1,26}$ = 199.9, $p < 0.00001$) groups. The significant effects detected in weekly external training loads for injured and non-injured participants are shown in Appendix XIII.

4.5.2.5. Correlation measures of external training loads and injury incidence

No significant correlations were detected between external training load and injury incidence per season phase. Additional weekly correlation measures of external training loads and injury incidence are shown in Appendix XIII.

4.5.3. Internal and external acute to chronic ratios and injury

4.5.3.1. Descriptive analysis of the internal and external acute to chronic ratio

Figure 7 demonstrates the weekly changes in internal and external training loads in exertional units and meters covered over the 28-week period. Internal training load showed fluctuations over weeks four to six, nine to twelve and seventeen to twenty in comparison to the large differences in week to week values of external training load.

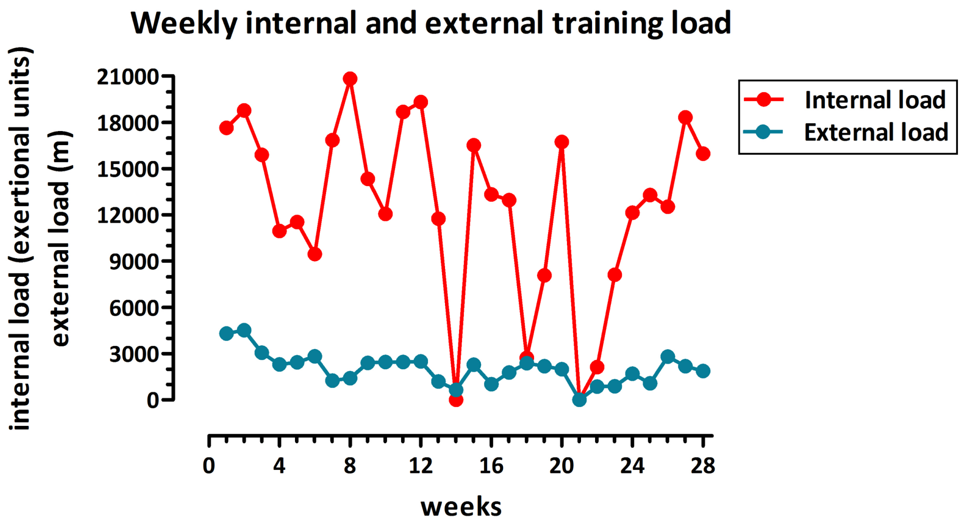

Figure 7: Weekly internal training load (exertional units) and external training load (m) over 28 weeks.

Scatter plots were used to model the trend of acute to chronic ratios over time as depicted in Figure 8 and Figure 9. Internal and external acute to chronic ratios showed a linear and positive increase in values over time which is represented by the regression lines (Figure 8 and Figure 9).

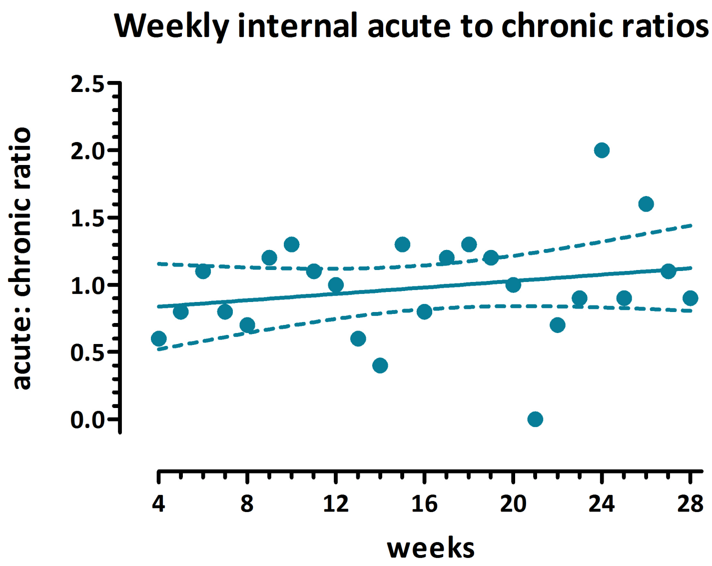

Figure 8: Internal acute to chronic ratios over 25 weeks. Dotted lines represent the 95% confidence interval. The solid line represents the regression line.

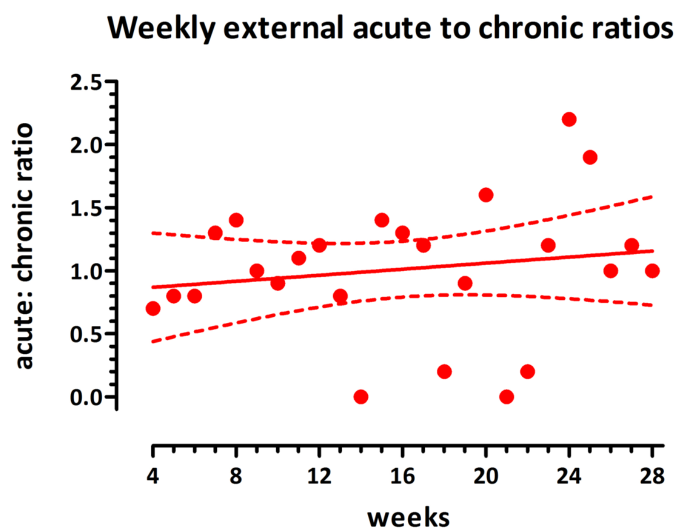

Figure 9: External acute to chronic ratios over 25 weeks. Dotted lines represent the 95% confidence interval. The solid line represents the regression line.

The total external acute to chronic ratios were greater than the internal ratios (Table 20). Per season phase, the greatest median acute to chronic ratio was during late competition for both internal and external training loads (Table 20). The lowest median value of the acute to chronic ratio was during the preseason for internal training load followed by preseason for external training load.

The median acute to chronic ratio for internal and external training load increased per season phase from preseason to late competition with 0.8 (0.4-1.3) to 1.1 (0.1-1.3) and 0.9 (0.2-1.6) to 1.0 (0-1.2) respectively. Internal and external acute to chronic ratios per main playing position is shown in Appendix XIII.

Table 20: The total internal and external acute to chronic ratios for 25-weeks for all participants.

Acute to Chronic Ratio	Median (Range)
Internal acute to chronic ratio:	
Overall (n = 39)	1.0 (0-2.0)
Preseason (n =39)	0.8 (0.4-1.3)
Early competition (n =39)	1.0 (0.9-1.3)
Late competition (n =39)	1.1 (0.1-1.3)
External acute to chronic ratio:	
Overall (n = 39)	1.0 (0-2.6)
Preseason (n =39)	0.9 (0.2-1.6)
Early competition (n =39)	1.0 (0.9-1.3)
Late competition (n =39)	1.0 (0-1.2)

4.5.3.3. Internal and external acute to chronic ratio and injury incidence

For all participants, there was a significant main effect of time in weekly internal acute to chronic ratios ($F_{1,24}$ = 567.8, $p < 0.00001$). Injured ($F_{1,24}$ = 414.4, $p < 0.00001$) and non-injured ($F_{1,24}$ = 162.2, $p < 0.00001$) groups illustrated a significant main effect of time in weekly internal acute to chronic ratio scores. The significant effects detected per week between internal acute to chronic ratios for injured and non-injured participants are shown in Appendix XIII.

A significant main effect of time in weekly external acute to chronic ratios was recorded for all participants ($F_{1,24}$ = 604.4, $p < 0.00001$). There was also a significant main effect of time in weekly external acute to chronic ratios of injured ($F_{1,24}$ = 420.5, $p < 0.00001$) and non-injured ($F_{1,24}$ = 195.3, $p < 0.00001$). The significant effects detected in weekly external acute to chronic ratios for injured and non-injured participants are shown in Appendix XIII.

4.5.3.5. Correlation measures between the internal and external acute to chronic ratio and injury incidence

Per season phase, there were no significant correlations between internal and external acute to chronic ratio scores and injury. Significant weekly correlation measures between internal and external acute to chronic ratios and injury incidence are shown in Appendix XIII.

4.5.3.6. Internal and external acute to chronic ratio and the odds of injury

The association between the exposure and non-exposure of internal and external acute to chronic ratios ≤ 0.8, 0.8-1.5, and ≥ 1.5 to determine injury risk at a given ratio was measured with odds ratios (OR) as shown in Table 21 and Table 22. No significant odds ratios were demonstrated between internal and external acute to chronic ratios and injury risk.

Table 21: Seasonal phase risk factors for injury according to internal acute to chronic ratios and odds ratios.

Acute to chronic ratio		Preseason		Early Competition		Late Competition	
Internal	**Reference group**	**Odds ratio (95% CI)**	**(p-value)**	**Odds ratio (95% CI)**	**(p-value)**	**Odds ratio (95% CI)**	**(p-value)**
≤ 0.8	≤ 0.8	1.00		1.00		1.00	
	0.8-1.5	0.27 (0.03-2.60)	(p = 0.26)	1.07 (0.56-2.03)	(p = 0.84)	1.11 (0.50-2.48)	(p = 0.79)
	≥ 1.5	0.04 (0-0.61)	(p = 0.08)	0.89 (0.28-2.86)	(p = 0.80)	3.06 (0.82-11.39)	(p = 0.10)
0.8-1.5	≤ 0.8	3.76 (0.38-36.99)	(p = 0.26)	0.92 (0.48-1.79)	(p = 0.90)	0.91 (0.43-1.91)	(p = 0.80)
	0.8-1.5	1.00		1.00		1.00	
	≥ 1.5	1.07 (0.56-2.03)	(p = 0.84)	0.73 (0.24-2.26)	(p = 0.59)	1.96 (0.57-6.78)	(p = 0.29)
≥ 1.5	≤ 0.8	0	0	0.96 (0.30-3.06)	(p = 1.00)	1.52 (0.37-6.20)	(p = 1.00)
	0.8-1.5	3.00 (0.13-73.40)	(p = 0.49)	1.50 (0.48-4.67)	(p = 0.48)	0.50 (0.15-1.74)	(p = 0.28)
	≥ 1.5	1.00		1.00		1.00	

Table 22: Seasonal phase risk factors for injury according to external acute to chronic ratios and odds ratios.

Acute to chronic ratio		**Preseason**		**Early Competition**		**Late Competition**	
External	**Reference group**	**Odds ratio (95% CI)**	**(p-value)**	**Odds ratio (95% CI)**	**(p-value)**	**Odds ratio (95% CI)**	**(p-value)**
≤ 0.8	≤ 0.8	1.00		1.00		1.00	
	0.8-1.5	1.07 (0.15-7.85)	(p = 0.95)	1.46 (0.60-3.55)	(p = 0.40)	2.01 (0.81-5.00)	(p = 0.13)
	≥ 1.5	0.30 (0.02-3.60)	(p = 0.36)	1.71 (0.45-6.52)	(p = 0.55)	1.31 (0.50-3.45)	(p = 0.64)
0.8-1.5	≤ 0.8	0.78 (0.11-5.71)	(p = 1.00)	0.73 (0.34-1.54)	(p = 0.42)	0.50 (0.20-1.23)	(p = 0.13)
	0.8-1.5	1.00		1.00		1.00	
	≥ 1.5	0.34 (0.01-3.77)	(p = 0.38)	2.02 (0.46-8.85)	(p = 0.38)	0.57 (0.23-1.38)	(p = 0.09)
≥ 1.5	≤ 0.8	0	0	0.80 (0.24-2.68)	(p = 1.00)	0.55 (0.21-1.44)	(p = 0.25)
	0.8-1.5	1.82 (0.08-40.81)	(p = 0.70)	0.89 (0.26-3.10)	(p = 0.60)	1.65 (0.63-4.29)	(p = 0.30)
	≥ 1.5	1.00		1.00		1.00	

4.6. INTERNAL AND EXTERNAL TRAINING LOADS AND ILLNESS

4.6.1. Internal training loads and illness

4.6.1.1. Internal training loads and illness incidence

For all participants, there was a significant main effect of time on internal training load between illness (n = 11) ($F_{1,27} = 228.3$, $p < 0.00001$) and non-illness groups (n = 28) ($F_{1,27} = 515.9$, $p < 0.00001$). The significant effects detected in weekly internal training loads between illness and non-illness participants are shown in Appendix XIII. No significant correlations were recorded between internal training load and illness.

4.6.2. External training loads and illness

4.6.2.1. External training loads and illness incidence

There was a significant main effect of time in weekly values of internal training load between illness ($F_{1,27} = 235$, $p < 0.00001$) and non-illness groups ($F_{1,27} = 483.1$, $p < 0.00001$). No significant correlations were detected between external training load and illness.

4.6.3. Internal and external acute to chronic ratio and illness

4.6.3.1. Associations between the internal and external acute to chronic ratio and illness incidence

Per season phase, there were no significant correlations between the internal and external acute to chronic ratio scores and illness. Significant weekly correlation measures between internal and external acute to chronic ratios and illness incidence are presented in Appendix XIII.

4.6.3.2. Internal and external acute to chronic ratio and the odds of illness

The odds ratios for illness risk according to the internal and external acute to chronic ratios are reported per season phase in Table 23 and Table 24. No illnesses occurred during the preseason phase. No significant odds ratios were demonstrated between internal and external acute to chronic ratios and illness risk

Table 23: Seasonal phase risk factors for illness according to internal acute to chronic ratios and odds ratios.

Acute to chronic ratio		Preseason		Early Competition		Late Competition	
Internal	**Reference group**	**Odds ratio (95% CI)**	**(p-value)**	**Odds ratio (95% CI)**	**(p-value)**	**Odds ratio (95% CI)**	**(p-value)**
≤ 0.8	≤ 0.8	0	0	1.00		1.00	
	0.8-1.5	0	0	5.27 (0.85-32.70)	(p = 0.07)	0.32 (0.04-2.67)	(p = 0.30)
	≥ 1.5	0	0	1.11 (0.13-9.50)	(p = 1.00)	0.95 (0.06-15.47)	(p = 1.00)
0.8-1.5	≤ 0.8	0	0	0.19 (0.03-1.18)	(p = 0.07)	2.63 (0.30-22.89)	(p = 0.67)
	0.8-1.5	0	0	1.00		1.00	
	≥ 1.5	0	0	0.29 (0.01-7.43)	(p = 0.46)	4.55 (0.26-80.64)	(p = 0.30)
≥ 1.5	≤ 0.8	0	0	0	0	0	0
	0.8-1.5	0	0	2.82 (0.11-70.99)	(p = 0.53)	1.30 (0.26-6.58)	(p = 0.75)
	≥ 1.5	0	0	1.00		1.00	

Table 24: Seasonal phase risk factors for illness according to external acute to chronic ratios and odds ratios.

Acute to chronic ratio		Preseason		Early Competition		Late Competition	
External	**Reference group**	**Odds ratio (95% CI)**	**(p-value)**	**Odds ratio (95% CI)**	**(p-value)**	**Odds ratio (95% CI)**	**(p-value)**
≤ 0.8	≤ 0.8	0	0	1.00		1.00	
	0.8-1.5	0	0	2.02 (0.21-19.87)	(p = 0.55)	2.13 (0.47-9.68)	(p = 0.33)
	≥ 1.5	0	0	1.53 (0.13-17.66)	(p = 1.00)	3.81 (0.42-34.69)	(p = 0.37)
0.8-1.5	≤ 0.8	0	0	0.24 (0.04-1.48)	(p = 0.15)	0.65 (0.14-2.98)	(p = 0.65)
	0.8-1.5	0	0	1.0		1.0	
	≥ 1.5	0	0	0.29 (0.04-2.07)	(p = 0.22)	1.95 (0.20-18.96)	(p = 0.33)
≥ 1.5	≤ 0.8	0	0	0.65 (0.06-7.50)	(p = 1.00)	0.26 (0.03-2.39)	(p = 0.37)
	0.8-1.5	0	0	4.00 (0.35-45.29)	(p = 0.26)	0.55 (0.06-5.36)	(p = 0.61)
	≥ 1.5	0	0	1.00		1.00	

4.7. SUMMARY OF RESULTS

The overall incidence of injury was 12.9 per 1000 player hours (95% CI: 10.0-15.8). Matches accounted for 241.0 per 1000 player hours (95% CI: 186.0-308.0) compared to training with 3.3 per 1000 player hours (95% CI: 2.1-5.0). In the squad of 39 participants, the proportion of players that sustained a time-loss injury was 76.9% (n = 30). In addition, 25.6% (n = 10) of participants acquired a time-loss injury severe enough to prevent eight days or more of participation in training or matches. The most frequently injured anatomical location was the lower limb (62.5%). The thigh region had the highest frequency of injuries (20%) according to specific anatomical location. Soft-tissue injuries accounted for 96.0% of all injuries with 64.9% occurring in muscles or tendons. The most common mechanism for all injuries was listed as 'other'. The second most common mechanism was the tackle (28.8%). The most frequent severity of injury was 'moderate' (37.5%) resulting in a total time-loss of 414 days.

The overall incidence was 1.8 per 1000 player days (95% CI:1.0-3.0). The proportion of players that acquired an illness was 28.3% (n = 11) with new illnesses accounting for 93.0% (n = 13). The respiratory system (50%) was the most commonly impacted bodily system. Acute respiratory tract infections were the most common specific diagnosis (28.6%). Infection and causes listed as 'other' were the most common suspected cause of illness (35.6%). From the total number of illnesses, 64.3% resulted in no time-loss.

A significant negative correlation between injury and internal training loads were detected in the preseason ($r = -0.34$, $p = 0.03$). This indicated that a decrease in internal training load coincided with an increase in the number of injuries. No significant correlations were detected between external training load and injury incidence. No significant odds ratios were demonstrated between internal and external acute to chronic ratios and injury risk per season phase.

No significant correlations between internal and external training loads and illness incidence were demonstrated. Per season phase, no significant odds ratios were demonstrated between internal and external acute to chronic ratios and illness risk.

CHAPTER 5: DISCUSSION

The aim of this study was to assess the relationships between training loads, injury profiles and illness rates in elite South African rugby players competing in the 2017 Super Rugby tournament. The first section of the discussion focuses on the generalisability of the findings. The second and third sections discuss the main findings on injury profiles and illness rates in this study and compare these findings to the literature with further reasoning into similarities or differences. The discussion focuses on how the main findings on training loads relate to injury and illness in this study population over the 28-week season. In addition, the discussion critically evaluates these results against the findings in the literature. Finally, we will present the limitations and recommendations before summarising the study.

5.1. GENERALISIBILITY OF THE STUDY RESULTS

The size of the study sample (n = 39) was smaller in comparison to previous studies on the Super Rugby tournament in 2008 (n = 441), 2010 (n = 259), 2012 (n = 152) and 2014 (n = 180) (Fuller et al., 2009; Schwellnus et al., 2012; Schwellnus, 2014; Whitehouse et al., 2016). These studies included multiple teams participating in the Super Rugby tournament. However, the sample size in this study is comparable to numerous studies in general professional Rugby Union (Cunniffe et al., 2010; Gabbett & Ullah, 2012; Hulin et al., 2016; Windt, Gabbett, Ferris, & Khan, 2016). The study population was representative of a team participating in the Super Rugby tournament squad as the mean age (25.3 $\pm$ 4.0) was similar to previously reported squads in the 2008 (24.7 $\pm$ 3.2), 2012 (25.0 $\pm$ 3.4) and 2014 (24.78 $\pm$ 3.2) Super Rugby tournaments. In addition, 86.7% of the initial cohort of players were eligible following consent and the application of the inclusion and exclusion criteria to participate in the study. As a result, the collected data from this population is representative of injury, illness and training load data of a team participating in the 2017 Super Rugby tournament.

Classification of 'level one' teams are considered to be teams that participate in the top ranked leagues in tier one ranked nations such as the Super Rugby tournament. Comparisons can be made with other studies that use the same 'level of play' classification, provided that the definitions and methodologies are standardised for injury, illness and training loads (International Rugby Board, 2012; Fuller et al., 2007). Data from this study may represent similar tournaments with a long duration played at a 'level one' classification.

The use of independent data collection procedures from the team's support staff demonstrated a high compliance rate and accurate recording of routinely collected data. Standardised definitions and methodologies were used for illness and training load data in Rugby Union and other sporting codes (Schwellnus et al., 2016; Soligard et al., 2016). This study also adhered to the definitions and methodologies of the 2007 Consensus Statement on Rugby Union injury epidemiology research which allows for interstudy comparisons (Fuller et al., 2007).

The 2007 Consensus Statement by the RICG endorsed the view that studies should extend for a minimum period of one season, one year, or for the duration of a major tournament which allows for an in-depth understanding of exposure factors related to injury (Fuller et al., 2007). Our study included preseason, early and late competition phases for a total duration of 28 weeks which is longer than reported in previous studies (Alonso et al., 2010; Dvorak et al., 2011; Engebretsen et al., 2010; Fuller et al., 2009; Gabbett & Ullah, 2012; Mountjoy et al, 2010; Schwellnus, 2012; Schwellnus, 2014; Whitehouse et al., 2016). The long duration of this study and the detailed analysis presented allows the results of this study to be compared with other Rugby Union studies. This study period will also allow for future comparisons to be made in studies that include the preseason phase for investigations into training loads, injury and illness in Rugby Union.

5.2. INJURY PROFILES

5.2.1. Frequency and incidence of all time-loss injuries including per main player position

A total of 80 injuries were recorded among 39 participants, with 53% of injuries reported in the early competition phase. The overall injury incidence of 12.9 per 1000 player hours (95% CI: 10.0-15.8) was higher than reported in the 2012 Super Rugby tournament with 9.2 per 1000 player hours (95% CI: 7.9-10.8) across five South African teams (Schwellnus et al., 2014). The overall incidence in this study was also higher than reported in the 2014 Super Rugby tournament across five Australian teams with 6.96 per 1000 player hours (95% CI: 5.89-8.04) (Whitehouse et al., 2016). The high overall injury incidence in this study could be due to numerous factors including the variations in training methods such as contact and non-contact training, coaching techniques, travel schedules in the expanded tournament format, gym based training and rotational player systems.

The incidence of match injuries of 241.0 per 1000 player hours (95% CI: 186.0-308.0) was higher than previously reported in the Super Rugby tournament and in general professional Rugby Union ranging from 66.1 to 96.3 per 1000 player hours (Fuller et al., 2009; Fuller, Sheerin, & Targett, 2013; Fuller et al., 2008; Schwellnus et al., 2014; Whitehouse et al., 2016; Williams et al., 2013).

The only study to report a similarly high rate of match injuries was by Brooks et al. (2005c) with 218 per 1000 player hours over 63 weeks in an international squad of 63 players. No confidence intervals were reported in this study and the authors concluded that the high injury rate was due to the concise reporting and data collection methods. The authors suggested that the increased time in which the 'ball' was in play during a given match contributed to the high incidence. Inter-study comparisons are limited between previous and current literature due to the varying injury definitions used in studies prior to the 2007 Consensus Statement (Fuller et al., 2007).

The incidence of training injuries of 3.3 per 1000 player hours (95% CI: 2.1-5.0) observed in this study was consistent with the findings from other studies (Fuller et al., 2013; Schwellnus et al., 2014; Williams et al., 2013). Per season phase, the greatest proportion of match and training injuries occurred in the early competition phase, which was contrary to previous studies that found a greater proportion of injuries in the preseason phase (Gabbett & Domrow, 2007).

Findings in this study were consistent with a number of studies showing a higher incidence of injuries in matches in contrast to training (Fuller et al., 2008; Fuller et al., 2013; Schwellnus et al., 2014; Whitehouse et al., 2016). In this study, the match-related injury incidence was 73 times higher in comparison to training which was greater than the 38 and 28 times, reported in the 2012 and 2014 Super Rugby tournaments respectively (Schwellnus et al., 2014; Whitehouse et al., 2016).

The expansion of fifteen to eighteen teams in the Super Rugby tournament from 2012 to 2017 was accompanied with an increase in tournament demands (Schwellnus et al., 2014). However, the minimum number of matches a team would play in the 2012 (16) compared to the 2017 (15) tournaments were similar. Schwellnus et al. (2014) found no significant difference in injury incidence whilst playing home or away, which included travel across more than six time zones. However, travel schedules change each year for various teams and the impact of an extended travel schedule on injury requires further investigation. Teams often experience reduced training loads in a given week of traveling or post traveling as teams aim to recover for the following match. Conversely, teams may choose to increase their weekly training loads in combination with travel, predisposing players to injury. This highlights the importance of team specific research as various teams prepare according to different tournament schedules and coaching strategies.

5.2.2. Injured player proportion

The use of injured player proportion has been proposed by Schwellnus et al., (2014) in tournaments of different durations. In this study, 76.9% (n = 30) of the squad sustained a time-loss injury which was greater than the injured player proportion of the 1999 and 2012 Super Rugby tournaments with 64.0% and 54.6% respectively (Schwellnus et al., 2014; Targett, 1998). The injured player proportion in this study was lower than reported in the 2008 Super Rugby tournament with 82% of 441 players sustaining match injuries (Fuller et al., 2009).

When compared to the RWC, among 615 players in the 2003, 2007 and 2011 competitions over seven weeks, the approximated injured player proportion was 26% to 34% as reported by Schwellnus et al. (2014). This is lower than the injured player proportion reported in our study (76.9%) (Best et al., 2005; Fuller et al., 2008; Fuller et al., 2013). The first study to report the injured player proportion documented that 34.9% of players had sustained an injury severe enough to prevent training or participation in matches for eight days or more (Schwellnus et al., 2014). In this study, a lower percentage was reported with 25.6% (n = 10). The reason for the large difference between previous Super Rugby tournaments and the 2017 Super Rugby tournament is unclear. However, the change in training methods, training environments due to travel, the implementation of game laws and individual injury prevention programs in teams over a five year period could have contributed to the large difference. The expanded tournament format resulted in the strongest teams playing against each other and the scheduled games played at a high level could explain the high incidence and severity of injury (Williams et al., 2013). Another possible explanation is the manner in which non-playing players are rotated into matches. From the total squad (n = 39), fifteen players are selected to participate in a match with seven or eight on the bench. Players who did not participate in a given match are required to train in a manner in which training loads are similar to the players participating on a regular basis. However, it is likely that non-playing participants perform (volume, intensity, type and frequency) insufficient contact to cope with the match demands once they are selected unless contact measures are used, resulting in an elevated risk to injury. Alternatively, this group of players could be less likely to be injured as a result of less exposure to matches and the players who are consistently selected for matches were therefore, more likely to sustain injuries due to the high exposure to match demands. Further investigation into individual team rotational systems is required to further understand the pattern of injuries between playing and non-playing groups.

Estimating the injured player proportion must be applied with caution as the number of players with more than one injury is not included in the calculation. This may result in an overestimation of the injured player proportion.

The injured player proportion from studies prior to 2007 used different definitions to conduct the injury counts, and true comparisons are limited. The 2007 Consensus Statement does not include the reporting of injured player proportion but authors have recommended further exploration into using this method (Fuller et al., 2007; Schwellnus et al., 2014).

5.2.3. Main anatomical location of injuries

In this study, the lower limb was the most frequently injured anatomical location (62.5%). This finding is higher than previously reported in the 2012 (48.1%) and 2014 (57.1%) Super Rugby tournaments (Schwellnus et al., 2014).

Results from this study are consistent with many studies which report the lower limb as the most commonly injured anatomical location (Brooks & Kemp, 2008; Fuller et al., 2008; Williams et al., 2013). According to specific anatomical location, thigh injuries had the highest frequency (20.0%) of injury, followed by the knee (12.5%). Contrary findings were reported in previous studies on the Super Rugby tournament and in general professional Rugby Union with concussion, posterior thigh, shoulder and knee injuries being the most commonly reported injuries (Fuller et al., 2008; Fuller et al., 2009; Schwellnus et al., 2014; Whitehouse et al., 2016).

Thigh and hamstring injuries have contributed significantly to the high burden of lower limb injuries in Rugby Union (Brooks et al., 2005a; Williams et al., 2013). To reduce the overall burden of injuries in Rugby Union, injury prevention strategies should target components of the game causing the most time-loss from participation in training and matches (Brooks & Kemp, 2008; Schwellnus et al., 2014; Williams et al., 2013). It has been recommended that injury prevention strategies should target lower limb injuries and increase safe methods in contact situations (Williams et al., 2013).

5.2.4. Type of injuries

Soft-tissue injuries (96.0%) represented a large proportion of all injuries with 64.9% in muscles or tendons and 25.0% in joints or ligaments. Similar trends were noted in the 2012 Super Rugby tournament where soft-tissue injuries accounted for 90.0% of all injuries with muscle or tendon injuries with 50.0% and joint or ligament injuries with 32.7% (Schwellnus et al., 2014). In the 2008 Super Rugby tournament, muscle or tendon injuries accounted for 27.8% of match-related injuries followed by joint or ligament (18.8%) (Fuller et al., 2009).

In the 2012 Super Rugby tournament, the majority of muscle or tendon injuries occurred during matches (46.2%) followed by joint or ligament injuries (33.6%) (Schwellnus et al., 2014). The match-related incidence of muscle or tendon injuries in this study were significantly higher than reported by Fuller et al. (2009), Fuller et al. (2013) and Schwellnus et al. (2014).

The high rate of soft tissue injuries during matches are unclear but is likely a result of the contact events during matches. In addition, the lack of refining of existing tackle techniques through the focus on effective tackle performance and the implementation of new techniques by Rugby Unions could have contributed to the high incidence of match injuries over the five year period (Hendricks & Lambert, 2014). Further investigation into the implementation of tackle techniques and the characteristics of the tackle event in the Super Rugby tournament is required (Austin, Gabbett, & Jenkins, 2011).

5.2.5. Injury mechanisms

The contact event accounts for the majority of injuries in Rugby Union (Bathgate et al., 2002; Brooks et al., 2005c; Fuller et al., 2007; Quarrie, & Hopkins, 2008). In this study, the category of 'other' (32.5%) was the most common mechanism of injury, similar to 26.3% reported by Schwellnus et al. (2014). As the category of 'other' represents the highest proportion of injury mechanisms, further investigation is required to determine what mechanisms could represent 'other' (Schwellnus et al., 2014). These could include 'dangerous play', side-stepping, punching, static grappling, landing from a jump, 'grass cutter' tackle and twisting related mechanisms.

From the tackle event, being tackled contributed to 21.3% of all injuries similar to previous findings (Fuller et al., 2013; Whitehouse et al., 2016; Williams et al., 2013). From the overall number of match-related injuries, being tackled (31.4%) was lower than reported in the 2008 Super Rugby tournament (41.4%) (Fuller et al., 2009). Overall, contact related injuries (37.5%) were greater than non-contact injuries (30%). These findings were lower than reported by Fuller et al. (2007) but higher than reported by Whitehouse et al. (2016) with 75.7% and 9.0% for contact and non-contact injuries respectively. However, interpretation of these findings are limited as the category of 'other' accounted for 32.5% of all injury mechanisms.

5.2.6. Injury severity

The most frequent severity of injury in this study was 'moderate,' which accounted for 4.8 per 1000 player hours (95% CI: 3.3-6.7) and resulted in a time-loss of 414 days. In a meta-analysis of five studies, the most common severity of injury was moderate but the incidence of 28.0 per 1000 player hours (95% CI: 25.0-31.0) was significantly higher than in this study (Williams et al., 2013).

However, the injuries in this study were more severe than one Super Rugby tournament study, as the most common severity of injury was 'moderate' (37.5%), in contrast to 'mild' (32.9%) reported by Schwellnus et al. (2014).

Data from two Super Rugby tournaments reported the most common severity of match injuries as 'mild' (Fuller et al., 2009; Schwellnus et al., 2014). Data from this study demonstrated contrary findings with 'moderate' (40.0%) accounting for majority of the match injuries.

The majority of the training injuries were of a 'mild' severity (35.0%) but in the 2012 Super Rugby tournament, 'moderate' (40.7%) accounted for the majority of training injuries. The difference in match and training severity in comparison to previous studies is unclear as the 'mild' severity of training injuries may be a result of injury prevention strategies.

However, the 'moderate' severity in matches could be related to numerous factors such as an increase in the 'level of play' over time, insufficient contact training or fatigue related mechanisms (Austin et al., 2011; Hendricks & Lambert, 2014).

5.3. ILLNESS

5.3.1. Incidence of all time-loss illnesses

The total player days (7722) of exposure in this study were significantly higher than the mean player days (2834) reported per team in the 16 week 2010 Super Rugby tournament (Schwellnus et al., 2012). However, in this study the incidence of illness was 1.8 per 1000 player days (95% CI: 1.0-3.0); which was lower than reported in the 2010 Super Rugby tournament with 20.7 per 1000 player days (95% CI: 18.5-23.1,) and the 2010 Confederations Cup Football tournament with 7.7 per 1000 player days (95% CI: 6.2-9.2) over five weeks (Dvorak et al., 2011; Schwellnus et al., 2012).

The reason for the low proportion of illness demonstrated in our study is unclear. Authors have previously related the high incidence of illness in the Super Rugby tournament to the weekly training and matches at a high intensity, travel (across multiple time zones), different climatic and environmental conditions (Schwellnus et al., 2012; Schwellnus et al., 2016). However, participants in this study experienced similar factors over the 28-week season.

The reason for the greater illness rates reported in these studies in comparison to our study could be related to other various factors. One of these factors is the large cohort of players (259 to 736) in the mentioned studies. Our study also focused solely on South African participants whereas previous studies used various populations (Dvorak et al., 2011; Schwellnus et al., 2012).

Population differences in lifestyle and behavioural factors such as nutrition, hygiene, alcohol consumption and supplement usage could be related to the difference in illness incidence (Schwellnus et al., 2016). Over a seven year period between 2010 and 2017, strict hygiene protocols within teams could have contributed to minimising the incidence of illness. In addition, the use of probiotics, stress management, early illness identification, dietary plans, airway inflammation screening, isolation of ill athletes, the use of vaccines, improved sleep hygiene, and the regular use of multi-vitamins in the team environment could have also contributed to the low incidence of illness in this study population (Schwellnus et al., 2016). Illness prevention protocols implemented in each Super Rugby tournament squad is not well established.

5.3.2. Illness player proportion

The proportion of players (n = 11) that acquired an illness (28.3%) in our study was lower than previously reported (72.2%) by Schwellnus et al. (2012). However, our study reported a higher frequency of new illnesses with 93.0% (n = 13) in contrast to 87.6%, and a lower frequency of recurrent illnesses of 7.0% (n = 1) in comparison to 12.4% in the 2010 Super Rugby tournament (Schwellnus et al., 2012). The high incidence of new illness could be related to the environment in which teams make use of communal facilities which could facilitate the spread of infection. According to Schwellnus et al. (2012), pre-tournament health of athletes may also be a factor in athletes acquiring and spreading infection. The lower incidence of recurrent illness could indicate sufficient prevention strategies in managing players that are susceptible to illness such as probiotics, vaccines and additional supplementation.

5.3.3. Bodily systems impacted by illness

Results from this study concur with the main findings in Rugby Union and across sporting codes that majority of the reported illness affected the respiratory system (Alonso et al., 2010; Cunniffe et al., 2010; Dvorak et al., 2011; Engebretsen et al., 2010; Moreira, Arsati, Lima-Arsati, Simões, & Araújo, 2011; Mountjoy et al., 2010; Schwellnus et al., 2012). The respiratory system accounted for 50% of all illnesses followed by the digestive system (43%) in our study. Prolonged competition load and insufficient recovery have been linked with immune changes associated with an increased risk of illness through the 'open window' phenomenon (Friman & Wesslén, 2000; Schwellnus et al., 2012). The severity and duration of illness has also been associated with the effort exerted during exercise training and as a result increasing the sensitivity to respiratory tract infections (Friman & Wesslén, 2000).

The increased risk to respiratory tract infections is related to a decrease in the saliva secretory immunoglobin A secretion, natural killer cells and pro-inflammatory cytokine production due to the temporary immune dysfunction post exercise (Gleeson et al., 2013). Respiratory infections are highly contagious and in team based settings, reducing the transmission of air-borne droplets and physical contact can reduce the overall occurrence of URTI (Friman & Wesslén, 2000).

5.3.4. Specific diagnosis and suspected cause of illness

According to specific diagnosis, acute URTI (28.6%) was the most common diagnosis in this study followed by gastroenteritis (21.4%). In the 2010 Super Rugby tournament, the most frequent diagnoses were gastroenteritis (19.8%) and acute respiratory infections (15.9%).

Findings in this study are also similar to the results reported across sporting codes with the most frequent specific diagnosis of URTI and infection being the most suspected cause of illness in aquatic sports, Winter Olympic Games, track and field athletes, and football (Alonso et al., 2010; Dvorak et al., 2011; Engebretsen et al., 2010; Mountjoy et al., 2010).

5.3.5. Time-loss of illness

From the total number of illnesses, 64.3% resulted in no time-loss which is lower than previously reported in the 2010 Super Rugby tournament with 83.0% (Schwellnus et al., 2012). In this study, 21.4% resulted in one day and 14.3% resulted in more than one day of time-loss which was higher than findings by Schwellnus et al., (2012) of 9.6% and 6.5%, respectively. Similar trends have been documented across numerous sporting codes which found that illness did not result in extensive time-loss from participation (Alonso et al., 2010; Dvorak et al., 2011; Engebretsen et al., 2010; Mountjoy et al., 2010). A possible explanation is the improvement of medical support, early diagnosis and treatment over a seven year period as franchises have endorsed professional approaches to managing athletes.

5.4. INTERNAL AND EXTERNAL TRAINING LOADS

5.4.1. Internal training loads and injury

The mean values of internal training load per season phase were higher in this study than reported across four English Premiership Rugby Union teams by Cross et al. (2016) with 2953, 1811, and 1628.9 in comparison to 2175, 1522, and 1582 for preseason, early and late competition phases.

Overall, internal training loads were highest in the preseason which is similar to other studies as preseason periods often include higher loads than in-season periods (Gabbett & Domrow, 2007; Cross et al., 2016). There is evidence that over time, playing demands in the Super Rugby tournament have increased for all player positions through high-intensity activities, frequency of sprints, game speed and work to rest ratios (Austin et al., 2011). Authors have related this increase to the changes and interpretation in game 'laws' resulting in a faster and more physically demanding game (Austin et al., 2011).

Despite the highest mean internal training loads in the preseason, the overall exposure in player hours and the incidence of injury were lowest with 1926 and 3.6 per 1000 player hours (95% CI: 1.6-7.2) in comparison to early and late competition phases, respectively. These findings were contrary to findings by Gabbett & Domrow (2007) and Brooks & Kemp (2005b).

The excessive internal training loads in the preseason phase potentially led to the high injury rates in the early competition phase (Gabbett, 2004; Gabbett, 2016). The significant correlation between internal training load and injury in the preseason suggests that a decline from the high internal training loads coincided with an increase in the number of injuries. The elevated injury incidence reported could also be related to the transition from preseason training into tournament matches.

Internal training loads were higher in the injured group in contrast to the non-injured group. A potential explanation could be related to off-feet conditioning for injured players to maintain physical fitness while injured. In addition, injury is known to elicit ongoing physiological and psychological stress which could affect an injured athletes RPE during and post training (Halson, 2014; Hurley, 2014).

5.4.2. External training loads and injury

Similar to internal training loads, preseason external training loads showed the highest mean total distance. This was contrary to findings by Gabbett & Ullah (2012) who found the highest mean total distance in the early competition phase in Rugby League. In addition, the mean total distances in our study were greater than documented in Rugby League for preseason, early and late competition (Gabbett & Ullah, 2012). A true comparison cannot be conducted as the duration of each season phase and the format of the Rugby League tournament was not described.

Injured participants had lower external training loads than non-injured participants. The high incidence of lower limb injuries may have resulted in the injured participants having to sit out of running based field-sessions.

5.4.3. Internal and external acute to chronic ratios and injury

Week to week differences between internal and external training loads followed a similar trend, but there were evident periods of mismatch between internal and external training loads. In weeks six to nine, a mismatch in training loads were documented as external training loads increased to the highest value whilst internal training loads during that period, decreased. Similarly, between weeks ten and twelve, there were no further increases in internal training loads despite an increase in external training loads. A possible explanation is the development of physical 'fitness' resulting in a lower perceived exertion rating per training session or an alternative training regime such as lower intensity but higher volume running sessions during those periods. The improved aerobic capacity and prolonged high-intensity running ability as a result of the high chronic loads could explain the athletes response to the internal training loads (Gabbett & Domrow, 2007; Gabbett & Ullah, 2012). The differences between internal and external training load highlights the importance of combining internal and external training load measures in determining the training outcome (Halson, 2014; Soligard et al., 2016).

The internal and external acute to chronic ratios showed a linear and positive increase over the 25 weeks. The median acute to chronic ratio for internal and external training load increased per season phase from preseason to late competition with 0.8 (0.4-1.3) to 1.1 (0.1-1.3) and 0.9 (0.2-1.6) to 1.0 (0-1.2) respectively similar to the recommended range of 0.8-1.3 reported by Gabbett (2016). This range is known to be associated to a reduced risk of injury, while a ratio of ≥ 1.5 represents a 'danger zone' associated with an increased risk of injury (Gabbett, 2016; Hulin et al., 2013; Hulin et al., 2016b; Orchard et al., 2015). However, different sports have different training-injury relationships, and interpretation must proceed with caution (Gabbett, 2016). In this study, the squad was within the ideal 'sweet spot' according to the literature but the overall incidence of injury was higher than previously reported with 12.9 per 1000 player hours (95% CI: 10.0-15.8) (Gabbett, 2016; Schwellnus et al., 2014; Whitehouse et al., 2016).

Per season phase, no significant odds ratios were demonstrated between internal and external acute to chronic ratios and injury risk. This is likely as result of the small sample size used in this study which potentially impacted the ability of statistical tests to detect any meaningful changes.

5.4.4. Internal and external training loads and illness

There were no significant differences between internal and external training loads and illness and non-illness groups. An explanation is that 64.3% of illnesses did not result in time-loss and 14.3% resulted in more than one day of time-loss.

This indicates that a large majority of the illness group did not spend time away from training. Changes in both internal and external training loads have been previously related to an increased risk of illness (Schwellnus et al., 2016). In this study, the low incidence of illness together with a small sample size potentially impacted the ability of statistical tests to detect any meaningful changes. However, this elite population could be representing the S-shaped curve where the risk of illness is not associated with high training loads as the highest training loads were recorded in the preseason and no illnesses were reported in this phase (Hellard et al., 2016; Malm, 2006; Schwellnus et al., 2016). Alternatively, players that were ill could have withheld from reporting illness characteristics over the season as players did not want to be excluded from training or competing. This could be applicable for younger players attempting to retain their position in the squad.

5.4.5. Internal and external acute to chronic ratio and illness

As the odds of illness based on the internal and external acute to chronic ratios has not been previously reported, comparisons with other studies are limited. No significant correlations between internal and external training loads and illness incidence were demonstrated.

In addition, no significant odds ratios were demonstrated between internal and external acute to chronic ratios and illness risk. The low illness incidence likely contributed to the non-significant values in combination with the small sample size used. However, these data findings contribute to the limited epidemiological data on training loads and illness.

5.5. LIMITATIONS OF THE STUDY AND RECOMMENDATIONS FOR FUTURE RESEARCH

There were several limitations of this study. The sample size used in this study was comparable to other studies on professional Rugby Union. However, the sample size was smaller than previous studies on the Super Rugby tournament. While a smaller sample was used, 86.7% of the squads data (injury, illness and training load) over 28 weeks represented a large data set and was used in the analysis. Future studies should aim to use more than one team in the Super Rugby tournament.

The lack of anthropometric data such as body mass, height and body mass index limits population specific comparisons with anthropometry to previous study populations in general professional Rugby Union and the Super Rugby tournament. The inclusion of demographic and anthropometric data in future studies could result in further inter-study comparisons to be made between study populations.

Another limitation is the use of data collected by medical and support staff as the analysis was limited to the routinely collected data. Further training of medical staff to strictly adopt the recommended data collection methods according to the 2007 Consensus Statement on data collection procedure in research epidemiology could result in the collection of standardised data. In addition, to improve the collection of data, the researcher could collect the data personally throughout study period. This would prevent categories such as 'other' under injury mechanism and causes of illness. This non-specific category requires further investigation as it represents a high proportion of injuries and illness limiting the interpretation of the results (Brooks et al., 2005c; Fuller et al., 2013; Schwellnus et al., 2014).

In the analysis of the training load-injury and training load-illness relationships, the longitudinal and repeated measures of these data were not observed. The use of linear mixed models and EWMA is recommended for future studies.

Future research is needed to determine the relationships between training loads, injury profiles and illness rates in professional Rugby Union. The inclusion of the preseason phase in the Super Rugby tournament and general professional Rugby Union is recommended as it contributes to the limited epidemiological data on training loads, injury profiles and illness rates.

CHAPTER 6: SUMMARY AND CONCLUSION

Internationally, professional Rugby Union is a popular team sport (Bathgate et al., 2002). Across professional team sports, Rugby Union is known to have one of the highest reported incidences of injury and illness (Williams et al., 2013; Schwellnus et al., 2012). As a result, training load in Rugby Union has become an important modifiable risk factor to injury and illness (Thomson, 2014; Williams et al., 2013). The demanding nature of the Super Rugby tournament provided the opportunity to further investigate the relationships between training loads, injury and illness. Understanding the relationship between training loads on injury profiles and illness rates may be important to further determine the patterns and impact of training loads on injury and illness. This study appears to be the first to assess the relationships between the combined measures of internal and external training load on injury profiles and illness rates over a complete Super Rugby season, which may contribute to the limited literature in Rugby Union.

Findings in this study have addressed and answered the following study objectives in Section 1.2.2 (page 2):

> *To determine the incidence of training and match injuries during pre-season training, and early and late competition during the 2017 Super Rugby tournament.*

In this study, the incidence of match injuries was significantly higher than training injuries with 241.0 per 1000 player hours (95% CI: 186.0-308.0) in contrast to 3.3 per 1000 player hours (95% CI: 2.1-5.0), respectively. The greatest incidence of match injuries per season phase was 245.0 per 1000 player hours (95% CI: 166.0-350.0), followed by 237.0 per 1000 player hours (95% CI: 165.0-331.0) for early and late competition phases with no incidence in the preseason phase. The greatest incidence of training injuries per season phase was 3.6 per 1000 player hours (95% CI: 1.6-7.2) for both preseason and early competition phases followed by 2.8 per 1000 player hours (95% CI: 1.1-5.7) in the late competition phase.

To determine the incidence of illness during preseason training, and early and late competition during the 2017 Super Rugby tournament.

The overall incidence of illness was 1.8 per 1000 player days (95% CI: 1.0-3.0). There were no illnesses in the preseason phase. The early and late competition phase showed a similar incidence of illness with 2.6 per 100 player hours (95% CI: 1.1-5.0) and 2.3 per 1000 player hours (95% CI: 1.0-4.6).

To determine the anatomical site, type, mechanism and time-loss of injuries sustained during preseason training, and early and late competition during the 2017 Super Rugby tournament.

The lower limb was the most frequently injured location (62.5%), specifically the thigh (20%) followed by the knee (12.5%). Soft-tissue injuries accounted for 96.0% of all injuries with 64.9% occurring in muscles or tendons. The most common mechanism of injury was the category 'other' (32.5%) followed by the tackle event (28.8%). The most common severity of injury was 'moderate' (35.7%). Overall, 25.6% of the squad sustained an injury that resulted in eight days or more of time-loss from participation in training and/or matches.

To determine potential associations between internal and external training loads; and injury and illness, respectively.

In the preseason, decreased internal training loads coincided with a rise in the number of injuries ($r = -0.34$, $n = 39$, $p = 0.03$). There were no significant correlations between acute to chronic training load and injuries. Per season phase there were no significant odds ratios between internal and external acute to chronic ratios and injury risk.

There were no significant correlations between internal and external training load measures on illness. Internal and external acute to chronic training load was not significantly correlated to illness. Per season phase there were no significant odds ratios between internal and external acute to chronic ratios and illness risk.

The overall injury incidence in the 2017 Super Rugby tournament was higher than previously reported. In addition, the incidence of match injuries were higher than previously reported. The training and match injuries, anatomical location, type, mechanism and severity of injuries were similar to previous studies. The illness rates in the 2017 Super Rugby tournament were lower than reported in Rugby Union and across sporting codes. Further studies are warranted to determine the relationship of training loads on injury and illness over consecutive seasons and in multiple teams.

CHAPTER 7: REFERENCES

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Appendix I: Human Research Ethics Committee approval and Protocol Amendment Form FHS: 006

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room E52-24 Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone [021] 404 7682
Email: nosi.tsama@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

28 February 2018

HREC REF: 124/2018

Dr K Buchholtz
Health & Rehab Sciences
Division of Physiotherapy
Old Main Building

Dear Dr Buchholtz

PROJECT TITLE: TRAINING LOAD, INJURY PROFILES AND ILLNESS IN ELITE SOUTH AFRICAN RUGBY PLAYERS (MSc candidate- Mr C Barnes)

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee for review.

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

Approval is granted for one year until the 28th February 2019.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

We acknowledge that the student Mr Curt Barnes will be involved in this study.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval before the research may occur.

Please quote the HREC REF in all your correspondence.

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

Yours sincerely

PROFESSOR M BLOCKMAN

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

This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Convention on Harmonisation Good Clinical Practice (ICH GCP), South African Good Clinical Practice Guidelines (DoH 2006), based on the Association of the British Pharmaceutical Industry Guidelines (ABPI),and Declaration of Helsinki (2013) guidelines.

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

UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

FACULTY OF HEALTH SCIENCES
Human Research Ethics Committee

Form FHS006: Protocol Amendment

HREC office use only (FWA00001637; IRB00001938)		
☑ Approved	✓ ☐ Type of review: Expedited	☐ Full committee
This serves as notification that all changes and documentation described below are approved.		
Signature Chairperson of the HREC		Date 23/1/2019

Note: All major amendments must include a local PI **Synopsis** justifying the changes for the amendment. Please note that incomplete amendment submissions will not be reviewed.

Comments from the HREC to the Principal Investigator:
Note: The approval of this protocol amendment does not grant annual approval. Please complete the FHS016 / FHS017 form for annual approval at least one month before study expiration.

Principal Investigator to complete the following:

1. Protocol information

Date (when submitting this form)	23/1/2019	
HREC REF Number	124/2018	
Protocol title	Training Loads, Injury Profiles and Illness in Elite South African Rugby Players	
Protocol number (if applicable)		
Principal Investigator	Kim Buchholtz	
Department / Office Internal Mail Address	Division of Physiotherapy Department of Health and Rehabilitation University of Cape Town Groote Schuur Hospital Anzio Road Observatory 7725	
1.1 Is this a major or a minor amendment? (see FHS006hlp) Major (tick box) Minor (tick box)	☐ Major	☑ Minor

1.2 Does this protocol receive US Federal funding?	☐ Yes	☑ No
1.3 If the amendment is a major amendment <u>and</u> receives US Federal Funding, does the amendment require full committee approval? **Note:** Any protocol amendments for **Full Committee** review MUST be submitted on the monthly HREC submission dates. (Please email an electronic copy to hrec-enquiries@uct.ac.za)	☐ Yes	☐ No

2. List of Proposed Amendments with Revised Version Numbers and Dates

Please itemise on the page below, all amendments with revised version numbers and dates, which need approval.
This page will be detached, signed and returned to the PI as notification of approval. Please add extra pages if necessary.

Section 2.2. (page 3): The addition of 'mechanism'.

Section 3.4.1. (page 6): The addition of 'Injuries will be defined according to the 2007 Consensus Statement on injury definitions and data collection procedures (Fuller et al., 2007)' and 'The Orchard Sports Injury Classification System 10.1 will be used to code injury diagnosis (Rae & Orchard, 2007)' and 'mechanism'.

Section 3.6.1. (page 9): The addition of 'Demographic data in the form of age will be collected as part of the collected injury data (Appendix C)' and 'mechanism'.

Section 3.7. (page 9): The addition of 'Demographical data in the form of age will be presented in mean values per squad and per main playing position such as forwards and backs.'

Section 7. (page 13): The addition of references used in Section 3.4.1-

'Fuller, C. W., Molloy, M. G., Bagate, C., Roald Bahr, B. C., Brooks, J. H. M., Donson, H., & Wiley, P. (2007). Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. *British Journal of Sports Medicine, 41*, 328-331.'

and

'Rae, K., & Orchard, J. (2007). The Orchard Sports Injury Classification System (OSICS) Version 10. *Journal of Sports Medicine, 17(3), 201-204.'*

3. Protocol status (tick ✓)

☐	Open to enrolment
☐	No participants have been enrolled
☐	Closed to enrolment (tick ✓)
☐	Research-related activities are ongoing
☐	Research-related activities are complete, long-term follow-up only
☑	Research-related activities are complete, data analysis only

4. Proposed changes will affect: (tick ✓ all the categories that apply)

	Protocol
☑	Study objectives, design (including investigator's brochure, clinical activities, study length)
☐	Study instruments, questionnaires, interview schedules
☐	Sample size
☐	Recruitment methods

☐	Eligibility criteria (inclusion and exclusion criteria)
☐	Drug/device (composition, amount, schedule, route of administration, combination with other drugs/devices, safety information)
☑	Data collection/ analysis
☐	Principal Investigator. (Please attach revised conflict of interest and PI declaration statements. Refer: sections 7 and 8.4 in the New Protocol Application Form FHS013)
☐	Consent form and information sheet
☐	Recruitment materials (e.g. advertisements)
☐	Administrative (e.g. change in sponsor's name, change in contact information)
☐	Other. Please specify:

4.1 In your opinion, will there be any **increase** in risk, discomfort or inconvenience to participants?	☐ Yes	☑ No
If yes, please provide a detailed justification/explanation:		

4.2 What follow-up action do you propose for participants who are already enrolled in the study?	
☐	Inform current participants as soon as possible
☐	Re-consent current participants with revised consent/assent forms (append)
☑	No action required
☐	Other. Please describe:

5. Detailed description of the change(s)

Please attach, for each amendment, a summary of all changes which clearly indicates:

i. Old wording (e.g. ~~strikethrough~~ text, CHANGED FROM and CHANGED TO)
ii. New wording (e.g. *italicized*, **bold**, tracked)
iii. Detailed rationale/ justification/ explanation for each change

6. Ethics Review Levy – cost including vat

Cost for Major Amendments - R3 659.10 (Protocols funded by UCT (e.g. departmental funding / student research) and by certain grant funding organizations (e.g. MRC, NRF, CANSA,) are exempt from charges)
For invoicing purposes, please provide:

Sponsor's name	
Contact person	
Address	
Telephone number	
Email Address	

7. Signature

My signature certifies that I will maintain the anonymity and/ or confidentiality of information collected in this research. If at any time I want to share or re-use the information for purposes other than those disclosed in the original approval, I will seek further approval from the HREC.			
Signature of PI		Date	21/01/2019

Appendix II: Informed Consent Form

Department of Health and Rehabilitation Sciences

Faculty of Health Sciences

Divisions of Communications Sciences and Disorders, Nursing and Midwifery, Occupational Therapy, Physiotherapy

F45 Old Main Building, Groote Schuur Hospital,

Observatory 7925

Tel: +27 (0) 21 406 6401 Fax: +27 (0) 21 406 6323

Internet: www.uct.ac.za

Dear participant,

RE: Informed Consent to participate in research study

I am currently completing my MSc in Exercise and Sport Physiotherapy at the University of Cape Town, the Division of Physiotherapy. I am conducting a study to determine the effect of training loads on injury profiles and illness in elite South African rugby players. This research study has been given ethics approval by the University of Cape Town, Faculty of Health Sciences Human Research Ethics Committee (HREC No).

Study title:

Training loads, injury profiles and illness in elite South African rugby players.

Why is this study being done?:

It is well known that both over-training and under-training have a negative effect on the number of injuries and illness in elite rugby players. There is limited data in South Africa recording these effects. The purpose of this study is to investigate how training loads relate to and affect injury profiles and illness during a full season of Super Rugby in 2017. There is limited research in South Africa on training loads, injury profiles and illness.

What is being done?

The study will look into your individual, and the complete squad's training data, the recorded injuries and illness over the course of 30 weeks (including pre-season, early and late competition). As a team member of this training squad, you qualify to take part in this study. The study will use an international injury prevention model as a guideline to assess the amount of training, number of injuries and illnesses. The study will also establish injury and illness trends as they relate to training load in the progressing Super Rugby competition format.

What are the study Procedures?

The study has been approved by the UCT Human Research Ethics Committee (HREC No). Permission has been granted by the Chief Executive Officer Mr Gary Teichmann to conduct this study. Individual and team data has already been collected by the Team Physician, Head of Strength and Conditioning and Head Physiotherapist over the course of the 30 week period. The data will now be analysed according to injuries, illness and training and match loads, should you give us your permission to use your information.

What is required of you?

If you take part in this study, your information will be used to evaluate trends and associations between training and match loads, injuries and illness over 30 weeks from pre-season to the end of the 2017 Super Rugby tournament (22 July 2017). No further information is required from you beyond that information already collected by the support staff routinely during the season.

Possible Risks Involved:

There are no direct risks involved in this study as there are no physical tests involved. In the event of severe or catatrophic injury during the season studied, and the subsequent publication of this study, it is possible that you may be unofficially indentified as being the injured team mate by the public. This could be due to media coverage and public interest in the Super Rugby tournament. Every effort to maintain your privacy and confidentiality will be maintained.

Benefits for participating in the study:

Benefits of participating in this study includes providing valuable data for training loads, injury and illness in South African Rugby. We hope it will form the basis for many future studies and aid in the management of elite South African rugby players in optimizing performance and reducing injury and illness.

You will be provided with an individual and confidential feedback report on your training loads, injury and illness profiles. The statistical results and any relevant trends in the squad as a whole will be provided to you at the end of the study in a presentation to the whole squad.

Voluntary Participation:

Participation in this study is completely voluntary. No payment will be made for participating in the study. You are free to refuse the use of any data about your training, illness or injury. Despite your knowledge of and relation to Curt Barnes, a current employee to the Medical staff at The Sharks (Pty) Ltd., you should, under no circumstances feel obliged to participate in this study. If you decide to participate, you are free to change your mind and withdraw at any time without penalty, explanation or prejudice.

Confidentiality:

Information obtained in this study will be kept confidential. Information will be securely stored on paper and computer, only accessible to the investigator. To protect your privacy, identifying information on training, injury and illness data will be assigned a random number to keep you anonymous. The information obtained from the study will not be made available to anyone else and will be destroyed on completion of the study. Any reports or publications about the study will not identify you or any other study participant. Overall feedback on the results of the study will be provided to the Chief Executive Officer and Team management in the form of overall statistics.

Feedback after the Study:

Information on feedback after the study is explained under benefits. The Team Management will also be provided with feedback regarding trends and associations of training loads, injuries and illness in the form of statistics in order for them to look into implementing prevention strategies over the Super Rugby preparation and competition phases.

Questions

Any study-related questions should be directed to:

Supervisor: Kim Buchholtz kim.buchholtz@uct.ac.za

Co-Supervisor: Theresa Burgess theresa.burgess@uct.ac.za

Curt Barnes
0734481665 curtbarnes@thesharks.co.za

The UCT's Faculty of Health Sciences Human Research Ethics Committee can be contacted on 021 406 6338 in case you have any ethical concerns or questions about your rights or welfare as a participant in this research study.

I understand that a study entitled "Training Loads, Injury Profiles and Illness in Elite South African Rugby Players" will be conducted by Curt Barnes through the University of Cape Town. I understand that my participation in this research project has no direct benefit or risk to me during the 2017 Super Rugby tournament. However, I understand that my participation will advance the medical and scientific knowledge related to rugby. Therefore, information collected through my participation in this study could advance the prospective medical care, training advice and performance of elite South African rugby players.

I have read the above and I am satisfied with my understanding of the study, it's possible benefits, risks and alternatives and I accept the request to participate in the titled study. I understand that I may freely withdraw from this study at any point without further question.

………………………… ………………………….

Participants Name: Participants Signature:

…………………………... ……………………………

Researchers Name: Researchers Signature:

Kind-Regards,

Curt Barnes

Appendix III: Injury Data Collection Form

Date	Athlete	Location (Match/Training)	Type	Contact vs Non-contact	Site	Time-loss (days)	Date: Return to training	Date: Return to play

Appendix IV: Boksmart- Serious Injury Report Form ("Boksmart: Serious Injury Report Form,").

This form is for all recorded injuries that fit the defined nature of injuries in this study. Level of experience and previous injury history for demographical background of each participant.

1. PLAYER (PRINT CLEARLY)

Forenames:

Surname:

Date of birth: / / Age:

Known as (Nickname):

ID Number

Address:

Contact Number:

Next of Kin:

Contact Number:

Rugby Club/School/Team:

Playing Position:

Level of experience:

Previous injury history:

2. INJURY (PRINT CLEARLY)

Date of Injury: ☐☐ / ☐☐ / ☐☐☐☐ At Time: ☐☐☐☐

Injury Occurred During: Match ☐

Training ☐ If "training" then during: Rugby skills training, full contact ☐

Rugby skills training, semi-contact ☐

Rugby skills, non-contact ☐

Site of Injury: Head ☐ Neck ☐ Spine ☐ Chest/Trunk ☐

Tackling (behind) ☐	Tackling (front) ☐	Tackling (side) ☐
Tackled (behind) ☐	Tackled (front) ☐	Tackled (side) ☐
Lineout ☐	Kicking ☐	Running ☐
Other(specify) ☐		

Did the player return to the field at any time? Yes ☐ No ☐

Appendix V: Illness Data Collection Form

Date	Athlete Name:	Presenting Symptoms:	Diagnosis:	Casue:	Time-loss (days):	Date: Return to Train	Date: Return to Play

Appendix VI: Internal Training load data collection form

Internal training loads: Exertional units calculated for on the day training, 1 week, 4 weeks and acute: chronic ratio.

Daily Internal load:

Date:	Player Name:	Session (Eg. Rugby training, gym, static skills):	Duration: (Minutes)	RPE Score:

Weekly Internal Load Cycle:

		RPE x Duration					
Week:	**Player Name:**	**Monday:**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**

Four-week (28 days) Internal Load Cycle:

Date:	Athlete Name:	RPE X Duration-Today	RPE X Duration- Last 7 days	RPE X Duration- Last 28 days	RPE X Duration-Acute:Chronic Ratio

Appendix VII: Modified Rating of Perceived Exertion Scale (Kelly & Coutts, 2007).

The Modified Rating of Perceived Exertion Scale Used for Athletes to Classify Their Perceived Intensity of Each Training Session (7)

Rating	Descriptor
0	Rest
1	Very Easy
2	Easy
3	Moderate
4	Somewhat Hard
5	Hard
6	
7	Very Hard
8	
9	
10	Maximal

Appendix VIII: External Training load data collection form

External training loads: Total distance covered in metres will be considered for on the given training day, 1 week and 4 weeks. The acute:chronic ratio is calculated from 1 week: 4 week rolling average.

Date:	**Athlete Name:**	**Open-field Total Distance (metres)- Today**	**Open-field Total Distance (metres)- Last 7 days**	**Open-field Total Distance (metres)- Last 28 days**	**Acute: Chronic Ratio**

Appendix IX: Letter of permission to conduct study

Department of Health and Rehabilitation Sciences

Faculty of Health Sciences

Divisions of Communications Sciences and Disorders, Nursing and Midwifery, Occupational Therapy, Physiotherapy

F45 Old Main Building, Groote Schuur Hospital,

Observatory 7925

Tel: +27 (0) 21 406 6401 Fax: +27 (0) 21 406 6323

Internet: www.uct.ac.za

Curt Barnes

02/03/2018

Dear Mr Gary Teichmann,

RE: PERMISSION REQUEST TO CONDUCT RESEARCH STUDY

I trust that this letter finds you well. Thank-you for receiving this letter regarding the above mentioned study.

I am currently completing my MSc in Exercise and Sport Physiotherapy at the University of Cape Town, the Division of Physiotherapy. I am conducting a study to determine the effect of training loads on injury profiles and illness in Elite South African rugby players. This research study has been given ethics approval by the University of Cape Town, Faculty of Health Sciences Human Research Ethics Committee (124/2018).

Title of Study: Training loads, injury profiles and illness in Elite South African Rugby Players.

Purpose:

It has been well established that both over-training and under-training have an adverse effect on the number of injuries and illness in elite rugby players. A well known injury prediction model has been established and used in various sports internationally including rugby in order to prevent injury incidence through maintenance of training loads within a certain range that have been proven valid.

To date, not much quantifiable data has been gathered in South Africa in general, or Super Rugby specifically, regarding injuries and illness as they relate to the high demands of the season. Verification of the injury prediction model and its impact on reducing injuries and illness has not been established in South Africa. The lessening of the impact of injuries and illness on team performance is imperative for the success of a team and thus this study aims to provide a foundation for limiting this impact.

Procedure:

The procedure would include gaining informed consent from the players. The data required is routinely collected on a daily basis by the mentioned coaching and support staff. Data will be retrieved at the end of the Super Rugby season from the Head Strength and Conditioning Coach, Team Physician and Head Physiotherapist. Data will include training loads, injury and illness incidence. Data will be matched according to injuries and illness and then coded for anonymity.

The data will be kept strictly confidential and anonymity will be upheld when published for submission. All data will be kept in a password locked computer and documents in a locked cabinet only accessible to the investigator. All data used in the study will be destroyed once published.

Once the study has been completed, a formal letter and follow-up report will be made available in order to provide feedback to the individual players, team management and CEO on the results of the study. This information will be valuable as it will provide detailed trends of various associations between training loads, injuries and illness at various parts of the season. The data from this study could provide imperative information on training load management for the team, within the advancing Super Rugby Tournament.

Conducting this study may provide information for possibly developing and adapting evidence based intervention strategies in order to minimize illness and injury and maximize team performance in the future.

I request your permission for me to conduct such a study. Please contact me, or one of my supervisors directly via e-mail or cell-phone: curtbarnes@thesharks.co.za or (0734481665) , supervisor: Kim Buchholtz kim.buchholtz@uct.ac.za, co-supervisor: Theresa Burgess theresa.burgess@uct.ac.za should you have any further questions relating to this study.

In recognition of your authorisation of the study , please sign the dotted line below and return the form by contacting me directly for collection.

I …GARY TEICHMANN… hereby grant the following researcher …CURT…BARNES… permission to conduct the above mentioned study at The Sharks (Pty) Ltd. in partial fulfilment of his MSc in Exercise and Sports Physiotherapy.

………….. Signature: (Chief Executive Officer) Gary Teichmann

……………… ……………………………………
Signature: (Researcher) Curt Barnes

Yours in Sport,

Curt Barnes

Supervisor: Kim Buchholtz kim.buchholtz@uct.ac.za

Co-Supervisor: Theresa Burgess theresa.burgess@uct.ac.za

Appendix X: Disclosure Statement to the Human Research Ethics Committee

Curt Barnes

Date

Dear Sir or Madam,

RE: Disclosure Statement of Contracted Employment at The Sharks (Pty) Ltd.

Thank-you for receiving this letter regarding the above mentioned. The purpose of this letter is to disclose my exact role and position at The Sharks (Pty) Ltd. as an employee and how it relates to the proposed research study at The Sharks (Pty) Ltd.

My name is Curt Barnes, I'm currently partaking in a MSc in Exercise and Sports Physiotherapy at the University of Cape Town, the Division of Physiotherapy. As part of my curriculum fulfilment, I am currently proposing to conduct a study titled: Training loads, Injury profiles and Illness in Elite South African Rugby Players. My study will be focused on one population group of elite rugby players from The Sharks (Pty) Ltd.

I am currently one of four Physiotherapists permanently contracted to The Sharks (Pty) Ltd. The purpose of this disclosure statement is to clearly outline that my role at The Sharks (Pty) Ltd is providing physiotherapy services for the Sharks XV squad and as Head of the Junior contracted players. I am by no means involved with the statistical collection of the Super Rugby Squad data. Statistical data is collected by the Team Physician (Dr. Alan Kourie), Head of Strength and Conditioning (T. J. Gabbett et al.) and Head Physiotherapist (Deane Macquet). On occasion, I do treat players involved in the Super Rugby squad and fulfil my legal obligation of completing medical notes on their progression, but this is distinctly separate from the statistics that are recorded on a daily basis regarding injury, illness and training loads.

The proposed study will be focusing on the 2016/2017 Super Rugby squad. I wish to eliminate any associations of potential conflict of interest and have therefore clarified my working role.

If you should require any further information, please contact me or one of my supervisors directly via e-mail or cell-phone.curtbarnes@thesharks.co.za or (0734481665) , supervisor: Kim Buchholtz kim.buchholtz@uct.ac.za, co-supervisor: Theresa Burgess theresa.burgess@uct.ac.za should you have any further questions relating to this study.

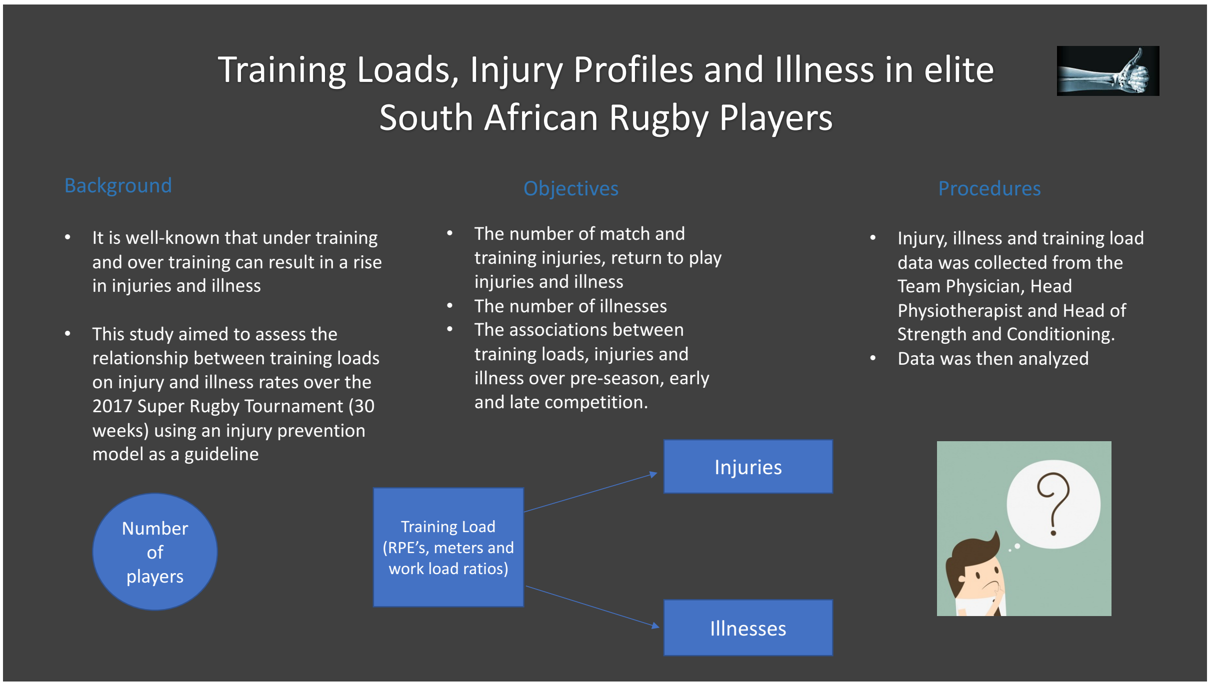
Kind Regards,

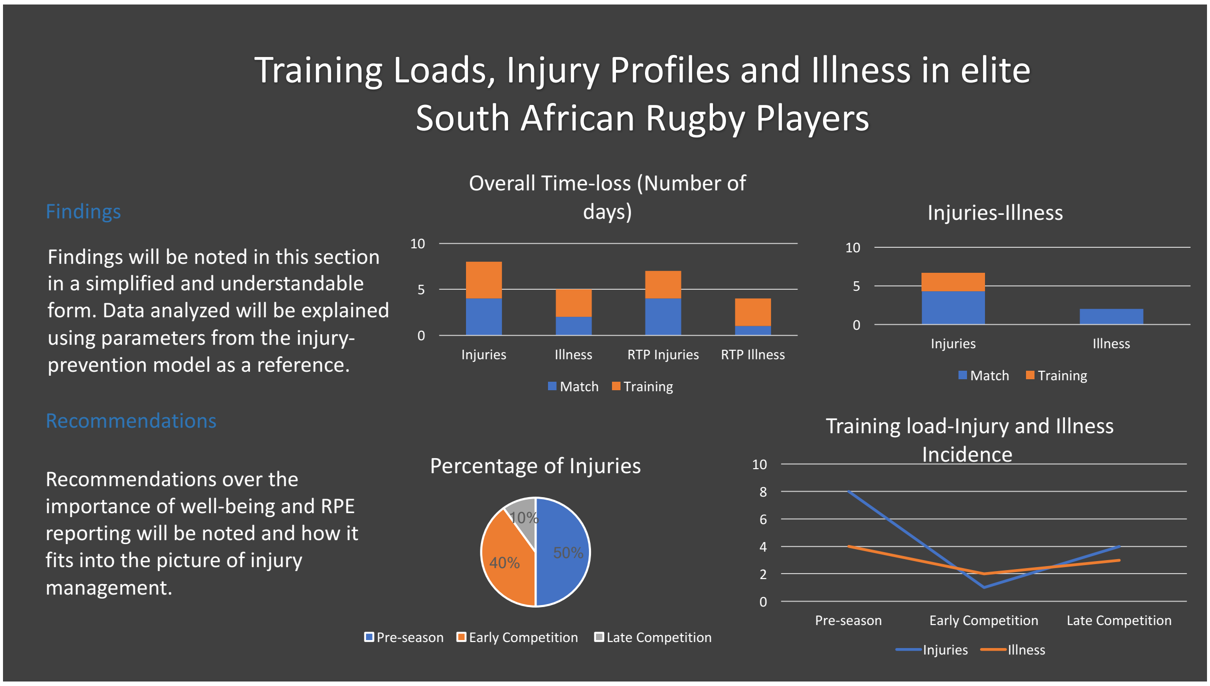
Curt Barnes

curtbarnes@thesharks.co.za

0734481665

Appendix XI: Infographic Presentation Example





Appendix XII: Individual Player Report Example

Full Name:

Date of Birth:

Position:

Games Played:

Injury Profile: 2017 Super Rugby Tournament			
	Pre-season:	**Early Competition:**	**Late Competition:**
Date:			
Diagnosis:			
Time-loss: Training			
Time-loss: Matches			

Illness Profile: 2017 Super Rugby Tournament			
	Pre-season:	**Early Competition:**	**Late Competition:**
Date:			
Diagnosis:			
Time-loss: Training			
Time-loss: Matches			

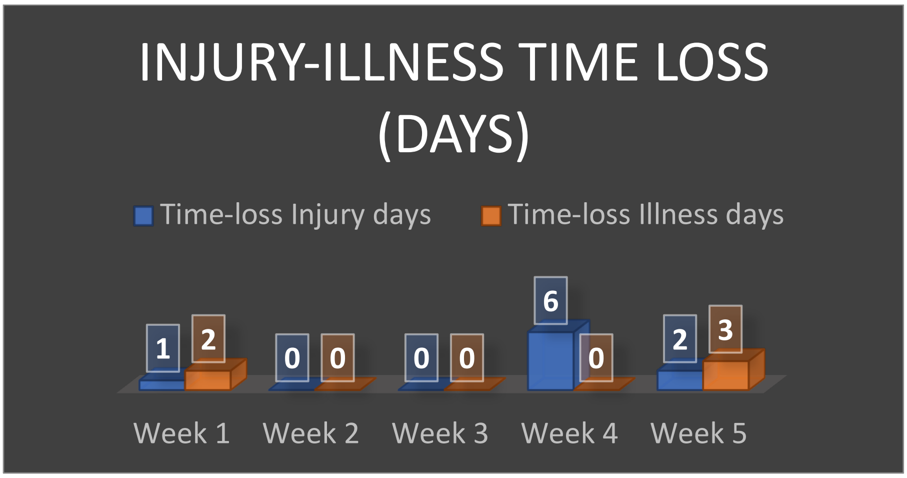
Training and Match Loads: Week by week information 2017 Super Rugby Tournament						
	Internal Load		**External Load**		**Acute: Chronic Ratio**	
	Training	**Match**	**Training**	**Match**	**Training**	**Matches**
Pre-season						
Team average:						
Position specific average:						
Week 1						
Week 2						
Week 3						

Glossary:

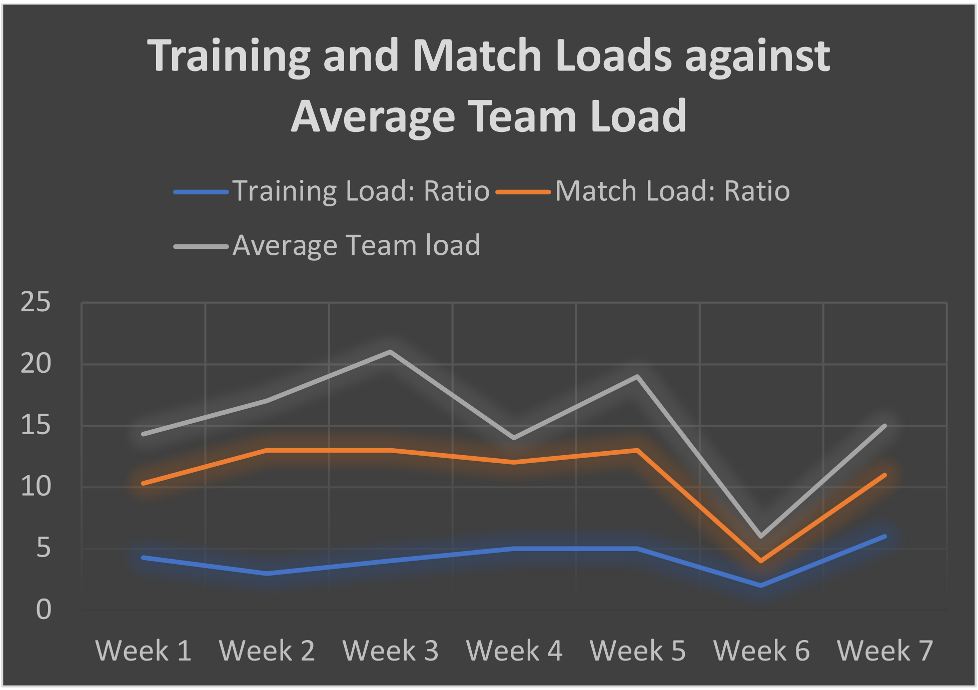
Internal training load: This is your rate of perceived exertion score multiplied by the duration of the session to indicate your bodies response to the training.

External training load: This is your distance covered in metres measured by the global positioning system (GPS)

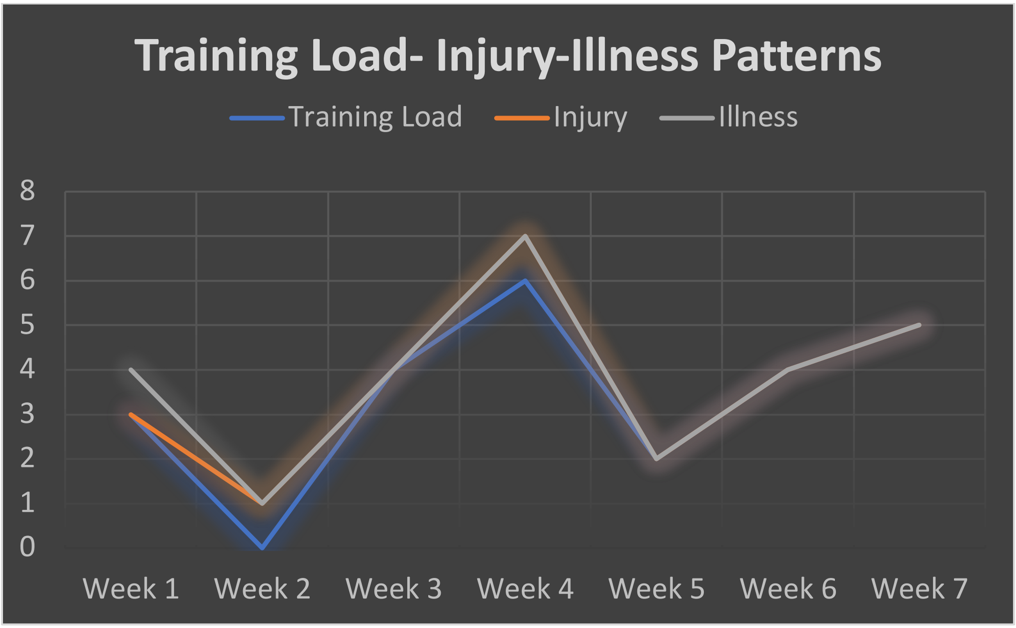
Acute: chronic ratio: This is the combined figure of your training load. The recommended guideline is between 0.8-1.5 in minimizing risk to injury.



Graph 1. Week by week display of time-loss in days due to injury and illness.



Graph 2. Individual training and match loads mirrored against the average team loads on a week by week basis.



Graph 3. Training loads, injury and illness all displayed over the course of the Super Rugby Tournament on a week by week display

Appendix XIII: Additional results

Table XIII.I: Overall, training and match exposure in player hours per season phase and per main player position.

Season Phase (weeks)	All players (n= 39)				Forwards (n= 21)				Backs (n= 18)			
	Overall	Training	Match	Mean	Overall	Training	Match	Mean	Overall	Training	Match	Mean
Preseason: (1-7)	1926	1926	0	275 ± 94	1037	1037	0	248 ± 50	889	889	0	127 ± 43
Early competition: (8-17)	2065	1930	135	120 ± 39	1119	1039	80	100 ± 32	946	891	55	206 ± 65
Late competition: (18-28)	2286	2172	114	113 ± 60	1238	1169	69	95 ± 51	1048	1003	45	207 ± 112

Overall, training and match exposures are expressed in hours.
Mean player hours are expressed as mean ± standard deviation.
Red colour represents the highest mean and player hours; Green colour represents the lowest mean and player hours

Table XIII.II: Player hours and the incidence of time-loss injuries for all participants and per main player position.

	All players (n= 39)			Forwards (n= 21)			Backs (n= 18)		
	Injury (n)	**Player hours**	**Incidence (95% CI)**	**Injury (n)**	**Player hours**	**Incidence (95% CI)**	**Injury (n)**	**Player hours**	**Incidence (95% CI)**
All injuries:	80	6277	12.8 (10.0-15.8)	46	3395	13.6 (10.0-17.9)	34	2882	11.8 (8.3-16.3)
Match injuries:	60	249	241.0 (186.0-308.0)	32	149	215.0 (149.0-300.0)	28	100	280.0 (190.0-399.0)
Training injuries:	20	6028	3.3 (2.1-5.0)	11	3246	3.4 (1.8-5.9)	9	2782	3.2 (1.6-5.9)

Incidence is expressed as injuries per 1000 player hours.

Red colour represents the higher incidence; Green colour represents the lower incidence.

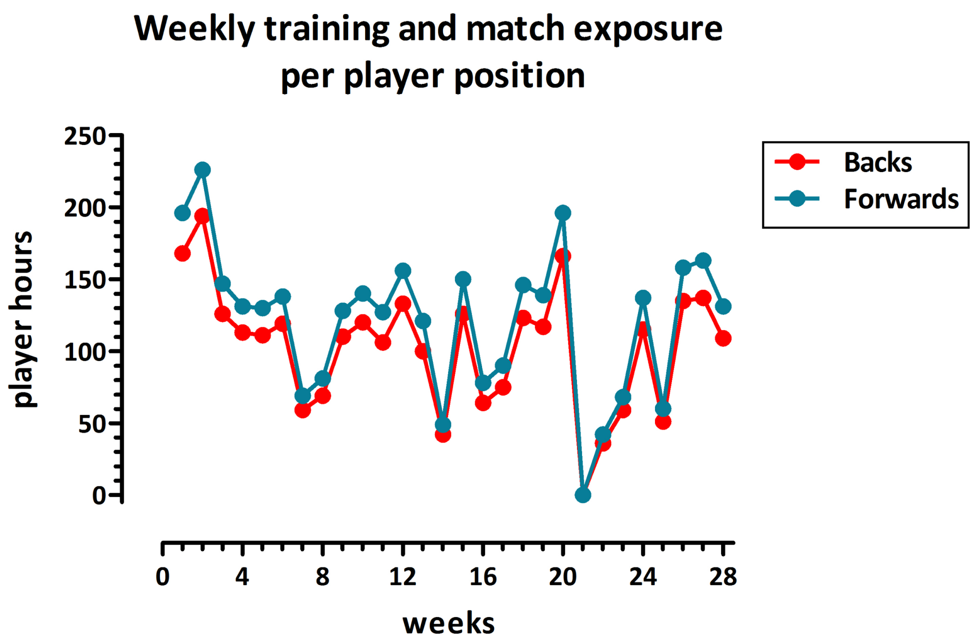


Figure XIII.I: Weekly training and match exposure per main player position over 28 weeks.

Table XIII.III: The percentage and incidence of injury for all participants and per main playing position according to main anatomical location.

Main Anatomical Region	**Number of injuries (n)**	**Percentage (%)**	**Player hours**	**Incidence rate**	**95% CI**
All players:	80	100	6277	12.7	10.0-15.8
Head/neck	12	15.0	6277	1.9	1.0-3.3
Upper limb	10	12.5	6277	1.6	0.8-2.8
Trunk	8	10.0	6277	1.3	0.6-2.4
Lower limb	50	62.5	6277	8.0	6.0-10.4
Forwards:	46	57.5	3395	13.6	10.0-17.9
Head/neck	6	13.0	3395	1.8	0.7-3.7
Upper limb	8	17.4	3395	2.4	1.1-4.5
Trunk	8	17.4	3395	2.4	1.1-4.5
Lower limb	24	52.2	3395	7.1	4.6-10.4
Backs:	34	42.5	2882	11.8	0.8-1.6
Head/neck	6	17.7	2882	2.1	0.8-4.3
Upper limb	2	5.9	2882	0.6	0.1-2.2
Trunk	0	0	2882	0	0
Lower limb	26	76.4	2882	9.0	6.0-13.0

Incidence is expressed as injuries per 1000 player hours.
Red colour represents the higher incidence; Green colour represents the lower incidence.

Table XIII.IV: The incidence of time-loss injuries from the overall number of injuries according to specific anatomical location and main player position.

Specific Anatomical Region	Total Number of injuries (n)			Incidence of injury			(95% CI)		
	All	Forwards	Backs	All	Forwards	Backs	All	Forwards	Backs
All injuries:	80	46	34	12.7	13.6	11.8	10.2-15.8	1.0-17.9	8.3-16.3
Head	6	2	4	1.0	0.6	1.4	0.4-2.0	0.1-1.9	0.4-3.3
Neck	6	2	4	1.0	0.6	1.4	0.4-2.0	0.1-1.9	0.4-3.3
Thoracic Spine	3	3	0	0.4	0.9	0	0.1-1.3	0.2-2.4	0
Chest	2	2	0	0.3	0.5	0	0-1.0	0.1-1.9	0
Shoulder	6	4	2	1.0	0.6	0.7	0.4-2.0	0.1-1.9	0.1-1.3
Upper arm	1	1	0	0.2	0.3	0	0-0.8	0-1.5	0
Wrist	3	2	1	0.4	0.5	0.3	0.1-1.3	0.1-1.9	0-1.7
Lumbar spine	3	3	0	0.5	0.9	0	0.1-1.3	0.2-2.4	0
Gluteal	3	1	2	0.4	0.3	0.7	0.1-1.3	0-1.5	0.1-2.2
Groin	3	3	0	0.4	0.9	0	0.1-1.3	0.2-2.4	0
Hip	1	1	0	0.2	0.3	0	0-0.8	0.01-1.5	0
Thigh	16	5	11	2.5	1.4	3.8	1.5-4.0	0.5-3.2	2.0-6.6
Knee	10	6	4	1.6	1.8	1.4	0.8-2.8	0.7-3.7	0.4-3.3
Lower leg	7	5	2	1.1	1.4	0.7	0.5-2.2	0.5-3.2	0.1-2.2
Ankle	7	2	5	1.1	0.5	1.7	0.5-2.2	0.1-1.9	0.6-3.8
Foot	3	2	1	0.4	0.6	0.3	0.1-1.3	0.1-1.9	0-1.7

Incidence is expressed as injuries per 1000 player hours

Red colour represents the higher incidence; Green colour represents the lower incidence.

Table XIII.V: The mechanism and percentage of match and training injuries per main player position.

Mechanism	Match injuries				Training injuries			
	Injury (n)		Percentage (%)		Injury (n)		Percentage (%)	
	Forwards	Backs	Forwards	Backs	Forwards	Backs	Forwards	Backs
Total injuries:	35	25	43.8	31.3	11	9	13.8	11.3
Conditioning	0	0	0	0	0	1	0	11.0
Tackling front on	3	2	8.6	8.0	0	0	0	0
Tackling side on	1	0	2.9	0	0	0	0	0
Tackled front on	4	4	11.4	16.0	0	1	0	11.0
Tackled side on	6	0	17	0	0	0	0	0
Tackled from behind	1	1	2.9	4.0	0	0	0	0
Twisted	5	0	14.3	0	0	0	0	0
Landing	1	0	2.9	0	0	0	0	0
Side step	1	2	2.9	8.0	0	0	0	0
Acceleration	2	2	5.7	8.0	1	1	9.0	11.0
Deceleration	0	2	0	8.0	0	1	0	11.0
Weight training	0	0	0	0	1	0	9.0	0
Slipped	0	1	0	4.0	1	0	9.0	0
Other	8	6	22.9	24.0	7	5	63.6	45.5
Collision	3	3	8.6	12.0	1	0	9.0	0
Kicked	0	1	0	4.0	1	0	9.0	0
Kneed	0	1	0	4.0	0	0	0	0

Red colour represents the higher incidence; Green colour represents the lower incidence.

Table XIII.VI: The percentage and incidence of injury according to time-loss severity for matches and training in the forwards.

Injury severity	Injury (n)	Percentage (%)	Time-loss in days	Incidence of injury (95% CI)
Match injuries: Forwards	35	100	305	235.0 (166.0-323.0)
Minimal (2-3 days)	11	31	22	73.8 (18.8-12.8)
Mild (4-7 days)	8	23	46	53.7 (24.9-102.0)
Moderate (8-28 days)	16	46	237	107.4 (635.7-170.7)
Severe (≥28 days)	0	0	0	0
Training injuries: Forwards	11	100	117	3.4 (1.8-5.9)
Minimal (2-3 days)	4	36	6	1.2 (0.4-3.0)
Mild (4-7 days)	2	18	12	0.6 (0.1-2.0)
Moderate (8-28 days)	4	36	46	1.2 (0.4-3.0)
Severe (≥28 days)	1	10	53	0.3 (0-1.5)

Incidence is expressed as injuries per 1000 player hours.
Red colour represents the higher proportion; Green colour represents the lower proportion.

Table XIII.VII: The percentage and incidence of injury according to time-loss severity for matches and training in the backs.

Injury severity	Injury (n)	Percentage (%)	Time-loss in days	Incidence of injury (95% CI)
Match injuries: Backs	25	100	252	250.0 (165.4-363.6)
Minimal (2-3 days)	7	28	13	70.0 (30.6-138.5)
Mild (4-7 days)	9	36	49	90.0 (43.9-165.2)
Moderate (8-28 days)	8	32	99	80.0 (37.2-152.0)
Severe (≥28 days)	1	4	91	10.0 (0.5-49.0)
Training injuries: Backs	9	100	62	3.2 (0.5-49.0)
Minimal (2-3 days)	2	22	3	0.7 (0.1-2.3)
Mild (4-7 days)	5	56	27	1.8 (0.7-4.0)
Moderate (8-28 days)	2	22	32	0.7 (0.1-2.3)
Severe (≥28 days)	0	0	0	0

Incidence is expressed as injuries per 1000 player hours.
Red colour represents the higher proportion; Green colour represents the lower proportion.

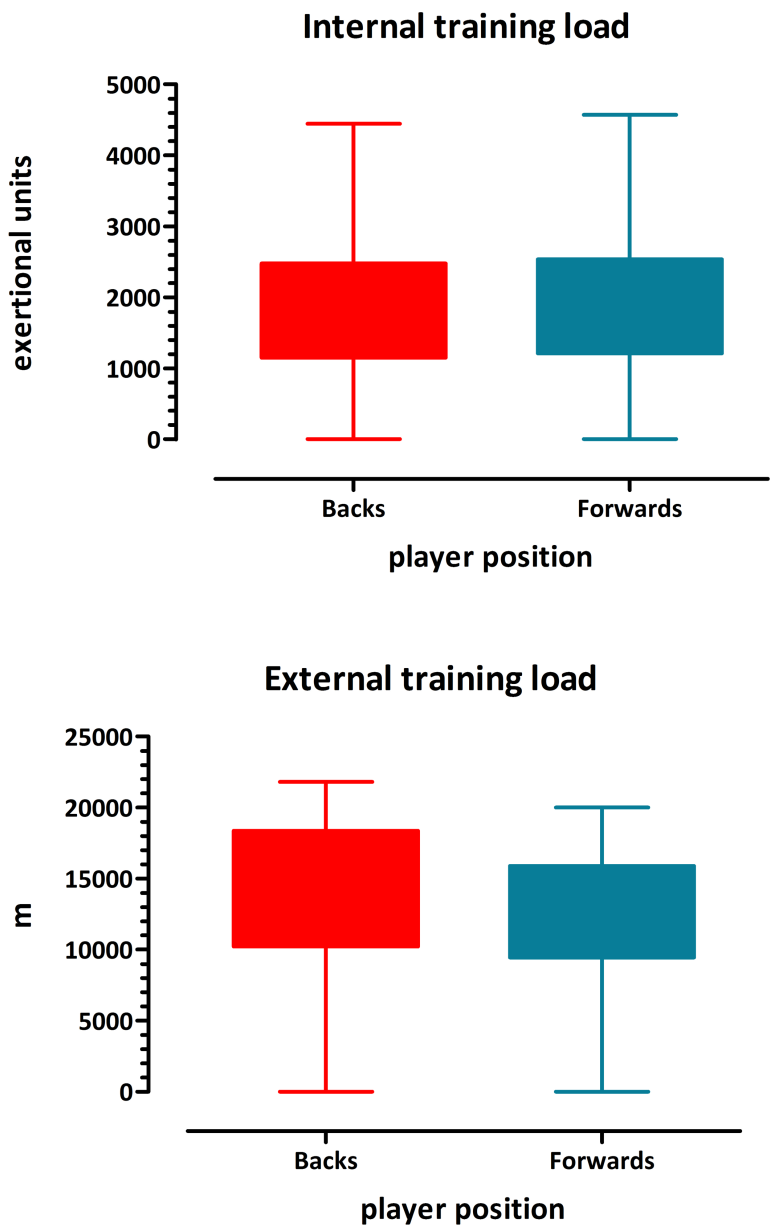


Figure XIII.II: Box and whisker plots for internal and external training loads per main player position.

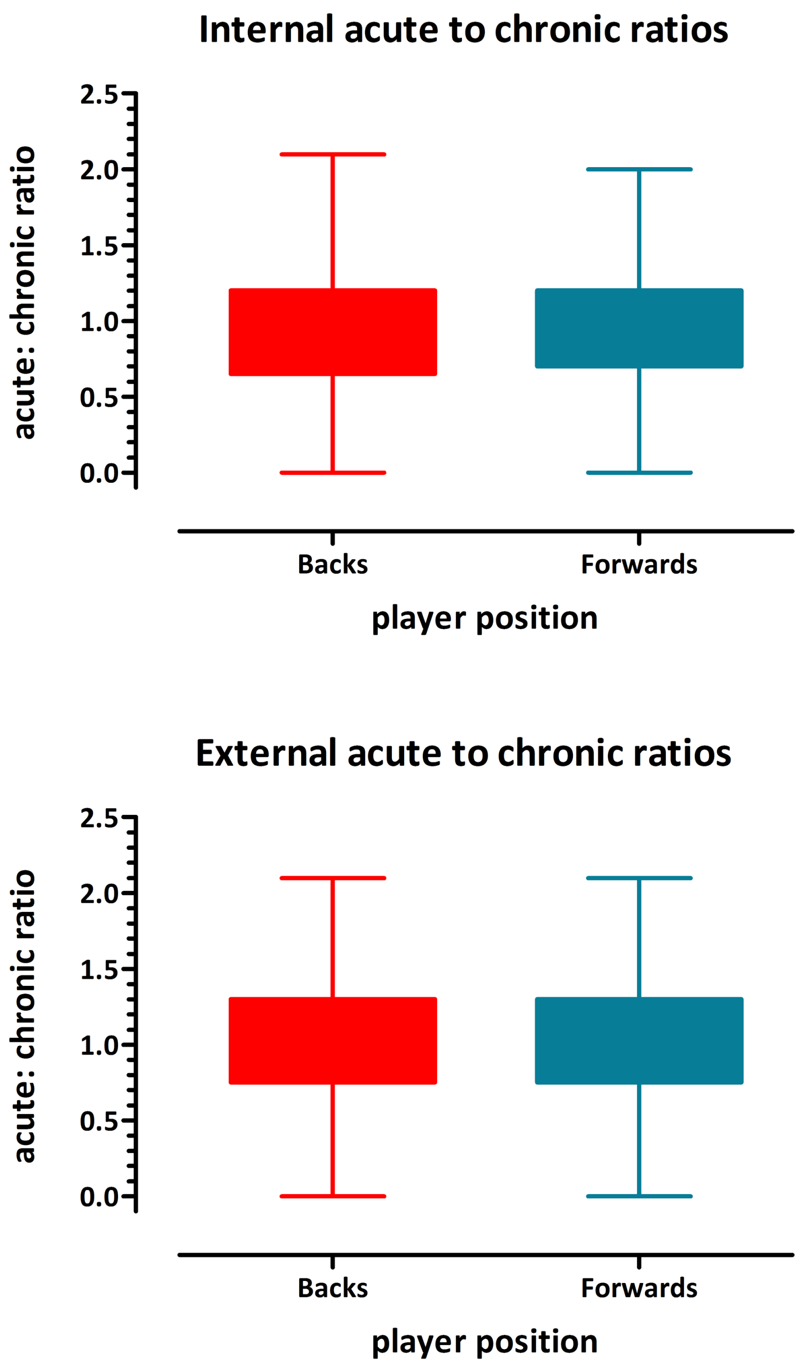


Figure XIII.III: Box and whisker plots for internal and external acute to chronic ratios per main player position.

Table XIII.VIII: Significant results of the Mann-Whitney U Test of weekly internal and external training loads for injured **and non-injured participants. Significant relationships ($p < 0.05$) are presented.**

		Rank Sum: Injured	Rank Sum: Non-injured	U- value	Z- value	p- value
Internal Load:	Week 5	511	269	46	-2.95	0.03
	Week 18	661	119	74	2.02	0.04
External Load:	Week 10	535	245	70	-2.15	0.03

Table XIII.IX: Significant results of the Mann-Whitney U Test of weekly internal and external acute to chronic ratios for injured and non-injured participants. Significant relationships ($p < 0.05$) are presented.

	Rank Sum: Injured	Rank Sum: Non-injured	U- value	Z- value	p- value
Week 17: Internal acute to chronic ratio	674	106	61	2.51	0.01
Week 4: External acute to chronic ratio	662	220	73	2.05	0.04

Table XIII.X: Significant results of the Mann-Whitney U Test of weekly internal training loads for illness and non-illness participants. Significant relationships ($p < 0.05$) are presented.

Internal Load:	Rank Sum: Illness	Rank Sum: Non-illness	U- value	Z- value	p- value
Week 6	493	287	87	-2.08	0.04

Table XIII.XI: Significant correlation measures between internal training loads and injury incidence per season phase and week. Note '+' indicates positive correlation, and '-' indicates negative correlation. Significant relationships (p < 0.05) are presented.

Correlation		Per Season Phase			Per Week					
		Preseason			Week 5			Week 18		
		Relationship	r (95% CI)	p-value	Relationship	r (95% CI)	P-value	Relationship	r (95% CI)	p-value
Injury	**Internal loads**	-	-0.34 (-0.59- -0.03)	0.03	-	-0.48 (-0.69- -0.19)	0.02	+	0.33 (0.01-0.59)	0.04

Table XIII.XII: Significant correlation measure between weekly external training load and injury incidence. Note '+' indicates positive correlation, and '-' indicates negative correlation. Significant relationships (p < 0.05) are presented.

Correlation		Week 10		
		Relationship	r (95% CI)	p-value
Injury	**External loads**	-	-0.4 (-0.63- -0.1)	0.03

Table XIII.XIII: Significant correlation measures between weekly internal and external acute to chronic ratios and injury incidence. Note '+' indicates positive correlation, and '-' indicates negative correlation. Significant relationships ($p < 0.05$) are presented.

Correlation		**Week 17- Internal acute to chronic ratio**			**Week 4- External acute to chronic ratio**		
		Relationship	**r (95% CI)**	**p-value**	**Relationship**	**r (95% CI)**	**p-value**
Injury	**Acute to chronic ratio**	+	-0.41 (-0.64- -0.11)	0.01	+	0.38 (0.07-0.62)	0.02

Table XIII.XIV: Significant correlation measures between internal and external acute to chronic ratios and illness incidence. Note '+' indicates positive correlation, and '-' indicates negative correlation. Significant relationships ($p < 0.05$) are presented.

Correlation		**Week 9- Internal acute to chronic ratio**			**Week 16- External acute to chronic ratio**		
		Relationship	**r (95% CI)**	**p-value**	**Relationship**	**r (95% CI)**	**p-value**
Illness	**Acute to chronic ratio**	-	-0.42 (-0.65- -0.12)	0.01	+	0.32 (0.01-0.51)	0.04